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# Do colleges and universities increase their region's human capital?

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## Abstract

We investigate whether the degree production and R&D activities of colleges and universities are related to the amount and types of human capital in the metropolitan areas where they are located. Our results indicate only a small positive relationship exists between a metropolitan area's production and stock of human capital, suggesting that migration plays an important role in the geographic distribution of human capital. We also find that academic R&D activities increase local human capital levels, suggesting that spillovers from such activities can raise the demand for human capital. Consistent with these results, we show that metropolitan areas with more higher education activity tend to have a larger share of workers in high human capital occupations. Thus, this research indicates that colleges and universities can raise local human capital levels by increasing both the supply of and demand for skill.

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## 1. Introduction

Colleges and universities are increasingly being viewed as engines of local economic development. This trend has been driven by the economic success stories of places such as Silicon Valley and the Route 128 corridor around Boston, as well as the more general recognition of the transition now underway towards a more knowledge-based economy. Furthermore, there appears to be a widespread belief among policymakers, particularly in declining regions, that the retention of graduates from local colleges and universities is a promising pathway to cure their economic ills.

Indeed, the amount of human capital in a region is one the strongest predictors of sustained economic vitality. Studies of regional economies have linked higher levels of human capital to increases in population and employment growth, wages, income and innovation (Glaeser et al., 1995; Simon, 1998; Carlino et al., 2007; Florida et al., 2008). Moreover, larger amounts of human capital within a region have been shown to lead to more rapid reinvention and long-run economic growth (Glaeser and Saiz, 2004; Glaeser, 2005). These empirical findings are explained by the fact that human capital increases individual-level productivity and idea generation (Becker, 1964). Thus, by extension, a higher level of human capital within a region raises regional productivity.

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In addition, the concentration of human capital within a region may facilitate knowledge spillovers, which further enhance regional productivity, fuel innovation and promote growth (Marshall, 1890; Jacobs, 1969; Lucas, 1988; Romer, 1990; Rauch, 1993; Moretti, 2004).

Given the importance of human capital to the economic performance of regional economies, there is surprisingly little research analyzing the factors that drive differences in human capital accumulation across space. This issue is of particular concern as recent research has demonstrated that a divergence in human capital levels has occurred across cities over the past several decades (Berry and Glaeser, 2005). The objective of this article is to shed some light on this issue by analyzing whether activities performed by colleges and universities ('higher education activities') are related to the amount and types of human capital located in metropolitan areas.

We consider two types of higher education activities that have the potential to raise local human capital levels. First, colleges and universities can increase the local supply of human capital through the production of skilled labor. Newly minted graduates directly raise the human capital level in a region if they remain in the area and enter the local labor market. However, because college graduates are highly mobile (Kodrzycki, 2001; Faggian et al., 2007; Whisler et al., 2008), it is not obvious that regions producing more graduates will also have higher human capital levels as a complex set of labor supply and demand factors are at work. Second, much of the research and development (R&D) activity in the USA occurs at colleges and universities. Such activities can also raise local human capital levels if there are spillovers into the local economy that increase the demand for human capital, whether such human capital is produced locally or not.

While the pathways through which these higher education activities can act to raise local human capital levels are clear, systematic empirical evidence documenting the existence and magnitude of such relationships is scarce. Because state governments are an important source of funding for US higher education institutions, much of the existing literature has attempted to examine the relationship between the production of degrees and stock of college graduates from the perspective of a state government analyzing the return on its investment (Bound et al., 2004; Groen, 2004). From the standpoint of local economic development, however, a state may not be a meaningful unit of measure because it is often too large to capture the local labor markets in which colleges and universities are located. Moreover, while these studies provide insight into the extent to which colleges and universities influence the supply side of the labor market, they do not consider the role colleges and universities play in shaping the local demand for human capital through the spillovers they can create.

Indeed, there is mounting evidence indicating that highly localized spillovers exist between university research and high technology innovative activity (Jaffe, 1989; Acs et al., 1991; Jaffe et al., 1993; Anselin et al., 1997; Varga, 2000; Adams, 2002). Such spillovers can alter the composition of local labor markets by increasing the demand for specialized skills and by attracting business activity, such as start up firms, seeking to gain access to academic R&D or human capital (Beeson and Montgomery, 1993; Audretsch et al., 2005; Woodward et al., 2006). While the existing literature demonstrates the importance of colleges and universities to specific industries, particularly those utilizing science and technology, little is known about the extent to which the activities of colleges and universities influence local economic development more generally. Recent research by Andersson et al. (2004, 2009), showing that the decentralization of higher education in Sweden yielded regional and national productivity benefits, has started to fill this void in the literature. However, this work emphasizes the research dimension of universities, rather than the broader set of higher education activities.

By analyzing the relationships that exist between the activities performed by colleges and universities and local human capital levels, this article extends the existing literature in three ways. First, our research provides new insight into the economic geography of higher education activities in the USA. We compile data on the degrees produced and academic R&D expenditures incurred at the metropolitan area level, and show that academic R&D activity tends to be much more geographically concentrated than degree production.

Second, we provide what we believe are the first estimates of the relationship between these two types of higher education activities and the stock of human capital at the metropolitan area level, a unit of measure that closely reflects local labor markets and can account for the localized nature of knowledge spillovers. Our analysis addresses issues that may arise from the potential endogeneity of a region's higher education activities. Among the reasons such endogeneity may exist is that colleges and universities require human capital to produce higher education degrees and to conduct academic R&D. Furthermore, if knowledge spillovers exist, they may flow in both directions if, for example, innovative activities in the local business sector flow back to influence the degree production or academic R&D activities of local colleges and universities.

To address potential endogeneity issues, we develop an instrumental variables approach that exploits exogenous variation in the characteristics of colleges and universities to predict differences in higher education activities across metropolitan areas. We use a set of three variables to simultaneously instrument for both degree production and academic R&D activity: the share of degrees awarded by public universities in a metropolitan area, the presence of a land-grant university and the presence of a Research I university as classified by the Carnegie Foundation. Since the instruments we propose capture differences in the colleges and universities themselves, it is plausible that any effect they may have on local human capital levels operate only *through* the activities of these institutions. As such, this analysis allows us to address the question of whether colleges and universities increase their region's human capital. Our results indicate only a small positive relationship exists between a metropolitan area's production and stock of human capital, suggesting that migration plays an important role in the geographic distribution of human capital. At the same time, we demonstrate that the academic R&D activities of higher education institutions act to increase local human capital levels, suggesting that the spillovers from such activities can increase the demand for human capital, creating opportunities to attract and retain skilled labor.

Finally, our analysis examines the link between the occupational structure of a metropolitan area and its higher education activities. Consistent with our main results, we find a positive relationship between a metropolitan area's higher education activities and the share of workers in high human capital occupations. This outcome appears to be particularly connected to the research intensity of metropolitan areas, as linkages between local economies and higher education institutions appear to be strongest in economic activities requiring innovation and technical training. In total, this research improves our understanding of whether and how local colleges and universities increase their region's human capital.

## 2. The geography of higher education activities

Colleges and universities in the USA conferred more than 2.2 million higher education degrees in 2006. About two-thirds of these degrees were bachelor's degrees, followed by master's degrees (27%), and first-professional degrees or doctoral degrees (7%). Similarly, in 2006, more than $49.6 billion was spent on R&D activities at academic institutions. We calculate the amount of this higher education activity occurring in metropolitan areas, and assess the geographic concentration of each.

### 2.1. Degree production in metropolitan areas

To measure a metropolitan area's degree production, we utilize Integrated Postsecondary Education Data System (IPEDS) data published by the National Center for Education Statistics (NCES) of the US Department of Education. IPEDS is a survey-based system that collects and provides data from all primary providers of postsecondary education in a number of areas, including enrollments, degree completions, faculty and staff, and finances.[1] To construct measures of degree production by metropolitan area, we map degree completion information for more than 4000 higher education institutions to their respective metropolitan areas using zip code information, aggregating over degree types. We collect this information for the 2005–2006 and 1999–2000 academic years, and are able to assign this information to 283 metropolitan areas in the USA.[2] The metropolitan areas in our analysis housed nearly 80% of the population and produced over 80% of the higher education degrees conferred in the USA in both years.

As Figure 1 shows, higher education degrees are produced widely across the USA, although the largest producers are located along the east and west coasts, around the Great Lakes region and in Texas. Table 1 reports the top 20 metropolitan areas based on degree production. In almost all cases, there are a number of well-known major institutions contributing to the total degree count. At nearly 144,000 degrees, the New York metropolitan area ranks first, followed by Los Angeles, Chicago and Boston. Also on the list are other large metropolitan areas, such as San Francisco, along with smaller metros such as Columbus, OH and Raleigh-Durham, NC. In total, the top 20 metropolitan areas accounted for >35% of all of the higher education degrees produced in the USA in 2006. The average metropolitan area produced around 6500 degrees in 2006, and more than 70 metropolitan areas produced fewer than 1000 degrees that year.

1 The Higher Education Act of 1992 mandates completion of IPEDS surveys for all institutions that participate in any federal student aid program. As a result, the IPEDS database captures information from virtually all higher education institutions operating in the USA. To the extent possible, we have omitted degrees conferred by institutions that primarily provide online training. We omit Associates degrees from our analysis because much of the existing literature focuses on attainment of 4-year college degrees and beyond to measure regional stocks of human capital.

2 The metropolitan area definitions we use correspond to those provided by the Integrated Public Use Microdata Series (IPUMS), which are designed to provide the most consistently identifiable unit of geography for the 2006 American Community Survey and 2000 Census (Ruggles et al., 2008). As such, our analysis does not include colleges and universities located outside these 283 metropolitan areas. The largest institutions omitted from our analysis are Cornell University and Virginia Tech, as Ithaca, NY and Blacksburg, VA are not considered metropolitan areas under the IPUMS definition.

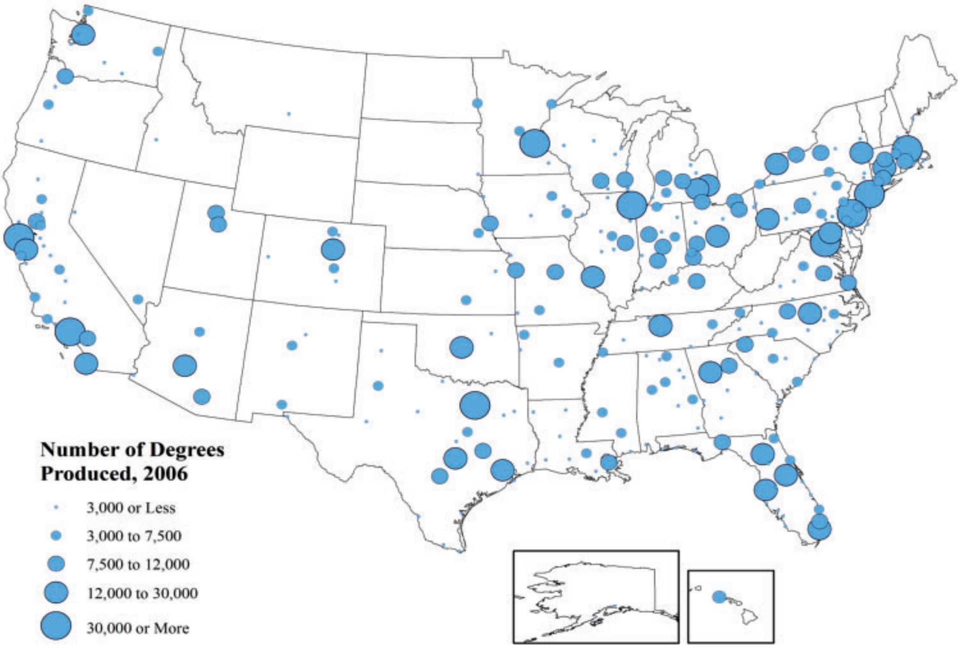


**Figure 1.** Geographic distribution of higher education degrees produced in US metropolitan areas, 2006. *Source*: IPEDS, National Center for Education Statistics.

## 2.2. Academic R&D expenditures in metropolitan areas

We follow a similar procedure to measure the academic R&D expenditures occurring in US metropolitan areas. Here, we utilize data compiled by the National Science Foundation (NSF) Survey of Research and Development Expenditures at Universities and Colleges. This survey reports all funds spent on activities specifically organized to produce research outcomes for a wide range of disciplines, including physical sciences, life sciences, engineering, math and computer sciences, social sciences, business and management, law, education, social work and the arts. As before, we map academic R&D expenditure information for individual higher education institutions to their respective metropolitan areas, aggregating science and non-science R&D expenditures.[3] To best match the academic years covered by our degree data, we collect this information for FY2006 and FY2000 and assign this information to the same 283 metropolitan areas as before. In both years, about 90% of the academic R&D expenditures nationwide were by colleges and universities located in metropolitan areas.

As Figure 2 shows, the geographic distribution of academic R&D expenditures is concentrated, with large amounts of such activity located along the Boston–NY–Washington corridor, in the Research Triangle area and the Great Lakes region, and in Texas and California. The top 20 metropolitan areas based on academic R&D

3 The NSF does not report information for institutions with less than $150,000 in total annual R&D expenditures. Academic R&D expenditures in 2000 are adjusted to account for non-science and engineering R&D expenditures, which were not regularly reported until 2004, using metro-specific average ratios of total R&D expenditures to science and engineering R&D expenditures during the 2004–2006 period.

**Table 1.** Geographic distribution and concentration of higher education activities in US metropolitan areas, 2006

| Degrees produced | | Academic R&D expenditures | |
|---|---|---|---|
| **Summary of geographic distribution** | | | |
| Top 20 metropolitan areas | Number | Top 20 metropolitan areas | $M |
| New York-Northeastern NJ | 143,971 | New York-Northeastern NJ | 2688.71 |
| Los Angeles-Long Beach, CA | 89,311 | Baltimore, MD | 2076.56 |
| Chicago, IL | 68,321 | Los Angeles-Long Beach, CA | 2013.16 |
| Boston, MA-NH | 59,032 | Boston, MA-NH | 1759.29 |
| Washington, DC/MD/VA | 48,525 | San Francisco-Oakland-Vallejo, CA | 1522.06 |
| Philadelphia, PA/NJ | 45,986 | Raleigh-Durham, NC | 1448.56 |
| San Francisco-Oakland-Vallejo, CA | 31,604 | Chicago, IL | 1291.74 |
| Minneapolis-St. Paul, MN | 31,315 | Houston-Brazoria, TX | 1261.81 |
| Dallas-Fort Worth, TX | 30,603 | Philadelphia, PA/NJ | 1027.42 |
| San Diego, CA | 25,905 | Atlanta, GA | 910.66 |
| Atlanta, GA | 24,955 | Madison, WI | 904.79 |
| St. Louis, MO-IL | 24,616 | Ann Arbor, MI | 844.44 |
| Denver-Boulder, CO | 24,186 | San Diego, CA | 841.96 |
| Baltimore, MD | 21,388 | Washington, DC/MD/VA | 827.74 |
| Pittsburgh, PA | 21,233 | Seattle-Everett, WA | 809.65 |
| Austin, TX | 20,564 | Pittsburgh, PA | 759.04 |
| Phoenix, AZ | 20,461 | San Jose, CA | 743.21 |
| Columbus, OH | 18,968 | Columbus, OH | 663.81 |
| Raleigh-Durham, NC | 18,880 | State College, PA | 656.63 |
| Seattle-Everett, WA | 18,101 | St. Louis, MO-IL | 655.63 |
| Mean value | 6480 | Mean Value | 157.13 |
| Total in US metropolitan areas | 1,833,969 | Total in US metropolitan areas | 44,468.70 |
| Total in USA | 2,223,029 | Total in USA | 49,639.97 |
| Percentage in metropolitan areas | 82.5 | Percentage in metropolitan areas | 89.6 |
| **Measures of geographic concentration** | | | |
| Raw Locational Gini | 0.192 | Raw Locational Gini | 0.258 |
| Relative Locational Gini | 0.143 | Relative Locational Gini | 0.267 |

*Sources*: Integrated Postsecondary Education Data System (IPEDS) and Digest of Education Statistics, National Center for Education Statistics, US Department of Education; Academic Research and Development Expenditures: Fiscal Year 2007, Detailed Statistical Tables, Report 09-303, National Science Foundation (NSF); 2006 American Community Survey (IPUMS 1% Sample), US Bureau of Census.

*Notes*: Degrees Produced includes Bachelors, Masters, Doctoral, and First-Professional degrees awarded by Title IV post-secondary institutions. Academic R&D Expenditures are expressed in millions of dollars.



expenditures are reported in Table 1. With expenditures of nearly $2.7 billion, the New York metropolitan area again ranks first, followed by Baltimore, Los Angeles and Boston, with the rankings differing somewhat from degree production. In total, the top 20 metropolitan areas accounted for almost 50% of all of the academic R&D expenditures. The average metropolitan area totaled $157 million in academic R&D expenditures that year, while more than 150 metropolitan areas had less than $10 million in expenditures in 2006.

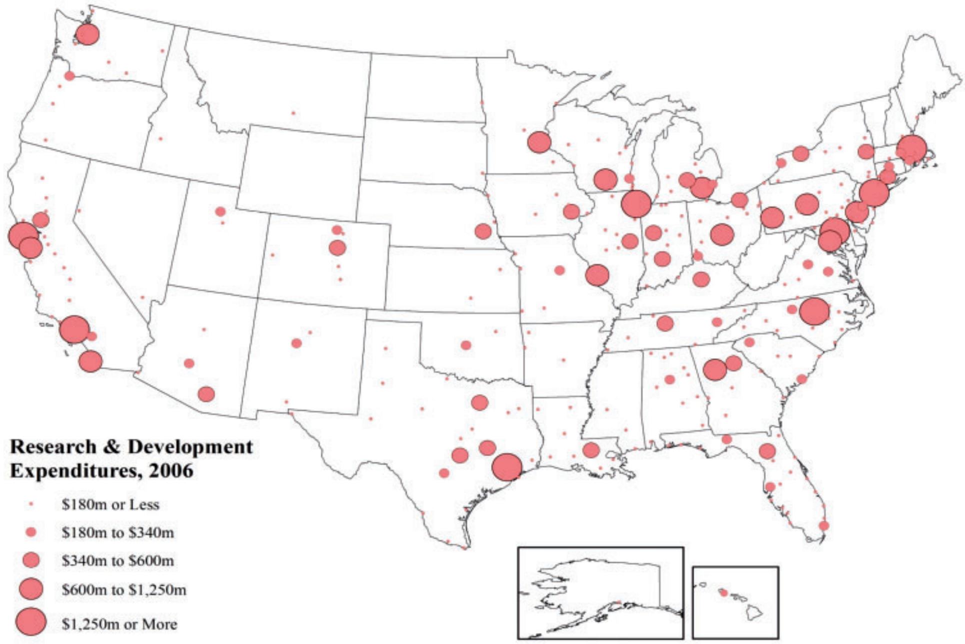


**Figure 2.** Geographic distribution of Academic R&D Expenditures in US metropolitan areas, 2006. *Source*: Academic R&D Expenditures, National Science Foundation.

## 2.3. Comparison of geographic concentration of higher education activities

The geographic concentration of each higher education activity can be quantified using a locational Gini coefficient, which measures the extent to which the distribution of activity across geographic units diverges from an equal allocation (Krugman, 1991; Audretsch and Feldman, 1996).[4] We calculate two versions of this measure of concentration: the raw Gini coefficient, which compares the distribution of each higher education activity to a hypothetical uniform distribution, and the relative Gini coefficient, which compares the distribution of each higher education activity relative to the distribution of population. Locational Gini coefficient values close to zero suggest that the activity is widely dispersed across US metropolitan areas or spread out in a manner similar to the distribution of population, while values close to 0.5 suggest that the activity is geographically concentrated in few places.

Locational Gini coefficients computed for the degree production and academic R&D activity taking place across metropolitan areas are reported in the bottom panel of Table 1. The raw locational Gini coefficient for degree production is 0.19 compared to 0.26 for academic R&D expenditures. Relative to the population, however, the

4 The formula used to compute locational Gini coefficients is $G_L \equiv \sum_i^n =_1 \sum_j^n =_1 |x_i - x_j|/4n(n-1)x_i$, where $i$ and $j$ denote US metropolitan areas ($i \neq j$) and $n = 283$, the number of metropolitan areas in the analysis. When calculating the raw Gini coefficients, $x_i$ is the share of each activity in each metropolitan area (i.e. $X_i/\sum_i^n =_1 X_i$); when calculating the relative Gini coefficients, $x_i$ is the share of each activity relative to the share of population in each metropolitan area (i.e. $(X_i/\sum_i^n =_1 X_i)/(P_i/\sum_i^n =_1 P_i)$).

**Table 2.** Descriptive statistics for human capital stock analysis

| Variable | Mean (Std dev.) | Minimum | Maximum |
|---|---|---|---|
| Human capital stock | 26.27 (8.31) | 10.39 | 58.25 |
| Degree production rate | 1.52 (2.09) | 0.00 | 14.75 |
| Research intensity | 0.28 (0.47) | 0.00 | 5.20 |
| Unemployment rate | 4.33 (1.48) | 2.00 | 16.66 |
| Manufacturing share | 12.31 (6.71) | 1.28 | 49.51 |
| Avg January temperature | 36.27 (13.17) | 6.80 | 73.00 |
| Average precipitation | 38.60 (14.25) | 3.00 | 66.30 |
| Population size | 0.81 (1.62) | 0.10 | 17.67 |

*Sources*: Integrated Postsecondary Education Data System (IPEDS), National Center for Education Statistics, US Department of Education; Academic Research and Development Expenditures: Fiscal Year 2007, Detailed Statistical Tables, Report 09-303, National Science Foundation (NSF); Current Employment Statistics (CES) Survey, Quartery Census of Employment and Wages (QCEW), US Bureau of Labor Statistics; Current Population Survey (CPS), *2007 City and County Data Book*, 2000 Census (IPUMS 5% Sample), 2006 American Community Survey (IPUMS 1% Sample), US Bureau of Census.
*Notes*: Descriptive statistics are for 2000 and 2006 combined. Human Capital Stock represents the percentage of each metropolitan area's working-aged population (i.e. $\geq$25 years) with at least a 4-year degree. Degree Production Rate is expressed as the number of degrees produced per 100 working-aged people. Research Intensity is measured as Academic R&D Expenditures ($10,000) Per Enrollee. Population size is expressed in millions of people. Based on 566 observations.

locational Gini coefficient for degree production falls to 0.14 while that for academic R&D expenditures increases to 0.27.[5] Thus, both measures of geographic concentration indicate that R&D activity is more concentrated than degree production.

## 3. Higher education activities and local human capital

With information about the degrees produced and academic R&D activities of colleges and universities at the metropolitan area level, we next develop measures of the degree production rate and research intensity of local colleges and universities and relate these variables to the amount of human capital in a large cross-section of metropolitan areas. Importantly, metropolitan areas are defined to include the geographic areas in which people live and work, which provides a good proxy for local labor markets and covers the geographic areas where local spillovers are most likely to be captured. As such, our analysis allows us to determine whether the human capital stock in a metropolitan area is related to the higher education activities carried out by its local colleges and universities. Table 2 presents descriptive statistics for the variables used in our main analysis.

5 The geographic concentration of higher education activities was nearly identical in 2000, with raw and relative Gini coefficients of 0.19 and 0.15 for degree production and 0.26 and 0.28 for academic R&D expenditures.

### 3.1. Description of variables

Our primary measure of human capital is the proportion of the working-aged population in each metropolitan area with a college degree. We compute this variable, HCSTOCK, for the same 283 metropolitan areas described above in both 2000 and 2006.[6] While this education-based measure of human capital likely fails to capture the full array of knowledge and skills within a metropolitan area, it is a conventional measure of human capital that has been linked to a number of measures of regional vitality.

With respect to higher education activities, we construct two variables to measure the activities of colleges and universities located in metropolitan areas. The first variable, *DEGREES*, measures the rate of *new* human capital production in a metropolitan area in each year. This variable is calculated as the number of degrees produced in a metropolitan area per 100 working-aged people. On average, about 1.5 degrees are produced per 100 working-aged people in a metropolitan area. Our second variable, *RESEARCH*, measures the research intensity of the colleges and universities in a metropolitan area. This variable is calculated as the academic R&D expenditures ($10,000) per enrolled student in a metropolitan area.[7] We construct this variable to measure the intensity of academic research activities in a metropolitan area, which serves as a proxy for the research orientation of its colleges and universities, capturing the potential for knowledge spillovers. On average, there is about $2,800 in R&D expenditures per enrollee in a metropolitan area.

Finally, as a set of controls, we collect data on several metropolitan area attributes that may also be related to local human capital levels. Specifically, for each year in our study, we gather data on the unemployment rate, share of employment in manufacturing, average January temperature, average precipitation and population size of the metropolitan areas in our study.[8] Consistent with recent research analyzing inter-regional flows of human capital, these variables capture important differences in the economic environment, amenities and agglomeration economies across metropolitan areas (Faggian and McCann, 2006, 2009).

### 3.2. Analysis of local human capital levels

To investigate the relationship between local human capital levels, the degree production rate and research intensity of metropolitan areas, we estimate the following

6 The 2000 data are drawn from the decennial Census (IPUMS 5% sample), while 2006 data are drawn from the American Community Survey (IPUMS 1% sample).

7 Enrollment data are drawn from IPEDS and represent enrollment in the fall semester of each academic year. We use Fall 2000 enrollment data for the 1999–2000 academic year as Fall 1999 data are not available.

8 Data on the unemployment rate and share of employment in manufacturing are drawn from the Current Employment Statistics (CES) survey and Quarterly Census of Employment and Wages (QCEW), published by the US Bureau of Labor Statistics. The climate variables, which are averaged over the period 1971–2000, are drawn from the *2007 County and City Data Book* published by the US Census, and correspond to the central city within each metropolitan area. Population data are from the US Census, as described previously.

pooled cross-sectional model:

$$1\text{n}(HCSTOCK_{it}) = \beta_1 DEGRESS_{it} + \beta_2 RESEARCH_{it} + \sum\nolimits_{j=1}^{n} \beta_j X_{jit} + v_i + \gamma_t + \varepsilon_{it} \quad (1)$$

where $i \equiv$ metropolitan area, $t \equiv$ year, $X_{jit} \equiv$ vector of $j$ metropolitan area controls, $v_i \equiv$ state fixed effects, $\gamma_t \equiv$ year fixed effects, and $\varepsilon_{it} \equiv$ error term. The dependent variable, *HCSTOCK*, is the conventional measure of the stock of human capital in a metropolitan area, while the key explanatory variables, *DEGREES* and *RESEARCH*, capture differences in each higher education activity between metropolitan areas. With this specification, the coefficients we estimate are identified by the cross-sectional variation in the degree production rate and research intensity that exists across metropolitan areas.[9] To mitigate any bias induced by potential omitted variables, we include both state and year fixed effects to control for a wide array of unobserved region-specific variables affecting local human capital levels, as well as unobserved factors affecting human capital levels over time. Moreover, we implement a novel instrumental variables approach simultaneously treating both higher education activities as endogenous to address the endogeneity issues that may arise.

Care must be taken in interpreting the results of our empirical analysis of local human capital levels. First, colleges and universities directly employ human capital themselves, so part of the empirical relationship we estimate between higher education activities and human capital levels may be picking up this direct effect. Second, since we do not observe the flow of people between metropolitan areas, the relationship we estimate between the local production and stock of human capital may not necessarily capture college graduates remaining in the area in which they obtained their degree, but rather the *net* relationship. This may include locally produced graduates remaining in the area, the swapping of locally produced human capital for that produced outside the region, or some combination of both.

Table 3 reports the results of our initial regression analysis as well as elasticity estimates calculated at the mean value of each higher education activity. To provide a direct link to the existing literature, we begin by estimating equation (1) focusing only on the degree production rate of metropolitan areas. As Column (1) shows, we find that the elasticity of a metropolitan area's human capital stock with respect its local degree production rate is around 0.12—one-third of that found for a cross-section of US states by Bound et al. (2004).[10] Taken at face value, this point estimate suggests that a doubling of degree production is associated with a 12% increase in a metropolitan area's human capital stock. The fact that the degree production elasticity falls when more disaggregated geographic areas are used as the unit of observation provides a first

9 Due to data limitations, there are some differences in how the college and university variables are measured in 2000 and 2006. For example, IPEDS reports degree completion information differently between years and some estimation is required to account for non-science and engineering R&D in 2000. As a result, we are not able to analyze our data using panel data techniques. These differences do not pose a problem for cross-sectional analysis, as the variation across metropolitan areas is large and persistent.

10 Bound et al. (2004) report state-level elasticity estimates of 0.32–0.34 using data on the number of bachelor's degrees produced per capita across the 48 continental states during the 1960–1990 period. When aggregating our data to the state level, we produce elasticity estimates of 0.31–0.32.

**Table 3.** Human capital stock regression results

| | OLS | | | IV | First stage results | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | Degrees | Research |
| Degree production rate | 0.080*** | 0.058*** | 0.044*** | 0.023 | – | – |
| | (0.005) | (0.007) | (0.005) | (0.023) | | |
| Research Intensity | – | 0.243*** | 0.160*** | 0.316*** | – | – |
| | | (0.052) | (0.034) | (0.096) | | |
| Unemployment rate | – | – | −0.953*** | −0.916*** | −0.128*** | −0.022*** |
| | | | (0.010) | (0.009) | (0.048) | (0.009) |
| Manufacturing share | – | – | −0.014*** | −0.014*** | −0.045*** | −0.003 |
| | | | (0.002) | (0.002) | (0.013) | (0.003) |
| Avg January temperature | – | – | −0.001 | −0.004 | −0.050** | 0.011* |
| | | | (0.002) | (0.003) | (0.021) | (0.006) |
| Precipitation | – | – | 0.001 | 0.000 | 0.016* | 0.006* |
| | | | (0.001) | (0.009) | (0.010) | (0.003) |
| Population size | – | – | 0.028*** | 0.020*** | −0.335*** | −0.024** |
| | | | (0.006) | (0.007) | (0.070) | (0.011) |
| Share public | – | – | – | – | 1.294*** | 0.122*** |
| | | | | | (0.166) | (0.036) |
| Land grant | – | – | – | – | 1.430*** | 0.203*** |
| | | | | | (0.376) | (0.052) |
| Research I | – | – | – | – | 2.051*** | 0.668*** |
| | | | | | (0.341) | (0.055) |
| Adj. $R^2$ | 0.371 | 0.481 | 0.692 | – | 0.442 | 0.434 |
| $N$ | 566 | 566 | 566 | 566 | 566 | 566 |
| Degree production elasticity | 0.12 | 0.09 | 0.07 | 0.03 | – | – |
| Research intensity elasticity | – | 0.07 | 0.04 | 0.09 | – | – |
| $F$-statistic of excluded instruments | – | – | – | – | 36.75*** | 104.87*** |
| Wald statistic for weak instrument test | – | – | – | $5.78^{+}$ | – | – |
| Stock and Yogo 10% LIML size threshold | – | – | – | 5.44 | – | – |
| $p$-value for overidentification test | – | – | – | 0.920 | – | – |

*Notes*: Dependent variable is the natural logarithm of human capital stock. All models also include state and year fixed effects. ***, ** and * denote significance at the 0.01, 0.05 and 0.10 levels, respectively. Robust standard errors reported in parentheses. IV estimates obtained using limited information maximum likelihood estimator. $^{+}$denotes that we can reject the null hypothesis of weak instruments based on the Stock and Yogo (2005) test ($\alpha = 0.05$) using the 10% maximal LIML size threshold.

indication that geographic mobility is an important source of the variation in human capital across space.

However, even this elasticity estimate is likely to be overstated because it does not control for the research activities at colleges and universities, which may also influence local human capital levels through spillovers into the local economy. Column (2) of Table 3 reports the results of our model when the research intensity of a metropolitan area is also included. Overall, the empirical model performs quite well, explaining nearly half of the variation in human capital levels across metropolitan areas compared to around 37% when only degree production is considered. In addition, the expected positive relationship holds at conventional levels of significance for both higher education variables we consider. Results show that a doubling of a metropolitan area's degree production rate is associated with a 9% increase in local human capital levels, while a doubling of a metropolitan area's research intensity is associated with a 7% increase in local human capital levels.

Column (3) of Table 3 reports estimation results for our full model when metro-level controls are included in the model along with state and year fixed effects. Including these variables in the model improves its overall explanatory power, as the adjusted $R^2$ rises from 48% to 69%. Most importantly, our key findings regarding the relationship between higher education activities and local human capital levels continue to hold. Results show that a doubling of a metropolitan area's degree production rate and research intensity is associated with a 7% and 4% increase in local human capital levels, respectively.[11] Thus, once other factors influencing local human capital levels are taken into account, our metropolitan area degree production elasticity estimate falls to about one-fourth the size of the most comparable state-level estimates (Bound et al., 2004).[12]

An important concern that arises in this empirical approach is that differences in the activities of colleges and universities are not randomly assigned across space, making causal inference difficult. Indeed, higher education activities may be endogenous to local human capital levels. As discussed earlier, highly skilled people at colleges and universities are necessary to produce higher education degrees and to conduct academic research.[13] Moreover, if knowledge spillovers exist, they likely flow in both directions.

11 As a robustness check, we also estimated a version of this model using the absolute level of academic R&D spending instead of our research intensity measure. The estimated coefficient on each higher education activity variable remained positive and significant, and the corresponding elasticities calculated at the mean were identical to those reported in Table 3.

12 Although metropolitan areas in the USA are often separated by significant distances, we also examined whether our results were sensitive to potential spatial interactions between metropolitan areas. To test for spatial dependence, we estimated our model incorporating a correction for either spatial error or spatial lag. In both cases, the sign, magnitude and statistical significance of the estimated coefficients were nearly identical to that obtained using OLS. Further, we investigated whether there were systematic spillover effects between the production and stock of human capital among metropolitan areas. We included a gravity-type variable calculated as the number of degrees produced in metropolitan areas outside of metropolitan area $i$, weighted by the inverse of the squared distance between each pair of metropolitan areas, scaled by the working-age population in metropolitan area $i$. We found no evidence of systematic spillover effects, and the estimated coefficients for our key higher education variables were identical to those reported in Table 3.

13 This particular concern is mitigated by the fact that colleges and universities rarely employ a large share of workers in a metropolitan area. However, to investigate this issue more directly, we used IPEDS to estimate the number of workers with at least a bachelor's degree employed by each higher education institution. On average, only 3.3% of the people with a bachelor's degree or above were employed by a college or university in the metropolitan areas we consider. Excluding these people from our human

That is, while local businesses may utilize the human capital and innovation developed by local higher education institutions, degree production and academic R&D activities themselves may be influenced by activities occurring in the local business sector. To address the potential endogeneity of the two higher education activities we consider, we re-estimate our empirical model using an instrumental variables approach that allows us to determine whether colleges and universities act to raise their region's human capital.[14]

Implementing instrumental variables estimation requires that we identify variables that are correlated with higher education activities across space (i.e. relevant), but not directly related to differences in current human capital levels across metropolitan areas (i.e. exogenous). Our instrumental variables strategy hinges on identifying characteristics of colleges and universities that predict places across the USA with a higher rate of degree production and research intensity that can be excluded from our main human capital equation. We consider a set of three such variables that we use to simultaneously instrument for both higher education activities: the share of degrees awarded by public universities in a metropolitan area, the presence of a land-grant university, and the presence of a Research I university as classified by the Carnegie Foundation. Thus, our key identifying assumption is that any relationship between these variables and local human capital levels occurs *through* the activities of these institutions.

The first variable in our instrument set is the share of degrees awarded by public higher education institutions in a metropolitan area. Although there are a large number of private colleges and universities in the USA, the development of the US higher education system was heavily influenced by federal and state government policy. Indeed, as Goldin and Katz (2008) demonstrate, an important distinguishing feature of education policy in the USA was the use of public funds to educate the masses. Due to this focus on creating access to educational opportunities, the size of public universities increased sharply in absolute terms and relative to private institutions throughout the 20th century. At the same time, institutions of higher education, particularly those in the public sector, evolved from places focused on teaching and learning to places that increasingly emphasized the creation of knowledge through research. Thus, we would expect metropolitan areas with a larger share of public institutions to have a higher degree production rate and to be more research intensive than those with a smaller public presence. Moreover, because the funding decisions for such institutions are largely outside of the control of the local population, there is little reason to expect any direct relationship between the local human capital levels and amount of higher education activities in a metropolitan area. Thus, it is plausible that the only influence this variable may have on local human capital levels is through the colleges and universities themselves.

We use the presence of a land-grant university within a metropolitan area as the second variable in our instrument set. The establishment of land-grant universities was

capital stock measure reduced the mean value by only 1 percentage point. Nonetheless, we re-estimated our model using this adjusted measure, and, consistent with our main results, found that a doubling of a metropolitan area's degree production rate and research intensity is associated with a 5% and 4% increase in local human capital levels, respectively.

14 We employ LIML for our instrumental variables regression analysis as Stock and Yogo (2005) demonstrate that it is superior to 2SLS in the presence of weak instruments. However, results using conventional 2SLS are nearly identical to those obtained with LIML.

a particularly important part of the development of public higher education in the USA.[15] Consistent with the broader purpose of public higher education support, the original mission of these institutions was to provide the working class with access to educational opportunities, particularly in fields related to agriculture, engineering and military science. In addition, land-grant universities receive unique annual federal and state appropriations to support research and extension work. As a result, these higher education institutions have evolved into relatively large, research-oriented universities. Thus, we would expect metropolitan areas with a land-grant university to have a higher degree production rate and be more research intensive than otherwise. Moreover, because land-grant universities were established in every state during the late 19th century, their location is clearly not influenced by current levels of human capital. Thus, it is highly likely that the only influence the presence of a land-grant university may have on local human capital levels is through its activities.

We include the presence of a Research I university within a metropolitan area, as identified in the Carnegie Classification of Institutions of Higher Education, as the third variable in our instrument set. An advantage of using this classification is that it allows us to identify the location of major research-intensive colleges and universities in the USA regardless of whether the institution is public or private. Since Research I universities offer a full range of degree programs, are committed to graduate education through the doctorate degree, and place a high priority on research, we would expect metropolitan areas with a Research I university to have a higher degree production rate and be more research intensive than otherwise. While the Carnegie Classification has evolved over time along with the higher education industry itself, we use the earliest classification available, from 1987, to ensure that the location of such institutions is independent of current local human capital levels.[16] Thus, it is reasonable to believe that the only influence the presence of a Research I university as of 1987 may have on local human capital levels is through the activities they perform.

The rightmost columns of Table 3 report first-stage regression results for the degree production rate and research intensity of colleges and universities located in metropolitan areas. Results show that all of our proposed instruments are positively and statistically significantly related to each higher education activity. Thus, consistent with expectations, metropolitan areas with higher education institutions that have higher shares of degrees awarded by public institutions, possess a land-grant institution, or have a Research I university tend to more intensively produce degrees and conduct academic research than otherwise. Further, the *F*-statistic for the excluded instruments

15 The Morrill Acts of 1862 and 1890 are credited for establishing the major land-grant universities that exist today in the USA. The original land-grant universities, known as 'the 1890 land-grants', are major universities located in places ranging from Boston, MA and Washington, DC to Columbus, OH; Tucson, AZ; and Corvallis, OR. Following Moretti (2004), we do not include the tribal institutions that were granted land-grant status by the 1994 Land-Grant Act in our analysis.

16 The Carnegie Classification system was developed during the 1970s in an effort to identify comparable groups of institutions for the purposes of conducting educational research and analysis. The major classifications as of 1987 were: Research I and II, Doctorate-Granting I and II, Comprehensive I and II, Liberal Arts I and II, as well as a number of more specialized designations. Research I institutions are generally major universities located in places ranging from New York City and Chicago, IL to Rochester, NY; St Louis, MO; and Las Cruces, NM. Beginning with the 2000 edition of the Carnegie Classification, the use of roman numerals was discontinued to avoid the incorrect inference that the categories signified quality differences. See <http://classifications.carnegiefoundation.org/> for more information.

is 36.75 when the degree production rate is the first-stage dependent variable, and 104.87 when research intensity is the first-stage dependent variable, well above the rule of thumb for strong instruments (i.e. *F*-statistic of at least 10) proposed by Staiger and Stock (1997). A key advantage of using more instrumental variables than potentially endogenous variables is that it allows us to test formally their validity. With a first-stage Wald statistic for the excluded instruments of 5.78, we can reject the null hypothesis of weak instruments using a weak instrument test developed by Stock and Yogo (2005).[17] Moreover, with a *p*-value of 0.92, a Sargan over-identification test indicates that our instruments are also uncorrelated with the error term.[18] As our instrument set meets both the relevance and exogeneity condition, we conclude our instruments are valid.

Turning to the parameter estimates presented in Column (4) of Table 3, while the results from the second-stage regression are generally consistent with those obtained using OLS estimation, the relative magnitude of the estimated effects changes. That is, we find that a doubling of a metropolitan area's degree production rate and research intensity is associated with a 3% and 9% increase in local human capital levels, respectively. However, as is common with instrumental variables analysis, particularly when multiple endogenous variables are involved, the standard errors of our estimates increase significantly, reducing the precision of our estimates considerably. Thus, while the point estimate for the research intensity variable remains statistically significant, the point estimate for the degree production rate variable does not. It is important to note, however, that the OLS point estimate for the degree production rate variable of 0.044 lies within one standard deviation (i.e. 0.023) of the corresponding point estimate of 0.023 obtained using instrumental variables. Similarly, the 95% confidence interval around the point estimate of 0.316 for the research intensity variable obtained using instrumental variables includes the OLS point estimate of 0.16.

Taken together, these findings provide evidence that colleges and universities raise local human capital levels by increasing both the supply of and demand for skilled labor. However, the small degree production elasticity we find indicates that migration plays an important role in the geographic distribution of human capital across metropolitan areas. This finding is consistent with recent empirical research analyzing the flow of college graduates in Great Britain demonstrating the importance of inter-region migration in determining the spatial distribution of human capital (Faggian and McCann, 2006, 2009).

The importance of migration in determining local human capital levels in the USA is illustrated further in Figure 3, which compares a metropolitan area's degree production rate to its net human capital consumption rate, measured as the average annual change in the number of people with at least a college degree per 100 working-aged people. The 45-degree line indicates where the annual production and consumption of human capital is in balance. The figure shows that a large number of metropolitan areas

17 This weak instrument test compares the first-stage Wald statistic from the two-stage regression model to a critical value that depends on the number of endogenous variables, number of instruments, and the tolerance for the 'size distortion' of a test ($\alpha = 0.05$) of the null hypothesis that the instruments are weak.

18 This test of overidentifying restrictions is computed as $N \times R^2$, where $N$ is the number of observations and $R^2$ is computed from a regression of the residuals from the second stage regression on all exogenous variables and the instruments. The test statistic is distributed $\chi^2$ with degrees of freedom equal to the number of overidentifying restrictions, in our case one.

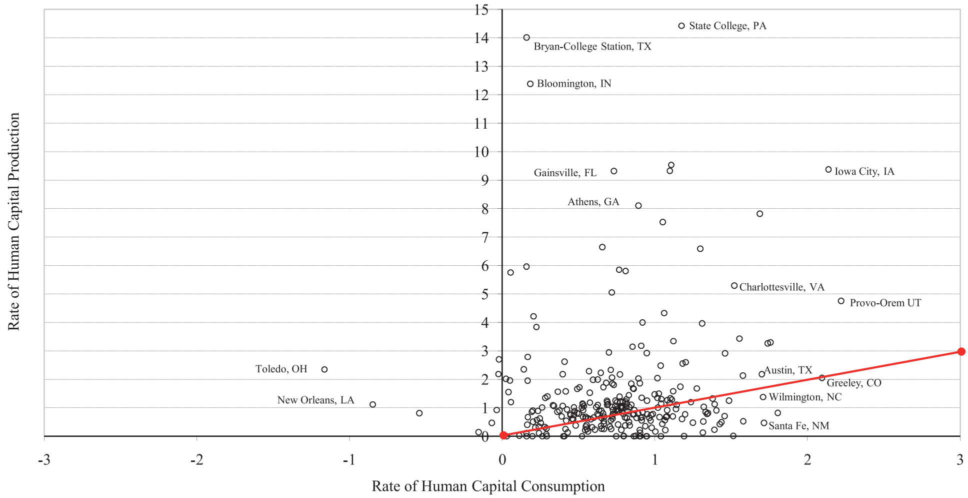


**Figure 3.** Balance of Human Capital Production and Consumption in US Metropolitan Areas, 2000–2006. *Sources*: Integrated Postsecondary Education Data System (IPEDS), National Center for Education Statistics, US Department of Education; 2000 Census (IPUMS 5% Sample), 2006 American Community Survey (IPUMS 1% Sample), US Bureau of Census. *Notes*: Rate of Human Capital Production is calculated as the average annual number of higher education degrees produced per 100 working-aged people in a metropolitan area. Rate of Human Capital Consumption is calculated as the average annual change in the number of people with at least a college degree per 100 working-aged people in a metropolitan area. Metropolitan areas above the 45-degree line are net exporters (i.e., production > consumption), while those below the 45-degree line are net importers (i.e. production < consumption) of human capital. Based on 283 metropolitan areas.

specializing in higher education produce far more human capital than they consume. In fact, the majority of metropolitan areas—62%—produce more human capital than they consume, while the remaining 38% consume more human capital than they produce. Clearly, both labor supply and labor demand factors are at work redistributing human capital across space.

Theories of urban agglomeration suggest that larger metropolitan areas may be better able to absorb newly produced college graduates and are more likely to offer an infrastructure that can support the spillover benefits to local business activity arising from academic research. To explore whether our data supported these ideas, we investigated whether the relationship between local human capital levels and each higher education activity varied with the size of a metropolitan area. OLS estimates indicated that the relationship between a metropolitan area's degree production rate and its human capital level increased with population size, while the relationship between the research intensity of a metropolitan area's colleges and universities and its human capital level remained relatively constant across the size spectrum. However, when we instrumented for both the level and interaction of these variables, with four potentially endogenous variables in a single estimating equation (i.e. degree production, research intensity, and the two corresponding interaction terms), the precision of our estimates was reduced considerably. Thus, the resulting standard errors were generally too large to yield statistically significant results, making a clear interpretation of this model difficult.

While the high degree of geographic mobility among skilled workers limits a region's ability to harness the full benefits of its local degree production, the spillovers that arise from academic R&D activities may help to mitigate the loss of locally produced graduates. This is because the research activities of colleges and universities can provide a local benefit that is anchored to the region, given the importance of physical proximity in the transmission of knowledge spillovers. Our analysis suggests these benefits are realized in part by creating opportunities for local businesses to retain and attract skilled workers, whether produced locally or elsewhere, which results in higher local human capital levels.

## 4. The occupational structure of metropolitan areas

To the extent that a metropolitan area has more human capital when there is more higher education activity, as our main results indicate, these activities may also be related to the *types* of human capital present for two reasons. First, research is more likely to create knowledge spillovers in some fields than others. For example, biomedical research at a local university may provide externalities to local life science companies, but is unlikely to do so for local manufacturing plants or restaurants. Second, to the extent that opportunities exist in particular fields within a metropolitan area, an increase in labor supply from local specialization in a field will result in higher equilibrium employment levels in said field. In addition, specialization in particular fields may offer opportunities for knowledge spillovers in those fields, for example, if professors spread academic knowledge by serving as consultants or start businesses of their own. However, these types of relationships cannot be identified when estimating the empirical relationship on net. We next consider how the types of higher education activities present in a metropolitan area are related to its occupational structure.

For this analysis, we collect occupational employment data for both 2000 and 2006, and calculate the share of workers in 21 occupation categories for most of the 283 metropolitan areas in our data.[19] We are also able to include a measure of the local specialization of higher education activities, which categorizes the types of degrees produced, by major, into fields that correspond to each occupational category.[20] These specialization variables, denoted *LOCSPEC*, are calculated as the share of degrees produced in a metropolitan area specifically for the occupational category under

19 The 2000 and 2006 data are drawn from the Occupational Employment Statistics (OES) survey published by the US Bureau of Labor Statistics. Certain occupational data were not available for a small number of metropolitan areas.

20 To calculate these variables, we use an occupational crosswalk provided by the National Center for Education Statistics (NCES) to link the types of degree majors listed in the Classification of Instructional Programs (CIP 2000) to broad occupational categories listed in the Standard Occupational Classification (SOC) system (http://nces.ed.gov/pubs2002/cip2000/). This classification is not mutually exclusive as degree majors can feed into multiple occupational categories. We deviate from this occupational crosswalk only in the Education, Training and Library category because the published crosswalk assumes that almost any degree recipient can become a teacher. Instead, we restrict this category to include only education and library majors.

**Table 4.** Descriptive statistics for occupational structure analysis

| SOC | Occupational Category | *N* | Share of employment Mean (Std dev.) | Local specialization Mean (Std dev.) |
|---|---|---|---|---|
| 11 | Management | 537 | 4.94 (1.45) | 30.74 (14.16) |
| 13 | Business and Financial Operations | 535 | 3.45 (1.28) | 16.68 (10.26) |
| 15 | Computer and Math | 522 | 1.72 (1.25) | 4.46 (2.92) |
| 17 | Architecture and Engineering | 528 | 1.76 (0.98) | 4.04 (4.80) |
| 19 | Life, Physical and Social Science | 517 | 0.76 (0.46) | 17.75 (9.99) |
| 21 | Community and Social Services | 532 | 1.28 (0.45) | 3.55 (4.67) |
| 23 | Legal | 517 | 0.60 (0.29) | 1.43 (2.47) |
| 25 | Education, Training and Library | 499 | 6.27 (1.81) | 11.42 (8.89) |
| 27 | Arts, Design, Entertainment, Sports and Media | 536 | 1.04 (0.37) | 9.35 (8.05) |
| 29 | Healthcare Practitioners and Technical | 526 | 5.29 (1.23) | 8.77 (11.05) |
| 31 | Healthcare Support | 533 | 2.69 (0.76) | 0.03 (0.21) |
| 33 | Protective Service | 522 | 2.18 (0.73) | 1.92 (2.31) |
| 35 | Food Preparation and Serving | 538 | 8.80 (1.67) | 0.03 (0.23) |
| 37 | Building and Grounds Cleaning | 537 | 3.36 (0.72) | 0.03 (0.14) |
| 39 | Personal Care and Service | 536 | 2.27 (0.92) | 1.80 (1.80) |
| 41 | Sales | 538 | 10.79 (1.29) | 0.47 (0.89) |
| 43 | Office and Administrative | 538 | 17.20 (1.95) | 0.23 (0.73) |
| 47 | Construction and Extraction | 538 | 5.09 (1.48) | 0.01 (0.05) |
| 49 | Installation, Maintenance and Repair | 537 | 4.28 (0.77) | 0.18 (0.95) |
| 51 | Production | 536 | 8.90 (4.56) | 0.37 (1.79) |
| 53 | Transportation and Material Moving | 533 | 7.32 (1.84) | 0.13 (1.37) |

*Sources*: Integrated Postsecondary Education Data System (IPEDS), National Center for Education Statistics, US Department of Education; Occupational Employment Statistics (OES) Survey, US Bureau of Labor Statistics.

*Notes*: Descriptive statistics are for 2000 and 2006 combined. Share of Employment is calculated using occupation-level information, and excludes Farming, Fishing and Forestry occupations (SOC 45). Local Specialization is calculated using information on the higher education degrees associated with each occupational category. See Table 2 for additional descriptive statistics.

consideration. Table 4 presents descriptive statistics for the occupation-specific variables.

With this information in hand, we are able to analyze the relationship between higher education activity and the specific types of human capital present in a local economy. In addition, because the amount of education required differs among occupations, our analysis allows for a deeper understanding of the mechanisms through which colleges and universities are related to the more conventional measure of local human capital. Table 5 provides information on the educational attainment of people working in the occupational categories included in our analysis, and shows that a clear break exists in the distribution of educational attainment across occupations. As such, we refer to ‘high’ human capital occupations as those with an above average amount of education required and ‘low’ human capital occupations as those with a below average amount of education required. Approximately 50% or more of the people in occupations classified in the ‘high’ category have at least a college degree compared to fewer than 25% of the workers in the ‘low’ category.

**Table 5.** Educational attainment by occupational category

| Classification | Occupational category | Percentage with at least BA |
|---|---|---|
| High | Life, Physical and Social Science | 76.3 |
| | Legal | 76.1 |
| | Education, Training and Library | 73.5 |
| | Community and Social Services | 66.9 |
| | Computer and Math | 63.2 |
| | Architecture and Engineering | 60.2 |
| | Business and Financial Operations | 58.8 |
| | Healthcare Practitioners and Technical | 54.4 |
| | Arts, Design, Entertainment, Sports and Media | 51.3 |
| | Management | 48.8 |
| Low | Sales | 23.6 |
| | Protective Service | 19.4 |
| | Office and Administrative Support | 15.5 |
| | Personal Care and Service | 12.3 |
| | Healthcare Support | 8.8 |
| | Installation, Maintenance and Repair | 6.8 |
| | Production | 6.2 |
| | Transportation and Material Moving | 6.1 |
| | Food Preparation and Serving | 5.9 |
| | Construction and Extraction | 5.4 |
| | Building and Grounds Clearing | 5.1 |
| | Total Among All Occupations | 26.4 |

*Source*: 2006 American Community Survey (IPUMS 1% Sample), US Bureau of Census.

Building from the empirical framework described earlier, we estimate the following pooled cross-sectional log-odds model for 21 separate occupational categories:

$$ln\left(\frac{s_{it}}{1-s_{it}}\right) = \beta_1 DEGRESS_{it} + \beta_2 RESEARCH_{it} + \beta_3 LOCSPEC_{it} + \sum\nolimits_{j=1}^{n} \beta_j X_{jit} + v_i + \gamma_t + \varepsilon_{it} \quad (2)$$

where $i \equiv$ metropolitan area, $t \equiv$ year, $X_{jit} \equiv$ vector of $j$ metropolitan area controls, $v_i \equiv$ state fixed effects, $\gamma_t \equiv$ year fixed effects, and $\varepsilon_{it} \equiv$ error term.[21] Here, the dependent variable measures the log-odds share, S, of employment in a specific occupational category, while the key independent variables, *DEGREES*, *RESEARCH* and *LOCSPEC*, each measure a different aspect of a metropolitan area's higher education activities.

Due to the difficulties associated with obtaining valid instruments for each of these potentially endogenous higher education variables across 21 different regression

21 Since this analysis focuses on the share of metropolitan area employment in different occupational categories, we do not include the share of employment in the manufacturing industry as a control since industry structure closely parallels occupational structure.

models, we limit our analysis here to OLS specifications.[22] As such, we are not able to make causal inferences when interpreting these results. Rather, we view our regression estimates as reduced form correlations that help illuminate how the occupational structure of a metropolitan area varies with its higher education activities. As with our main analysis, we include several metro-level controls along with state and year fixed effects.

Table 6 presents the results of our occupation-based regression analysis. To help assess the magnitude of these correlations and allow for a uniform comparison across occupational categories, each of the higher education variables has been standardized. As such, these coefficient estimates can be interpreted as the percentage change in each occupation share associated with a one standard deviation change in each higher education activity. Results show a strong connection between a metropolitan area's research intensity and the presence of high human capital occupations, as a positive and significant relationship exists for seven of the ten 'high' human capital occupations. This relationship is particularly pronounced for occupations requiring innovation and technical training, such as those in Computer and Math; Life, Physical and Social Sciences; Business and Financial Operations; and Architecture and Engineering. Like academic R&D, economic activity in these areas tends to cluster geographically, consistent with the importance of knowledge spillovers to innovative activity.

In contrast, low human capital occupations in categories such as Production; Food Preparation and Serving; Transportation and Material Moving; and Installation, Maintenance, and Repair do not appear to benefit from access to academic research. Instead, people working in many of these occupations, as well as those in education, community and social services, and healthcare, are more likely to be distributed in proportion to the population because the customer base for such business activity tends to be local. Since the dependent variables are expressed in shares, these latter categories tend to have negative and significant coefficients. In combination, these results suggest that metropolitan areas with more research-intensive colleges and universities tend to have a higher share of workers in high human capital activities. Indeed, evaluated at mean employment shares (reported in Table 4), we find that a one standard deviation increase in a metropolitan area's research intensity is associated with a 5.3% increase in the share of workers in 'high' human capital occupations.

In terms of the degree production rate, we find a positive and significant relationship for only five of the ten 'high' human capital occupations and three of the 11 'low' human capital occupations. In particular, we find that the share of people working in the categories Life, Physical and Social Sciences; Education, Training and Library; Community and Social Services; Arts and Media; and those in healthcare is positively associated with degree production. These findings suggest that access to local human capital is important for businesses in these fields. In contrast, we find that the share of

22 Although finding instruments for each of the local specialization variables was beyond the scope of the current paper, we did consider whether to estimate these regressions instrumenting for only degree production and research intensity using the instrument set from the previous analysis. However, given that the local specialization variable may also be endogenous, it is not clear such estimation would be a viable alternative. Moreover, even though we have strong instruments for the degree production and research intensity variables, there is no guarantee that the exogeneity condition would be met for each of the individual 21 regression models we consider here because each has a different dependent variable. In fact, in attempting to use this instrument set, over-identification tests failed in about one-third of the regressions, casting doubt on the exogeneity of our instrument set across all regression models.

**Table 6.** Occupational structure regression results, standardized

| Classification | Occupational category | Degree production rate | Research intensity | Local specialization | Adj. $R^2$ | *N* |
|---|---|---|---|---|---|---|
| High | Life, Physical and Social Science | 0.059** | 0.240*** | −0.019 | 0.43 | 517 |
| | | (0.029) | (0.021) | (0.022) | | |
| | Legal | −0.033* | 0.073*** | 0.099** | 0.34 | 517 |
| | | (0.020) | (0.026) | (0.040) | | |
| | Education, Training and Library | 0.151*** | 0.005 | −0.003 | 0.37 | 499 |
| | | (0.026) | (0.012) | (0.016) | | |
| | Community and Social Services | 0.038** | −0.015 | 0.021* | 0.44 | 532 |
| | | (0.015) | (0.019) | (0.011) | | |
| | Computer and Math | −0.041 | 0.241*** | 0.152*** | 0.48 | 522 |
| | | (0.026) | (0.030) | (0.029) | | |
| | Architecture and Engineering | −0.135*** | 0.110*** | 0.155*** | 0.34 | 528 |
| | | (0.027) | (0.027) | (0.031) | | |
| | Business and Financial Operations | −0.049*** | 0.090*** | 0.009 | 0.39 | 535 |
| | | (0.017) | (0.014) | (0.016) | | |
| | Healthcare Practitioner and Technical | 0.034* | −0.011 | 0.010 | 0.21 | 526 |
| | | (0.018) | (0.013) | (0.012) | | |
| | Arts, Design, Entertainment, Sports and Media | 0.049*** | 0.055*** | 0.017 | 0.45 | 536 |
| | | (0.014) | (0.017) | (0.014) | | |
| | Management | −0.024** | 0.056*** | 0.014 | 0.70 | 537 |
| | | (0.010) | (0.009) | (0.010) | | |
| Low | Sales | −0.005 | −0.020*** | −0.002 | 0.21 | 538 |
| | | (0.008) | (0.006) | (0.005) | | |
| | Protective Service | −0.052*** | 0.017 | 0.006 | 0.40 | 522 |
| | | (0.015) | (0.013) | (0.013) | | |
| | Office and Administrative Support | 0.006 | 0.008 | 0.003 | 0.30 | 538 |
| | | (0.006) | (0.006) | (0.009) | | |
| | Personal Care and Service | 0.042** | −0.018 | 0.020 | 0.39 | 536 |
| | | (0.019) | (0.012) | (0.015) | | |
| | Healthcare Support | 0.021*** | −0.054*** | 0.014** | 0.30 | 533 |
| | | (0.013) | (0.014) | (0.006) | | |
| | Installation, Maintenance, and Repair | −0.045*** | −0.016** | 0.005** | 0.38 | 537 |
| | | (0.009) | (0.007) | (0.003) | | |
| | Production | −0.064*** | −0.055*** | −0.007 | 0.50 | 536 |
| | | (0.020) | (0.017) | (0.009) | | |
| | Transportation and Material Moving | −0.043*** | −0.033*** | −0.001 | 0.34 | 533 |
| | | (0.010) | (0.011) | (0.005) | | |
| | Food Preparation and Serving | 0.046*** | −0.030** | −0.002 | 0.28 | 538 |
| | | (0.010) | (0.014) | (0.008) | | |
| | Construction and Extraction | −0.036*** | −0.015 | −0.005 | 0.43 | 538 |
| | | (0.013) | (0.010) | (0.004) | | |
| | Building and Grounds Cleaning | 0.030*** | −0.012 | 0.015** | 0.31 | 537 |
| | | (0.010) | (0.008) | (0.007) | | |

*Notes*: Dependent variable for each regression is the log-odds share of workers in stated occupational category. All models also include metropolitan area unemployment rate, average January temperature, average precipitation, and population size, as well as state and year fixed effects. ***, ** and * denote significance at the 0.01, 0.05 and 0.10 levels, respectively. Robust standard errors reported in parentheses.

people working in manufacturing and goods distribution-related occupations, such as Production; Transportation and Material Moving; Construction and Extraction; and Installation, Maintenance and Repair, is negatively associated with degree production. In combination, we find that a one standard deviation increase in a metropolitan area's degree production rate is associated with a 2.4% increase in the share of workers in 'high' human capital occupations when evaluated at mean employment shares, which is less than half of that associated a metropolitan area's research intensity.

This difference in results stems in large part from the types of human capital that appear to benefit from the degree production and R&D activities of colleges and universities located in metropolitan areas. In particular, research-intensive metropolitan areas tend to have larger shares of the most highly skilled occupations (e.g., those in the categories Life, Physical and Social Science; Legal; Computer and Math; Architecture and Engineering; Business and Financial Operations) and smaller shares of the lower-skilled occupations (e.g. those in Food Preparation and Serving; Production). In contrast, metropolitan areas specializing in the production of degrees tend to have larger shares of workers in both 'high' and 'low' human capital occupations, but smaller shares of many of the most human capital-intensive occupations.

Interestingly, some of the most highly skilled occupations, such as those in the Computer and Math, Architecture and Engineering, Business and Financial Operations and Legal categories also have a negative relationship with degree production. However, these groups have a positive relationship with specialized degree production. These patterns suggest that access to field-specific human capital and proximity to specialized knowledge is important for these groups, as opposed to access to generic pools of human capital. To the extent a relationship exists at all, specialization in the production of a certain type of human capital is generally associated with a higher share of people working in occupations that utilize that type of human capital, although this variable is positive and significant in only one-third of the occupational categories.

## 5. Conclusions and policy implications

The amount of human capital within a region is a key determinant of economic vitality and long-run economic success. As the US economy continues to shift away from manufacturing and the distribution of goods toward the production of ideas, the importance of human capital to a region will only grow. However, there is surprisingly little research exploring why some regions possess more human capital than others do. This article contributes to this small but growing literature by focusing on the extent to which the amount and types of local human capital are related to the activities of colleges and universities located in metropolitan areas.

Our research demonstrates that colleges and universities can raise local human capital levels by increasing *both* the supply of and demand for skill within metropolitan areas. We find only a small positive relationship between a metropolitan area's degree production and stock of human capital, which clearly points to the key role migration plays in redistributing human capital across space. At the same time, we find that academic R&D activities act to increase a metropolitan area's local human capital stock, suggesting that spillovers into the local economy create demand for skilled workers. Building on our main results, we show that the activities of colleges and universities are related to the composition of local labor markets, consistent with the findings of Beeson and Montgomery (1993) focusing more narrowly on science and technology occupations. In particular, metropolitan areas with a larger amount of higher education activity tend to have a higher share of workers in high human capital occupations. This outcome is particularly connected to the research intensity of metropolitan areas, as linkages between local economies and higher education institutions appear to be strongest in economic activities requiring innovation and technical training such as computers, math and science, as well as business-related fields. Importantly, activities in these areas have been shown to be particularly important drivers of local economic development (Florida et al., 2008).

There are a number of extensions to this research that would allow for a more complete understanding of the complex relationships that exist between the activities of colleges and universities and local human capital stocks. Disaggregating our college and university variables to explore whether the types of institutions (e.g. public or private, liberal arts or research) or kinds of degrees awarded (e.g. BA or PhD) in metropolitan areas affect local human capital levels might prove particularly illuminating. Further work might also explore whether the type and quality of research conducted affects a region's human capital stock. Finally, while the results we present are persistent and robust over the period studied, as more data become available, a longitudinal analysis of metropolitan areas would provide a more controlled environment for studying the relationships we identify.

Nonetheless, we believe there are important policy implications from our findings. First, there is only a small net positive relationship between the production and stock of human capital in metropolitan areas. Thus, policymakers may have a limited ability to raise local human capital levels by solely focusing on the generic expansion and retention of local graduates. Second, our work provides new evidence on the role that academic R&D activities play in shaping local human capital levels. We find evidence to suggest that knowledge spillovers from such activities into the local economy act to increase the demand for skilled labor, whether such human capital is produced locally or is imported from elsewhere. Finally, we show that the types of degrees produced in a metropolitan area are correlated with the types of human capital present. The production of graduates in high human capital fields, such as computers, math, and engineering, is associated with more workers in parallel occupations. Overall, our research suggests that policies aimed at increasing a region's human capital through the expansion of local colleges and universities will be most effective if they target *both* the supply and demand sides of local labor markets, as doing so can help to retain and attract human capital.

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