ESSAYS IN ECONOMICS OF SCIENCE

DISSERTATION

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ABSTRACT

This dissertation has two chapters. Chapter 2 provides a first step to a formal economic model of science. We model science as a set of fields that draw on one another. Knowledge flows from upstream fields that tend to be theoretical to downstream fields that tend to be applied. Scientists seek to maximize their scientific influence on other scientists and, in a competitive equilibrium, locate heavily in upstream fields, that command a greater number of downstream researchers to cite them. In contrast, a social planner cares about the relative impact of fields on final output. The planner allocates more scientists to applied downstream fields with more immediate returns to increase current consumption. Using Econlit classification codes of papers in economics we show that there is a tendency for applied fields to draw on theoretical fields.

Chapter 3 estimates the effect of universities and colleges on their local economies using panel data on cities from 1980 to 2000. The panel structure of the data allows me to include fixed effects for metropolitan areas. To further investigate causality I use two sets of instrumental variables (1) historic values of university variables and (2) a shift share index of R&D. In contrast to the literature, the estimates show a statistically significant and empirically important relationship between universities and the incomes and employment of individuals in a metropolitan area. A one standard deviation increase in
academic R&D, (per capita) Bachelors degrees, and the share of S&E degrees in total Bachelors degrees and the stock of Bachelors degree holders in a city each increase individual income by 2%-7% and all of them together increases probability of individual employment by 2.2%.
Dedicated To

My Grandmother (Didu), Srimati Brojorani Saha.

My Parents, Sri Dipak Kumar Saha and Srimati Bharati Saha.

My Little Woman, Summer K. Loehr.
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CHAPTER 1

INTRODUCTION

Recent work shows the importance of technological progress for economic growth. Technological progress draws on scientific knowledge that is largely produced in universities. This dissertation explores different issues in academia. The second chapter of this dissertation analyzes if academic research is really conducted in “ivory towers” and discusses policies that can affect the nature of research done. To follow this, the third chapter estimates the effect of universities and colleges have on the earnings and employment of people in their communities, above and beyond the effects of by their individual education and experience.

In Chapter 2, we form a first step to a formal economic model of science to understand why industry and the public often question the practical relevance of basic
scientific research even though it is important for technology. In our model science is seen as fields that draw on one another. There are upstream fields, which tend to be abstract or theoretical, from which knowledge flows to more applied downstream fields. We assume that in the competitive equilibrium scientists maximize their scientific influence on other scientists, which we think of as citations. The allocation of scientists across fields is compared between the competitive equilibrium, a social planner’s maximization of social welfare and the allocation that maximizes the growth of knowledge. By contrast, the planner’s allocation is quite different from the others. Intuitively, the planner cares about final output but the other solutions do not depend on it. In the competitive equilibrium, scientists tend to locate in upstream fields where there are more researchers downstream to cite them. Consequently, downstream fields are relatively neglected under competition. This finding is consistent with the “ivory tower” view of academic research with few practical applications.

We also estimate a weighting matrix of how fields in science draw on one another. We use data from Economics. The results are consistent with our view that theory tends to be highly influential.

Chapter 3 estimates the economic effects of universities on their local markets. It extends and enriches existing empirical work. Panel data on universities and colleges, and the city fixed effects and two different instrumental variables are used to investigate causality between university activities and individual labor market outcomes. In contrast to the literature, my findings suggest that universities increase earnings and the
probability of employment of people, above and beyond the effect of an individual’s own education. A one standard deviation of the share of Bachelors degrees in science and engineering, R&D and the stock of Bachelors degrees individually increase the mean earnings in a city by 2%-7%. The different measures of university activities together increase the probability of employment by 2.2%. The fixed effects and the instrumental variable regressions show that R&D still positively and significantly affects earnings and that the stock of Bachelors degrees always affects earnings and probability of employment positively. The study implies that while R&D and the share of S&E degrees have important external effects on individual earnings, the per capita flow of Bachelors degrees are important. This chapter underlies the importance of academic science in general and suggests policies for university presidents and local governments to make universities have larger effects on their communities.

To summarize, this dissertation addresses different issues concerning academia. A main finding is that academia may be justifiably called “Ivory Tower”, but the policies to remedy this, by making academic research more applied, might reduce the growth of knowledge. Furthermore, I find evidence that university research and granting degrees has external effects on individual earnings and employment. The implication is that local and federal governments should pay more attention to academia and academics to develop universities as potent contributors to technological change and economic growth.
CHAPTER 2

THE ECONOMICS OF IVORY TOWERS

2.1 Introduction

Recent work emphasizes the importance of technological progress for economic growth (Lucas [1988, 1993]; Romer [1986, 1994]; Aghion and Howitt [1992]). Technological progress in turn depends on scientific knowledge and academic researchers are one of the main producers of science.¹ Even though science is an important input into technology, industry and the public often question the practical relevance of basic scientific research. In an article in The Scientist the author McPherson [1997] laments that “academics seemingly equate professionalism with writing more and more about less and less”. A blue-ribbon panel convened by the Office of Science and

¹ Dasgupta and David [1994], David [1985], David [1998], David and Hall [2003], David Mowrey and Steinmueller [1994], Mowery and Rosenberg [1989], Stephan [1996], and Levin and Stephan [1991] discuss the different channels through which technology draws on basic science.
Technology Policy to enhance university-industry technology transfer concluded that, “University research is viewed by industry as ivory-tower with little thought to applicability” (Prager and Omenn [1980]).” Despite the importance of science for technological progress, there are, to the best of our knowledge, no formal economic models of science that can help understand the claim that academic research is done in “ivory towers” and analyze policies to affect the nature of research.

We model science as a set of fields that draw on each other. There are \textit{upstream} fields, which tend to be abstract and theoretical, from which knowledge flows to more applied \textit{downstream} fields\textsuperscript{2}. We assume that scientists maximize their scientific influence on other scientists, which we think of as citations\textsuperscript{3}. In the competitive equilibrium, scientists distribute themselves across fields so that the citations received by researchers are the same in all fields.\textsuperscript{4} We compare the competitive equilibrium allocation of scientists to that of a social planner maximizing social welfare and to the allocation that maximizes the growth of knowledge.

Our model has predictions for the equilibrium distribution of scientists across fields and the growth of knowledge. We show that in general the competitive equilibrium distribution neither maximizes social welfare nor the growth of knowledge. In the

\textsuperscript{2} The categorization of upstream theoretical fields and downstream applied fields tends to be general across fields. Stokes [1997] argues that when theoretical fields often have multiple dimension – they can be pure theory without any applicability and theory with some applicability; there are fields which have only applied work in all scientific disciplines. Rosenberg and Nelson [1994] show the location of American universities in respect to Stoke’s notion of applicability of the fields in science.

\textsuperscript{3} See Simonton [1988] and citations therein (page 84-85) for the discussion on citations as a measure of influence and other measures of academic success, including publication and awards.

\textsuperscript{4} The assumption that entry decisions equate the payoffs to different fields is standard in the occupation choice literature. See Rosen [1992].
competitive equilibrium, scientists tend to locate in upstream fields so that more researchers downstream will cite them. Consequently relatively few scientists work in downstream fields. In contrast, a social planner allocates more scientists to downstream fields that generate immediate returns.

As the competitive equilibrium does not maximize social welfare, policies in our model that shift the distribution of scientists toward more applied fields may raise welfare. We find that under competition, a policy induced increase in the value of citations in a certain field is associated with more scientists choosing to be in that field. There is considerable interest in analyzing the consequences of policies such as the Bayh-Dole Act [1980] which were, in part, intended to affect the distribution of scientists across fields. Our model implies that stronger links between science and industry will shift scientific research toward applied work. Consistent with this implication, Blumenthal et. al. [1986, 1996] report “commercial concerns are two to four times as likely to affect the research of life scientists receiving industry support compared to those

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5 The Bay-Dole Act [1980] “gave US universities, small businesses and non-profits intellectual property control of their inventions and other intellectual property that resulted from such funding…. Bayh-Dole permits a university, small business, or non-profit institution to elect to pursue ownership of an invention in preference to the government.” (Wikipedia http://en.wikipedia.org/wiki/Bayh-Dole_Act ). To reap the benefits of this act, universities opened up technology transfer offices, chalked out licensing agreements with industry of academic research and opened up the door for industries to fund university research to create closer university industry connection.
who do not. Our model implies that such policies increase the current flow of benefits, but reduces knowledge growth. 

The model implies that changes in field size generate a feedback process. Thus, policies have large effects on the distribution of scientists implying that policies need to be calibrated. A shift of scientists to relatively applied fields will decrease citations to the least applied work and toward other more applied fields. This change will in turn induce more scientists to move away from the least applied fields and toward more applied fields, amplifying the initial shift. Thus, small changes intended to increase the applicability of science may have large effects on the distribution of scientists and hence have large effects on the long run growth of knowledge. We conjecture that one reason for the strong performance of science in the United States is the autonomy given to science in the United States.

In addition to the theoretical work, we estimate a weighting matrix indicating how fields in science draw on one another. We study how each field in Economics (as defined by Econlit codes) depends on all other fields in the discipline. The theoretical fields tend to have a relatively larger impact on other fields supporting the model assumption that relatively applied downstream fields draw more on relatively theoretical

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6 The vast majority of academic biotechnology academics are concerned about these effects, including 70% of those who receive industry support (Blumenthal et al. [1986]). Our model implies that Blumenthal et al.’s estimates understate the true effect, because they do not incorporate general-equilibrium effects.

7 In state legislatures there is a clear preference for applicable research. The Ohio Legislature is more likely to finance projects that have immediate applicability than basic research like the “Third Frontier Project”. Moreover, often grants are given to fund projects, which analyze topics that are trendy but based on faulty science.

8 We choose Economics because as economists we are most comfortable and knowledgeable about academic publications in Economics. Besides, like other sciences, Economics also has theoretical and applied fields, which will help us to estimate the weight matrix and support our model.
upstream fields than vice-versa. It also gives us a sense of the magnitude of inter-linkages that exist between different fields within a discipline.

There is a large literature investigating the aspects of technology transfers between universities and industries. Few papers model scientists’ motivations and their implications for scientific knowledge production and growth, although Dasgupta and David [1994] argue that open science maximizes the disclosure of scientific discoveries. Their view is related to our result that competition among scientists comes close to maximizing the growth rate of knowledge, although their mechanism is quite different from ours and we show that competition does not maximize the growth of knowledge in general.

Our work also relates to Pieters and Baumgartner [2002], who study citation links between fields in economics and between economics and other fields. Our analysis differs from theirs in that we classify articles using their Econlit codes, whereas Pieters and Baumgartner classify works based on the journals in which they were published, which generates a bias toward theory and general economics, where the general-interest journals are classified, being influential.

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10 They show how differences of the institutions in academia versus industry allow academia to maximize the disclosure of discoveries of scientific knowledge. While academic scientists want to disclose original ideas, industry scientists would maintain secrecy of an idea, till it can be transformed into a patent.
The paper is organized as follows. Section 2.2 presents the model including analytic and numerical results. Section 2.3 discuss the methods for deriving the weighting matrix and present our empirical results. Section 2.4 concludes.

2.2 A Model with Two Fields

We start with a simple model of science with two knowledge producing fields. Let \( K_i(t) \) denote the stock of knowledge in field \( i \) at time \( t \). The change in the stock of knowledge of each field depends on the knowledge stocks in both fields and the number of scientists in that field.

Formally,

\[
K_i(t) = K_1^{\alpha_i} K_2^{\alpha_i} L_i^{\gamma} - \delta K_i \quad i = 1, 2 \tag{2.1}
\]

Here \( L_i \) denotes the amount of labor allocated to field \( i \), given by \( L_i \). We normalize the total number of scientists working in both the fields to unity i.e. \( L_1 + L_2 = 1 \). We assume that there are diminishing returns to additional worker in each field, so \( \gamma \in (0,1) \)\(^{11}\). The \( \alpha_j > 0 \) indicate the weight that field \( i \) places on knowledge in field \( j \). For simplicity, we assume constant returns to scale in knowledge stocks i.e. \( \sum_{j=1}^{2} \alpha_j = 1 \) for all \( i = 1, 2 \)\(^{12}\). Knowledge in each field depreciates at a constant rate \( \delta > 0 \) reflecting the

---

\(^{11}\) In addition to reflecting the limits to what can be achieved by simply allocating more resources to a field at a point in time this assumption can be thought as capturing variations in the comparative advantage of scientists in a reduced form manner.

\(^{12}\) If we assumed decreasing (increasing) returns to scale, growth would slow asymptotically (provided that the size of the scientific workforce would remain constant). In this case scientists work harder (less hard) to produce knowledge advances. Assumption of constant returns to scale is taking the middle case.
obsolescence of knowledge with the passage of time. Lastly we assume that final output is produced according to \( Y(t) = K_1^{\pi_1} K_2^{\pi_2} \), where \( \pi_1 \) (\( \pi_2 \)) is the weight of field 1 (field 2) in the final output and \( \pi_1 + \pi_2 = 1 \).

The analysis focuses on the balanced growth path (BGP) of the economy, along which knowledge grows at the same rate in both the fields. Because of CRS knowledge production the growth of knowledge in \( i \) i.e. \( g_{k_i} = \frac{\dot{K}_i}{K_i} \) \( i = 1, 2 \) can be expressed as:

\[
\frac{\dot{K}_i}{K_i} = g_{k_i} = \left( \frac{K_1}{K_2} \right)^{-(1-\gamma)(1-\delta)} L_i^\gamma - \delta \quad \forall i = 1, 2 \tag{2.2}
\]

The ratio of capital stocks along a balanced growth path can be solved by setting \( g_1 = g_2 \) implying

\[
\left( \frac{K_1}{K_2} \right)_{BGP} = \left( \frac{L_1}{L_2} \right)^{\gamma (\omega_1 + \omega_2)} \tag{2.3}
\]

Equation 2.3 shows that along the balanced growth path the ratio of the stock of knowledge in a field increases relative to the other field as the share of workers allocated to that field increases. The long run growth of knowledge along a balanced growth path is

\footnote{We have also explored models, in which obsolescence depends on the rate at which new knowledge is produced. This model delivers implicates that are quite similar to those reported below.}
From Equation 2.4 the long run growth \( g^* \) is a Cobb Douglas function of the scientists in two fields.

**Growth Maximizing Solution**

Given the Cobb-Douglas structure, the allocation of scientists that maximizes the growth rate of knowledge in Equation 1.4 is

\[
\begin{align*}
L_1^* &= \frac{\alpha_{21}}{\alpha_{12} + \alpha_{21}} \\
L_2^* &= \frac{\alpha_{12}}{\alpha_{12} + \alpha_{21}}
\end{align*}
\]

i.e. \( L_1^* = \frac{\alpha_{21}}{\alpha_{12} + \alpha_{21}} \) and \( L_2^* = \frac{\alpha_{12}}{\alpha_{12} + \alpha_{21}} \).

The productivity of each scientist only affects the “returns to scale” so \( \gamma \) does not play a role in the allocation. If the cross effects of two fields are equal (\( \alpha_{21} = \alpha_{12} \)) then growth is maximized when \( L_1^* = L_2^* \). As the importance of field \( i \) increases the share of scientists allocated to field \( i \) increases.

**Competitive Equilibrium**

Under competition scientists choose fields to maximize their influence, which we model as the discounted flow of impact-adjusted citations. We assume that each
scientist generates one unit of work and that each work contains citations of measure \(1^{14}\).

The gross production of knowledge in field \(j\) is given by \(\dot{K}_j(\tau) + \delta K_j(\tau)\) at time \(\tau\).

The impact adjusted citations from field \(j\) to \(i\) at time \(\tau\) are

\[
C_{ij}(\tau) = \alpha_{ji} \left( \dot{K}_j(\tau) + \delta K_j(\tau) \right)
\]

(2.5)

The citations are proportional to the knowledge produced in field \(j\) at time \(\tau\) and the weight that field \(j\) places on \(i\). These citations are distributed evenly across the stock of knowledge in field \(i\) at time \(\tau\). A scientist working in time \(t\) produces

\[
\frac{\dot{K}_i(t) + \delta K_i(t)}{L_i}.
\]

Hence the citations to a scientist who is active at time \(t\) at time \(\tau\) are units of knowledge of which \(\exp\{-\delta(\tau-t)\}\) remains at time \(\tau\).

Total impact adjusted citations in field \(i\)

\[
c_i(\tau; t) = \sum_j \left[ \alpha_{ji} \left( \frac{\dot{K}_j(\tau) + \delta K_j(\tau)}{K_j(\tau)} \right) \left( \frac{\dot{K}_i(t) + \delta K_i(t) \exp\{-\delta(\tau-t)\}}{L_i} \right) \right]
\]

Where \(c_i\) gives the value of citations in field \(i\) which we allow to vary later. Here the first function gives knowledge produced in field \(j\) at \(\tau\) multiplied by the impact of

\[14\text{ We abstract from differences in ability, although they can be incorporated quite simply by assuming that high ability scientist produce more units of output and citations in whatever field they enter than low ability scientists.}\]
citations from field \( j \) and the second function gives the amount of un-depreciated knowledge from the contribution at time \( t \).

A scientist entering field \( i \) at time \( t \) has utility
\[
U_i = \int_{\tau=t}^{\infty} \exp\{-\beta(\tau - t)\} c_i(\tau; t) d\tau;
\]
where \( \beta \) is the individual scientist’s rate of time preference and free entry into fields.

Substituting \( c_i(\tau; t) \) from above and manipulating we get
\[
U_i = \int_{\tau=t}^{\infty} \left\{ \frac{K_i(t)}{K_i(t)} K_i(t) \exp\{-\delta(\tau - t)\} \right\} \left[ \sum \alpha_j \left( \frac{K_j(t)}{K_j(t)} + \delta \right) \frac{K_j(t)}{K_j(t)} \right] d\tau
\]

Using
\[
\frac{\dot{K}_2(\tau)}{K_2(\tau)} = \frac{\dot{K}_1(\tau)}{K_1(\tau)} = g \quad \forall \tau \implies
\]

\[
U_i = \left( g + \delta \right)^2 c_i K_i(t) \frac{1}{L_i} \int_{\tau=t}^{\infty} \exp\{-\beta(\tau - t)\} \exp\{-\delta(\tau - t)\} \left[ \alpha_{i1} \frac{K_i(\tau)}{K_i(\tau)} + \alpha_{i2} \frac{K_2(\tau)}{K_2(\tau)} \right] d\tau \quad (2.6)
\]

Free entry into the fields implies that the utility in both fields must be the same. Using this equilibrium conditions and assuming \( \dot{c}_1 = \dot{c}_2 = 1 \) for the moment implies
\[
\begin{align*}
\dot{c}_1 K_1(t) \frac{1}{L_1} \left[ \alpha_{11} + \alpha_{21} \frac{K_2(\tau)}{K_1(\tau)} \right] &= \dot{c}_2 K_2(t) \frac{1}{L_2} \left[ \alpha_{12} \frac{K_1(\tau)}{K_2(\tau)} + \alpha_{22} \right] \\
\left[ \alpha_{i1} \frac{K_i(t)}{K_i(t)} + \alpha_{21} \right] &= \frac{L_1}{L_2} \left[ \alpha_{i2} \frac{K_i(\tau)}{K_2(\tau)} + \alpha_{22} \right] \quad (2.7)
\end{align*}
\]
Using equation 2.3 which characterizes the capital stocks and required manipulations yield

\[
\left(1 - \alpha_{12} - \alpha_{12} \frac{L_1}{L_2}\right) \left(\frac{L_1}{L_2}\right)^{\gamma_{12} + \gamma_{21}} = \left(\frac{L_1}{L_2} - \alpha_{21} - \frac{L_1}{L_2} \alpha_{21}\right)
\]

(2.8)

The proof is given in section 2.6 called Competitive Equilibrium.

One way in which the growth maximizing solution and the competitive equilibrium differ is that under competition, the average contribution is equated across fields, while the growth maximizing solution equates marginal contributions. Assuming that scientists focus on the average rather than the marginal return in a field implicitly assumes that scientists ignore the negative externality that their entry into a field imposes on the scientists in it already. This assumption is related to the patent race literature which emphasizes that any given innovator benefits in part by crowding out contributions, which would have been made by others (Baye and Hoppe [2002]).

One way in which the competitive equilibrium differs from the growth maximizing solution is that rate at which the marginal product of scientists diminishes i.e. \( \gamma \). As a field becomes more important and scientists move into it, other scientists will have an incentive to move into it assuming that it cites itself. Thus the competitive equilibrium is expected to be highly responsive to the change in the weights of each field in knowledge production.
Moreover, equation 2.8 implies that if $\alpha_{21} = \alpha_{12}$ i.e. then $L_1 = L_2$ in equilibrium. If $\gamma = \alpha_{21} + \alpha_{12}$ then also the balanced growth maximizing solution and the competitive equilibrium are the same and knowledge grows at the same rate. Further analytic characterizations are difficult. Consequently, we present the numeric results below.

**Social Planner’s Problem**

This section investigates the allocation of scientists to fields by a social planner maximizing the present discounted value of utility of final output. As indicated above output is produced according to the Cobb-Douglas function

$$Y(t) = \{K_1(t)\}^{\pi_1} \{K_2(t)\}^{\pi_2}, \; \pi_i > 0 \; i = 1, 2, \; \pi_1 + \pi_2 = 1 \tag{2.9}$$

The planner’s objective function is represented by:

$$\max_{L_1, L_2} \int_{t=0}^{\infty} Y(t) \exp\{-\beta t\} dt \tag{2.10}$$

The time preference of the planner is $\beta^{15}$, the current value Hamiltonian is:

$$H_C = K_1^{\pi_1} K_2^{\pi_2} + \lambda_1[K_1^{\alpha_{11}} K_2^{\alpha_{12}} L_1^\gamma - \delta K_1] + \lambda_2[K_1^{\alpha_{21}} K_2^{\alpha_{22}} L_2^\gamma - \delta K_2] \tag{2.11}$$

This expression is maximized with respect to the resource constraint and the laws of motion of the knowledge stocks (given by equation 2.1).

Along the balanced growth path the first order conditions are:

---

15 Let $m_i$ and $n_i$ denote the shadow values of the knowledge stocks, which are the state variables in this problem. $\lambda_1 = \exp\{\beta t\} m_i i = 1, 2$ as the discounted shadow values of the state variables.
\[
\frac{\partial H_C}{\partial L_1} = 0
\]

\[
\Rightarrow \lambda_1 = \left(\frac{L_1}{L_2}\right)^{1 - \frac{\gamma}{\alpha_{12} + \alpha_{21}}} \lambda_2 \quad (2.12)
\]

\[
\dot{\lambda}_1 = \rho \lambda_1 - \left\{ \frac{\partial H_C}{\partial K_1} \right\},
\]

\[
\Rightarrow \dot{\lambda}_1 = -\left\{ \pi_1 \left(\frac{L_1}{L_2}\right) \frac{\pi_2}{\alpha_{12} + \alpha_{21}} + \lambda_1 \left( \alpha_{11} (g + \delta) - (\delta + \rho) \right) + \lambda_2 \alpha_{21} (g + \delta) \alpha_{12} + \pi_2 \right\} \quad (2.13)
\]

\[
\dot{\lambda}_2 = \rho \lambda_2 - \left\{ \frac{\partial H_C}{\partial K_2} \right\},
\]

\[
\Rightarrow \dot{\lambda}_2 = -\left\{ \pi_2 \left(\frac{L_1}{L_2}\right) \frac{\pi_1}{\alpha_{12} + \alpha_{21}} + \lambda_2 \alpha_{12} (g + \delta) \alpha_{12} + \pi_2 \right\} \quad (2.14)
\]

We use equation 2.12 to eliminate \(\lambda_1\) by \(\lambda_2\) and \(\dot{\lambda}_1\) by \(\dot{\lambda}_2\) wherever possible in equation 2.13 and 2.14 and equating the implied expressions for \(\dot{\lambda}_2\) implies

\[
\dot{\lambda}_2^* = \frac{\left[ \pi_1 \left(\frac{L_1}{L_2}\right)^{-1} - \pi_2 \left(\frac{L_1}{L_2}\right)^{\frac{\pi_1}{\alpha_{12} + \alpha_{21}}} \right]}{(g + \delta) \left[ \alpha_{12} \left(\frac{L_1}{L_2}\right) - \alpha_{21} \left(\frac{L_1}{L_2}\right)^{-1} + (\alpha_{22} - \alpha_{11}) \right]} \quad (2.15)
\]
This expression is independent of time (i.e. \( \dot{\lambda}_1^* = \dot{\lambda}_2^* = 0 \)) which is intuitive given constant returns to scale in final output production and linear utility.

Substituting \( \dot{\lambda}_2 = 0 \) and substituting \( \lambda_2 \) for \( \lambda_1 \) in equation into equation 2.13 yields a second equation for the shadow value of knowledge in field 2

\[
\lambda_2^* = -\left\{ \frac{\pi_1 \left( \frac{L_1}{L_2} \right)^{\gamma \alpha_1 \alpha_2 \alpha_3 \alpha_4}}{\alpha_2 + \alpha_3} \right\} \left( \alpha_1 \left( g + \delta - \Delta \right) \left( \frac{L_1}{L_2} \right) + \alpha_2 \left( g + \delta \right) \right)
\]  

(2.16)

Equating equation 2.16 and 2.18 and simplifying yields:

\[
g^* \left( \frac{L_1}{L_2} \right) \left( \alpha_1 - \alpha_2 \right) + g^* \left( \pi_1 - \pi_2 \right) + \left( \delta + \rho \right) \left( \pi_2 \left( \frac{L_1}{L_2} \right) - \pi_1 \right) = 0
\]  

(2.17)

This equation characterizes the planner’s allocation of scientists to fields. In here \( g^* \) is given by equation 2.4 above. The proof is given in section 2.7 called The Planner’s Solution.

Unlike the growth maximizing solution or the competitive equilibrium, the planner’s allocation depends on the production function for final output and the rate of time preference. The competitive equilibrium does not depend on the production technology of output because the objective of the agents under competition is to maximize citations, which do not depend on final output. The rate of time preference
does not affect the competitive equilibrium as the citations grow at the same rate in both fields. As expected growth maximizing solution does not depend on final output. Equation 2.17 shows that if the production function for knowledge in the two fields is equal and the production function for final output places equal weight on the two fields then \( L_1 = L_2 \) in the equilibrium.

**Numerical Results**

Figure 2.1 shows how the allocation of scientists to field 1 relative to field 2 \( \frac{L_1}{L_2} \) under growth maximization, competition and the planner’s problem depends on the technological parameters \( \alpha_{1_2} \) and \( \alpha_{2_1} \) for producing knowledge. For high values of \( \alpha_{1_2} \) or low values of \( \alpha_{2_1} \) the importance of field 2 increases and the importance of field 1 decrease. The planner’s solution is indicated by a dark line, the competitive equilibrium by a dashed line and the growth maximizing outcome by a dotted line. Assuming that a period is 10 years, which implies the annual discount rate of 0.5 and the obsolescence rate of 1 i.e. \( \beta \approx 0.5 \) and \( \delta \approx 1 \). We set \( \gamma = 0.5 \). Intuitively assume that both the fields are equally important producing final output i.e. \( \pi_1 = \pi_2 \).

The three curves cross at \( \alpha_{1_2} = \alpha_{2_1} = 0.5 \) when the two fields have identical influence on knowledge production, and equal number of scientists is allocated to both fields under all the three regimes. The competitive equilibrium differs from the balanced growth maximization equilibrium because the growth maximizing solution allocates scientists according to the marginal value, while scientists care about average value under
competition. But this difference is relatively small and so both allocations are quite different from the planner’s solution. This indicates that competition does not maximize growth of knowledge but comes close.

The growth maximizing and the competitive equilibrium allocations are both more responsive to changes in $\alpha_{12}$ and $\alpha_{21}$ than the planner’s solution. Intuitively, scientists maximizing their influence have an incentive to locate in upstream fields where their work will influence more downstream fields. As a field moves further upstream, more people enter it (assuming it draws on itself), irrespective of field influence. This is because they want to be upstream of the many people who are now in it. Hence a feedback process develops. The planner places less weight on knowledge growth and more weight on current utility so the planner’s solution is less responsive to the technology for producing knowledge.

Figure 2.2 shows how the three allocations depend on the production function for final output. We use the same parameter values as in Figure 2.1, but vary $\pi_1$. As discussed competitive and growth maximizing allocations do not depend on $\pi_1$. Figure 2.3, while all other parameters are the same as in Figure 2.2, field 2 contributes relatively more than field 1 in producing knowledge i.e. $\alpha_{12} > \alpha_{21}$. Under competition more scientists are in field 2 than growth maximization. The planner initially allocates more scientists to field 2, but as the importance of field 1 in the production of final output increases, the planner allocates more scientists to field 1 despite the importance of field 2 on knowledge production.
Figure 2.4 shows growth rates under the three regimes as a function of the importance of field 1 for knowledge production and as a function of the rate of time preference holding $\alpha_{12}$ constant. The parameters are set at the values for Figure 2.1 except we assume field 1 contributes more than field 2 in final output ($\pi_1 = 0.7 > \pi_2 = 0.3$).

By definition the growth maximizing solution maximizes the growth of knowledge. The competitive equilibrium allocations are quite close to the growth maximization solution so the growth rate is only slightly lower. Growth under the planner is considerably less than the other allocations, which is intuitive because the planner and trades off growth for current output. When $\alpha_{21}$ is high all three regime solutions allocate most scientists to field 1 so there is little difference in growth rates. As $\alpha_{21}$ decreases the planner reduces the number of scientists in field 1 more slowly than the other allocations because the short run benefits reducing growth are considerably below the other allocations. Moreover as the planner grows more and more impatient, he allocates more scientists to field 1 yielding higher immediate benefits but reducing growth further.

Figure 2.5 shows how the allocations under the three regimes change as field 1 become more important in production of final output (i.e. $\pi_1$ increases) and as the planner’s impatience increases (i.e. $\beta$ increases). We set the parameters as in Figure 2.1 but vary $\pi_1$ and $\beta$. The competitive equilibrium and the balanced growth maximization equilibrium allocation are identical and they do not depend on these parameters. The
planner allocates more scientists to field 1 for any given $\beta$ as $\pi_1$ increases. The planner also allocates also becomes more responsive to $\pi_1$ as $\beta$ increases. Intuitively as the planner becomes more impatient, he allocates more labor to the field that contributes more to the final output.

Before deriving equation 2.7 we assumed that the value of citations in a field $c_i$ is equal to 1. If we relax this assumption, the equation that characterizes the competitive equilibrium becomes

$$\left( p - p\alpha_{12} - \alpha_{12} \frac{L_1}{L_2} \right)^\gamma \left( \frac{L_1}{L_2} \right)^{\gamma_{\alpha_{12}} + \gamma_{\alpha_{21}}} = \left( \frac{L_1}{L_2} - p\alpha_{21} - \frac{L_1}{L_2} \alpha_{21} \right)^\gamma$$

Where, $p = \frac{c_1}{c_2}$ is the ratio of the values of citations in both fields. Figure 2.6 shows how the allocations under the three regimes behave when the value of citations increases in a field relative to another field (i.e. $p = \frac{c_1}{c_2}$ changes) holding the other parameters as in Figure 2.1. As expected, neither the growth maximizing nor the planner’s solutions depends on this parameter. In the competitive equilibrium, scientists move to the sector where the value of citations increases. This implies that increases the value of citations in a field would lead more scientists to enter that field. Examples of such policies may be government agencies giving more grants in one particular field over another.
Summary and extensions

We have characterized the allocation of scientists under the three regimes growth maximization, competition, and the planner’s solution. The equilibrium allocation are the same in all the three cases if the cross effects of the two knowledge producing fields are equal to one another i.e. $\alpha_{12} = \alpha_{21}$. In all three cases the size of the fields (i.e. the number of scientists in the field) increases with importance in the field.

Our simulations show that the competitive equilibrium and the growth maximizing allocation respond more to changes in the weights placed on knowledge in each sector for knowledge growth than the planner’s solution. The planner cares about final output but the other solutions do not depend on it. In the competitive equilibrium, scientists tend to locate in upstream fields where there are more researchers downstream to cite them. Consequently downstream fields are relatively neglected.

The planner’s solution depends on the influence of field 1 and field 2 on the final output and on his time preference. As the planner becomes increasingly impatient, he allocates more scientists to the field with the highest contribution to the final output. In other words, an impatient planner will allocate more scientists to downstream fields that generate immediate returns. As a result, growth of knowledge suffers even more and the social planner trades off future knowledge creation in favor of increased current consumption.

We have extended the model by adding a third field of knowledge production. All the major results from the three field model hold in the two field model. In particular
the competitive equilibrium is more responsive than the planner’s allocation with respect to the weights of each field in knowledge production. The planner allocates more scientists to fields that contribute more to final output. As before the rate of time preference and the contributions to the final product does not affect the competitive or the growth maximizing solution.

2.3 Empirical Analysis

Data Analysis

This section estimates the interrelationships between the fields (the technology parameters governing the knowledge production in the model). We construct a sample of articles in economics and estimate the fields on which they draw based on their references. Both main articles and their references are classified into fields based on their (1-digit) Econlit code.16

We randomly sample articles sampling those in more influential journals more heavily. To identify the influence of each journal, we use the rankings by Kalaitzidakis, Mamuneas and Stengos [2003] which cover a broad range of articles and an improved methodology over that used by Laband and Petit [1994]17. Their sample covers articles published between 1994 and 1998. The articles in our sample are from 1994 the first year covered by their analysis.

---

16 JEL codes started to be used after 1991. Articles published after 1991 have both JEL and Econlit codes. Since the main articles come from 1994, using Econlit code as descriptors help in encountering problems like absence of JEL codes for references of most main articles.

After choosing the number of articles to draw from each journal based on its impact factor, individual articles were drawn in the sequence they appear in Econlit from a particular journal. Presidential addresses, comments, and replies were excluded since they are not peer reviewed academic work. Table 2.1 lists the top 10 journals, their impact factors based on (Kalaitzidakis, Mamuneas and Stengos [2003]) and shows how many articles from them were used in the sample. The sample contains 48 articles from American Economic Review, 39 from Quarterly Journal of Economics, 23 from Econometrica. These articles are referred to as “main articles”. The number of references sampled from each main article varied according to the number of references it cited\textsuperscript{18}.

The raw data set contains 71 journals and 423 main articles. Of these Econlit descriptors were not available for any of the references of 34 main articles. Deleting this yields a sample of 389 main articles and their references.

Table 2.2 provides information on the Econlit descriptors. The first column gives the one digit Econlit codes. The second lists the names of the fields. The third and the fourth columns shows the share of references articles with each descriptor.

Method

Let $d_{accr}$ denote the total number of times that descriptor $c'$ appears in each reference $r$ of article $a$ in category $c$. Define $r_{acc}$ be the total number of times that

\textsuperscript{18} Five references were drawn from articles containing 10 or fewer references, with 1 additional reference included for every 5 reference. For instance, main article with the most references had 162 citations. Twenty one references were sampled from it. The reference articles were sampled according to the sequence they appear in the main articles as long as the articles were peer reviewed journal publications.
descriptor $c$ appears in all the references of article $a$ in category $c$ i.e. $r_{acc} = \sum_r d_{race}$.

The total number of descriptors listed among the sampled references in article $a$ in category $c$ i.e. $\sum_r r_{acc}$. We estimate the amount that an article $a$ in category $c$ draws field $c$ using field $c$’s share of descriptors among the references in that article. To calculate the extent to which field $c$ draws on $c$, we calculate the average across all articles in category $c$ of $\kappa_{acc} = \frac{r_{acc}}{\sum_r r_{acc}}$. Formally the extent to which field $c$ draws on $c$, the $c^{th}$ row and the $c^{th}$ column in the weighting matrix is given by $\frac{1}{N_c} \sum_a r_{acc} \sum_c r_{acc}$.

where $N_c$ is the share of descriptors in category $c$, across all articles. This process ensures that all articles in the sample receive the same weight.

**Empirical Results**

Table 2.3 presents the estimated weighting matrix, showing the extent to which each field draws on each other field. As indicated by the row sums, the fields as a whole draw the most on economic theory followed by quantitative economic methods and data, manpower labor and population. This is consistent with our view that theory is highly influential.

---

19 The column sum of this matrix is equal to 1. This is because Incidentally,

$$\sum_c \frac{1}{N_c} \sum_a r_{acc} \sum_c r_{acc} = \frac{1}{N_c} \sum_a \sum_c r_{acc} \sum_c r_{acc} = \frac{1}{N_c} \sum_a \sum_c r_{acc} = \frac{1}{N_c} \sum_a 1 = 1$$
As indicated our procedure places the same weight on each main article regardless of the number of references it has or the number of descriptors its references have. We present an alternative weighting matrix assuming that places equal weight on each reference. Maintaining our notation $\sum_c d_{race}$ is the total number of descriptors in each reference $r$ of article $a$ in category $c$. We can calculate $\kappa_{race} = \frac{d_{race}}{\sum_c d_{race}}$, the percentage contribution of category $c$ in field $c'$ for each reference $r$ of article $a$. To ensure that all references to article $a$ receive the same weight, we take the average of the percentage contribution for a main article $a$ from all the references $r$ i.e. $r_{acc} = \frac{1}{r} \sum_r d_{accr}$. Our weighting matrix, given in Table 2.4 captures the influence of $c'$ on category $c$ is given by $\frac{1}{N_c} \sum_a r_{acc}$. where $N_c$ is the share of descriptors in category $c$, across all articles. The results in Table 2.4 are quite similar to those in Table 1.3. Indeed the theoretical fields are more influential compared to Table 2.3 The ranking of the categories by their influence is also unchanged.

2.4 Conclusion

This paper presents an early formal economic model of science. We model science as fields that draw on one another. There are upstream fields, which tend to be abstract or theoretical, from which knowledge flows to more applied downstream fields. We assume that scientists maximize their scientific influence on other scientists, which
we think of as citations. We compare the competitive equilibrium allocation of scientists across fields to that of a social planner maximizing social welfare and the allocation that maximizes the growth of knowledge. By contrast the planner’s allocation is quite different from the competitive growth maximizing allocations. Intuitively, the planner cares about final output but the other solutions do not depend on it. In the competitive equilibrium, scientists tend to locate in upstream fields where there are more researchers downstream to cite them. Consequently downstream fields are relatively neglected under competition. This finding is consistent with the view that academic research is conducted in “ivory towers” with few practical applications.

We also estimate a weighting matrix of how fields in science draw on one another. We use data from Economics. The results are consistent with our view that theory tends to be highly influential.
2.5 Competitive Equilibrium

\[ U_i = \int_{t-1}^{\infty} \left( \exp\{-\beta(\tau-t)\} \right) c_i \left( \frac{\alpha_i \left( \frac{\dot{K}_i(t) + \delta K_i(t)}{K_i(t)} \right) \exp\{-\delta(\tau-t)\}}{L_i} \right) \left[ \frac{1}{K_i(\tau)} \sum_j \alpha_{ij} \left( \frac{\dot{K}_j(\tau) + \delta K_j(\tau)}{K_j(\tau)} \right) \right] d\tau \]

\[ U_i = \int_{t-1}^{\infty} \left( \exp\{-\beta(\tau-t)\} \right) c_i \left( \frac{\alpha_i \left( \frac{\dot{K}_i(t) + \delta K_i(t)}{K_i(t)} \right) \exp\{-\delta(\tau-t)\}}{L_i} \right) \left[ \sum_j \alpha_{ij} \left( \frac{\dot{K}_j(\tau) + \delta K_j(\tau)}{K_j(\tau)} \right) K_j(\tau) \right] d\tau \]

\[ U_i = \left( g + \delta \right)^2 c_i K_i(t) \frac{1}{L_i} \int_{t-1}^{\infty} \exp\{-\beta(\tau-t)\} \exp\{-\delta(\tau-t)\} \left[ \alpha_{1j} \frac{K_j(\tau)}{K_i(\tau)} + \alpha_{2j} \frac{K_j(\tau)}{K_i(\tau)} \right] d\tau \]

Therefore

\[ U_1 = \left( g + \delta \right)^2 c_1 K_1(t) \frac{1}{L_1} \int_{t-1}^{\infty} \exp\{-\beta(\tau-t)\} \exp\{-\delta(\tau-t)\} \left[ \alpha_{11} \frac{K_1(\tau)}{K_1(\tau)} + \alpha_{21} \frac{K_2(\tau)}{K_1(\tau)} \right] d\tau \]

\[ U_1 = \left( g + \delta \right)^2 c_1 K_1(t) \frac{1}{L_1} \left[ \alpha_{11} + \alpha_{21} \frac{K_2(\tau)}{K_1(\tau)} \right] \int_{t-1}^{\infty} \exp\{-\beta(\tau-t)\} \exp\{-\delta(\tau-t)\} d\tau \]

\[ U_2 = \left( g + \delta \right)^2 c_2 K_2(t) \frac{1}{L_2} \int_{t-1}^{\infty} \exp\{-\beta(\tau-t)\} \exp\{-\delta(\tau-t)\} \left[ \alpha_{12} \frac{K_2(\tau)}{K_2(\tau)} + \alpha_{22} \frac{K_2(\tau)}{K_2(\tau)} \right] d\tau \]

\[ U_2 = \left( g + \delta \right)^2 c_2 K_2(t) \frac{1}{L_2} \left[ \alpha_{12} \frac{K_2(\tau)}{K_2(\tau)} + \alpha_{22} \frac{K_2(\tau)}{K_2(\tau)} \right] \int_{t-1}^{\infty} \exp\{-\beta(\tau-t)\} \exp\{-\delta(\tau-t)\} d\tau \]

Now using the equilibrium condition that the utilities are equal across all fields we get:
We can substitute \( c_1 = c_2 = 1 \) for the time being, we get an equation that characterizes the competitive equilibrium.

\[
\begin{align*}
\left( g + \delta \right)^2 c_1 K_1(t) \left[ \frac{\alpha_{11} + \alpha_{21}}{L_1} \frac{K_2(\tau)}{K_1(\tau)} \right] &= \left( \frac{L_1}{L_2} \right)^\gamma \frac{K_1(t)}{K_2(t)} = \left( \frac{L_1}{L_2} \right)^\gamma \\
\left( \alpha_{11} + \alpha_{21} \right) &= \left( \frac{L_1}{L_2} \right)^\gamma \\
\left( \alpha_{11} - \alpha_{12} \right) &= \left( \frac{L_1}{L_2} \right)^\gamma \\
\left( 1 - \alpha_{12} \right) &= \left( \frac{L_1}{L_2} \right)^\gamma
\end{align*}
\]

The equation * characterizes the competitive equilibrium allocation.
2.6 The Planner’s Solution

Max \[ \int \exp\{-\rho t\} K_1^{\pi_1} K_2^{\pi_2} \, dt \]

Subject to

\[ \dot{K}_1 = K_1^{\alpha_1} K_2^{\alpha_2} L_1^\gamma - \delta K_1 \]

\[ \dot{K}_2 = K_1^{\alpha_3} K_2^{\alpha_4} L_2^\gamma - \delta K_2 \]

\[ L_1 + L_2 = 1 \]

Define

\[ \exp\{\rho t\} m_1 = \lambda_1 \]

\[ \exp\{\rho t\} m_2 = \lambda_2 \]

\[ H_C = K_1^{\pi_1} K_2^{\pi_2} + \lambda_1 [K_1^{\alpha_1} K_2^{\alpha_2} L_1^\gamma - \delta K_1] + \lambda_2 [K_1^{\alpha_3} K_2^{\alpha_4} L_2^\gamma - \delta K_2] \]

\[ \frac{\partial H}{\partial L_1} = 0 \]

\[ \Rightarrow \lambda_1 \gamma \frac{K_1^{\alpha_1} K_2^{\alpha_2} L_1^\gamma}{L_1} - \lambda_2 \gamma \frac{K_1^{\alpha_3} K_2^{\alpha_4} L_2^\gamma}{L_2} = 0 \]

\[ \frac{\lambda_1 K_1}{L_1} \left( \frac{K_1^{\alpha_1} K_2^{\alpha_2} L_1^\gamma}{K_1} \right) = \frac{\lambda_2 K_2}{L_2} \left( \frac{K_1^{\alpha_3} K_2^{\alpha_4} L_2^\gamma}{K_2} \right) \]

Using the Balanced Growth path Conditions 3, 4 and 5 we get

\[ \frac{\lambda_1 K_1}{L_1} = \frac{\lambda_2 K_2}{L_2} \]
\[ \Rightarrow \lambda_1 = \left( \frac{K_1}{K_2} \right)^{-1} L_1 \lambda_2 \]

\[ \Rightarrow \lambda_1 = \left( \frac{L_1}{L_2} \right)^{\frac{\gamma}{\alpha_{12} + \alpha_{21}}} \lambda_2 \]

\[ \Rightarrow \dot{\lambda}_1 = \left( \frac{L_1}{L_2} \right)^{\frac{\gamma}{\alpha_{12} + \alpha_{21}}} \dot{\lambda}_2 \]

\[ \frac{\partial H}{\partial \lambda_1} = \dot{K}_1 \]

\[ \dot{K}_1 = K_1^{\alpha_{11}} K_2^{\alpha_{12}} L_1^\gamma - \delta K_1 \]

\[ \frac{\partial H}{\partial \lambda_2} = \dot{K}_2 \]

\[ \dot{K}_2 = K_1^{\alpha_{21}} K_2^{\alpha_{22}} L_2^\gamma - \delta K_2 \]

\[ \dot{\lambda}_1 = -\left\{ \frac{\partial H}{\partial K_1} \right\} + \rho \lambda_1 \]

\[ \Rightarrow \dot{\lambda}_1 = - \left\{ \pi_1 \left( \frac{L_1}{L_2} \right)^{\frac{\pi_1 \gamma}{\alpha_{12} + \alpha_{21}}} + \lambda_1 (\alpha_{11} (g + \delta) - \Delta) + \lambda_2 \alpha_{21} (g + \delta) \left( \frac{L_1}{L_2} \right)^{\frac{\gamma}{\alpha_{12} + \alpha_{21}}} \right\} \]

\[ \Rightarrow \dot{\lambda}_2 = - \left\{ \pi_1 \left( \frac{L_1}{L_2} \right)^{-1 + \frac{\pi_1 \gamma}{\alpha_{12} + \alpha_{21}}} + \lambda_2 (\alpha_{11} (g + \delta) - \Delta) + \lambda_2 \alpha_{21} (g + \delta) \left( \frac{L_1}{L_2} \right)^{-1} \right\} \quad \text{--- (I)} \]

31
\[ \Delta = \delta + \rho \]

\[ \dot{\lambda}_2 = -\left( \frac{\partial H}{\partial K_2} \right) + \rho \lambda_2 \]

\[ \Rightarrow \dot{\lambda}_2 = -\left( \pi_2 \left( \frac{L_1}{L_2} \right)^{\gamma_{12}^{\gamma}} + \lambda_2 \alpha_{12} (g + \delta) \left( \frac{L_1}{L_2} \right)^{\gamma_{22}^{\alpha_{22}}} + \lambda_2 (\alpha_{22} (g + \delta) - \Delta) \right) \]

\[ \Rightarrow \dot{\lambda}_2 = -\left( \pi_2 \left( \frac{L_1}{L_2} \right)^{\gamma_{12}^{\gamma}} + \lambda_2 \alpha_{12} (g + \delta) \left( \frac{L_1}{L_2} \right) + \lambda_2 (\alpha_{22} (g + \delta) - \Delta) \right) \]

---(II)

Where \( \Delta = \delta + \rho \)

Transversality Conditions (In case we need them)

\[ \lim_{T \to \infty} \exp(-\rho t) \lambda_1(T) \geq 0 \]

\[ \lim_{T \to \infty} \exp(-\rho t) \lambda_2(T) \geq 0 \]

\[ \lim_{T \to \infty} \exp(-\rho t) \lambda_3(T) K_1(T) = 0 \]

\[ \lim_{T \to \infty} \exp(-\rho t) \lambda_2(T) K_2(T) = 0 \]

Equate I to II
\[ \Rightarrow \lambda_2^* = \frac{\left[ \pi_1 \left( \frac{L_1}{L_2} \right)^{-1} - \pi_2 \right]^{\pi_1\gamma}_{\alpha_{12} + \alpha_{21}} \left( \frac{L_1}{L_2} \right)}{(g + \delta) \left[ \alpha_{12} \left( \frac{L_1}{L_2} \right) - \alpha_{21} \left( \frac{L_1}{L_2} \right)^{-1} + (\alpha_{22} - \alpha_{11}) \right]} \] --- (III)

\[ \Rightarrow \lambda_2^* = 0 \]

Substitute this in I to get:

\[ \lambda_2^* = \left\{ \frac{\pi_1 \left( \frac{L_1}{L_2} \right)^{\pi_1\gamma}_{\alpha_{12} + \alpha_{21}}}{(\alpha_{11}(g + \delta) - \Delta) \left( \frac{L_1}{L_2} \right) + \alpha_{21} (g + \delta)} \right\} \] ----(IV)

Where \( \Delta = \delta + \rho \)

Equate III to IV to get:
\[
\frac{\pi_1 - \pi_2 \left( \frac{L_1}{L_2} \right)}{\left( g + \delta \right)} \left[ \alpha_{12} \left( \frac{L_1}{L_2} \right)^2 - \alpha_{21} + (\alpha_{22} - \alpha_{11}) \left( \frac{L_1}{L_2} \right) \right] = \\
\left\{ \frac{\pi_2 \left( \frac{L_1}{L_2} \right)}{\alpha_{12} + \alpha_{21}} \right\} - \left\{ \alpha_{12} \left( g + \delta \right) \left( \frac{L_1}{L_2} \right) + \left( \alpha_{22} \left( g + \delta \right) - \Delta \right) \right\}
\]

\[
(g + \delta) \left( \frac{L_1}{L_2} \right) (\alpha_{12} - \pi_2) + (g + \delta) (\pi_1 - \alpha_{21}) + \Delta \left( \pi_2 \left( \frac{L_1}{L_2} \right) - \pi_1 \right) = 0 \quad (*)
\]

Equation (*) Characterizes the distribution of scientists across fields in the planner’s problem.
### 2.7 Tables

<table>
<thead>
<tr>
<th>Journal Name</th>
<th>Impact Factor of an Article</th>
<th>Number of Articles from each Journal</th>
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<tr>
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Table 2.1: Journals Ranked by their Impact and Number of Articles Sampled from Them
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<th>Mean Of Reference Articles (Standard Deviation)</th>
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Table 2.2: Descriptive Statistics of Reference Articles, Number of Main Articles and the Category Descriptors
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Table 2.3: The Weighting Matrix
Table 2.4: The Weighting Matrix: Equal Weight for Each Reference Article

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2.8 Figures

Figure 2.1: Ratio of Scientists under Three Regimes: Comparative Static Results to Parameters in Knowledge Production

Note: Parameter Values for this graph: $\pi_1 = 0.5$, $\pi_2 = 0.5$, $\gamma = 0.5$, $\delta = 1$, $\beta = 0.5$

Dotted Line: Growth maximization, Dashed Line: Competitive Equilibrium, Solid Line: Planner’s Solution
Figure 2.2: Ratio of Scientists under Three Regimes: Comparative Static Results to Parameters in Final Output

Note: $\alpha_{12} = \alpha_{21} = 0.5$, $\gamma = 0.5$, $\delta = 1$, $\beta = 0.5$

Dotted Line: Growth maximization, Dashed Line: Competitive Equilibrium, Solid Line: Planner’s Solution
Figure 2.3: Ratio of Scientists under Three Regimes: Comparative Static Results to Parameters in Final Output: Field 2 more important in Knowledge Production

Note: $\alpha_{21} = 0.5 < \alpha_{12} = 0.7$, $\gamma = 0.5$, $\delta = 1$, $\beta = 0.5$

Dotted Line: Growth maximization, Dashed Line: Competitive Equilibrium, Solid Line: Planner’s Solution
Figure 2.4: Growth of Knowledge under Three Regimes: Comparative Static Results to Parameters in Knowledge Production and Final Output

Note: $\pi_1 = 0.7 > \pi_2 = 0.3$, $\gamma = 0.5$, $\delta = 1$

Dotted Line: Growth maximization, Dashed Line: Competitive Equilibrium, Solid Line: Planner’s Solution
Figure 2.5: Ratio of Scientists in Two Fields Under Three Regimes: Comparative Static Results to all Parameters in Final Output

Note: $\alpha_{12} = \alpha_{21} = 0.5$, $\gamma = 0.5$, $\delta = 1$

Dotted Line: Growth maximization, Dashed Line: Competitive Equilibrium, Solid Line: Planner’s Solution
Figure 2.6: Ratio of Scientists in Two Fields Under Three Regimes: Comparative Static Results to increase in citations

Note: $\alpha_{12} = \alpha_{21} = 0.5$, $\gamma = 0.5$, $\delta = 1$, $\beta = 0.5$

Dotted Line: Growth maximization, Dashed Line: Competitive Equilibrium, Solid Line: Planner’s Solution


Stokes, Donald E. (1997): *Pasteur’s Quadrant*, Brookings

Wikipedia http://en.wikipedia.org/wiki/Bayh-Dole_Act
CHAPTER 3

ECONOMIC EFFECTS OF UNIVERSITIES AND COLLEGES

3.1 Introduction

Endogenous growth theory argues that a highly skilled workforce and technological innovations fuel economic growth (Romer [1993] and Lucas [1988]). Universities and colleges are “at the crossroads of education and innovation” (Pianalto [2006]) supplying both talent and technology to the US industries\(^\text{20}\). Indeed, universities and colleges in Boston, Silicon Valley and the Research Triangle have produced a lot of graduates and R&D, especially in science and engineering (S&E). They are both believed to be the causes of the economic prosperity of these regions (Bania and Eberts [1993])\(^\text{21}\). In comparison to the national averages, in Silicon Valley and Route 128, the electronics

\(^{20}\) After 1980 the US industries have adopted cutting edge technologies across the board (Feldman and Barcovitz [2006]). From mid 1980s the industries relied on scientists who have direct or indirect ties to university research (Marschke et al [2006]).

\(^{21}\) It is documented that local firms were benefited by the supply of available electronics and computer scientists from Stanford and MIT in the case of Silicon Valley and Route 128 respectively (see Dorfman [1983], Saxenian [1996]).
sector earnings were approximately 1.4 times and per worker earnings were approximately twice as higher (see Hill [2006]). Based on the success stories of these regions, policymakers are increasingly looking to universities and colleges for economic growth and technological innovations (Cleveland Federal Reserve [2007]).

This paper uses the result that in equilibrium even with mobile labor and capital across metropolitan areas, differences in metropolitan area characteristics can make wages and employment differ between them (Roback [1982]). Given this context, I examine the impact of universities and colleges on their local labor markets using panel data on universities and colleges aggregated to the metropolitan area level. The labor market activities considered in this study are annual earnings and employment status. There are many aspects of universities that can affect labor market conditions. Of them, the flow of Bachelors degrees, the share of Science and Engineering (S&E) in total Bachelors degrees granted and the flow of R&D conducted by universities and colleges are considered in this paper. Several studies report that in a city, universities and colleges influence the stock of Bachelors degree holders (Bound et al [2001]), which is suggested to be an important source of human capital externalities (Rauch [1992], Glaeser [2001], Morretti [2004a, 2004b]). Following them, I also include stock of Bachelors degree holders in a city as an aspect of universities.

To measure these university activities, data on total degrees granted, degrees granted in S&E, R&D conducted by universities and colleges for 1980, 1990 and 2000 at the level of individual university and college is obtained. Each university or college is
matched to its metropolitan areas using its zip codes and is then aggregated to the metropolitan area level. I get the data for stock of Bachelors degree in a city from the 1980, 1990 and 2000 Census by metropolitan areas. Labor market conditions were estimated from the 1980, 1990 and 2000 Census for each metropolitan area. University variables are measured in per capita terms to control for differences in the size of the cities.

A variety of empirical strategies were used to estimate the effects of universities on their local labor markets, beginning with OLS. The concern with OLS is that it fails to capture unobservable factors that are correlated with the labor market conditions and university activities. For example, city specific factors like urban amenities may attract students to a city and thereby affect university activities. Furthermore, better local amenities can draw more able workers to a city and make the wages high. The panel aspect of the data is used to control the effect of the unobservable variables correlated with both university and labor market variables, by including metropolitan area fixed effects and time dummy variables. Time dummy variables eliminate any time trends in the university activities. The metropolitan area fixed effects eliminate time invariant differences across metropolitan areas in factors including weather, business opportunities, movement in prices and urban amenities, which may be correlated with the university variables.

To explore causality, it is also important to control for metropolitan area level unobservable factors that vary across time. For example, shifts in the demand for highly
educated workers in the metropolitan areas might increase earnings and lead to growth in universities and colleges. I employ an instrumental variables strategy to control for this.

Historical values of degrees and R&D for each metropolitan area interacted with a time dummy variable for each decade, serve as instrumental variables for current degrees and R&D. The intuition is that the historical values of degrees and R&D are related to current degrees and R&D, but do not directly influence current labor market conditions in the metros.

A shift-share index is also used as an instrumental variable for R&D. The shift-share considers growth in the variable under consideration decomposed by categories (Bound and Holzer [2000]). This paper uses data for R&D by fields of study and source of funding. The national trends in funding are weighted differently for each city. The intuition for identification in this case is simple. Different regions have universities that are specialized in different fields. Shifts in R&D in a particular field caused by decisions made by federal or state governments impact otherwise similar metropolitan areas differently. For example, Dallas has the most engineering R&D while San Francisco has the most R&D expenditure in life sciences including medicine. An increase in government expenditures in medicine will increase R&D in San Francisco more than in Dallas.

It is not clear whether Bachelors degree holders locate themselves in a city attracted by its high earnings opportunities or that Bachelors degree holders bring about higher earnings opportunities in the metropolitan area. To establish causality, the cities
with Land Grant universities and colleges is used as an instrument. Land Grant Act or the Morrill Act of 1862 allocated land randomly to cities within the states to build universities. It is likely that these cities developed a higher stock of Bachelors degree holders because of the presence of the land grant universities, which affects the current share of Bachelors degree holders without having any direct relationship with the current labor market conditions. This instrument is used in the literature by others (see Morretti [2004a, 2004b]).

The estimates show that per capita R&D, the share of science and engineering degrees in total Bachelors degrees, per capita Bachelors degrees and the stock of Bachelors degree holders have a positive effect on earnings and the probability of employment. In the income regressions, per capita R&D, the share of science and engineering Bachelors degrees and the stock of Bachelors degree holders are always statistically significant. A one standard deviation increase in each of the university activity variables increases mean log earnings by 2% - 7%. In the employment regressions, the share of Bachelors degree per capita, the stock of Bachelors degree holders and the share of S&E degrees are positively and statistically significantly related to employment status of individuals. A one standard deviation increase in all the university variables increases the probability of individual employment by 2.2%. All these results are calculated after controlling for the effects of individual characteristics on their wages and employment like years of education, experience, race, gender and marital status. Over last two decades, the share of the population with a Bachelors degree
increased by 14%. Controlling for own education this increase in area education increased employment by 17%.

These results stand in contrast to the existing literature on university effects on local labor markets. Using data from 1980, Beeson and Montgomery [1993] find that total R&D, total degrees and the percentage of science and engineering degrees in a metropolitan area are not statistically significantly related to individual earnings. Goldstein and Renault [2004] found that between 1969 and 1986 the presence of a research university had no effect on an area’s relative earnings. However, the effects are significant between 1986 and 1998. Wang [2003] reports weak income spillovers from universities in neighboring counties using a spatial model with data from 1995 and 2000. Desrochers and Feldman [2003] show that although Johns Hopkins University is a large contributor to academic research and well known in academic circles, it has little impact on its local economies. Universities are found to have their largest impact on the middle and small sized metropolitan areas (Goldstein and Drucker [2006]).

There is also a literature on knowledge spillovers in innovation. The goal of this work is not to study the mechanisms through which universities operate but it may provide some suggestive evidence. This paper suggests that a city can get external returns

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22 There is ample evidence that academic R&D impacts technological innovations measured by patent citations (Jaffe [1986]). Research shows that academic R&D and university science graduates aid growth of start up companies, new firm openings (Bania, Eberts, and Fogerty [1993], Smith [2006]) and development of industrial research laboratories (MacGarvie and Furman [2005]). Academic scientists who made early contributions to gene sequencing caused to create the US biotechnology industry (Zucker, Darby and Brewer [1998]). Recent work reports that variation in the stock of college graduates in cities, largely influenced by flow of college graduates from universities and colleges (Bound et al [2001]), explains to the wage variation across cities (Morretti [2004a, 2004b], Rauch [1991], Glaeser [2004], Shapiro [2006]).
from having universities. It may form a basis for policies at the level of university presidents or local governments to maximize benefits of universities to their local communities.

The remainder of the paper is organized in the following way: Section 3.2 discusses the data, variables for the empirical analysis and trends in these variables. Section 3.3 reports fixed effects estimates for incomes and employment. Section 3.4 shows instrumental variable estimates. Section 3.5 concludes.

3.2 Data, Variables and Trends

In the empirical analysis I assume that a variety of local labor market activities at the individual level are related to individual and local area characteristics. The university variables are a subset of the local area characteristics. I use the Higher Education General Information Survey (HEGIS) data from 1980-81, and the Integrated Postsecondary Education Data System (IPEDS) 1990-91 and 2000-01 to measure total Bachelors degrees and Bachelors degrees in S&E at the level of the universities and colleges23.

Aggregating the S&E degree data to the metropolitan area level yields information on degrees for 226 (259, 280) metropolitan areas. Not surprisingly the largest cities like New York, Chicago, Los Angeles, Boston, Philadelphia etc. generate the most degrees in total and in S&E. As indicated before, to account for scale effects, total Bachelors degrees in a region is divided by the population of that metropolitan area to estimate the importance of Bachelors degrees. In the analysis the share of Bachelors

---

23 The science degrees include Biological sciences, Mathematics, Engineering, Physical Sciences, Computer and Information and Health Professionals.
degrees in S&E in total Bachelors Degrees granted is used, which is neutral to the size of a city. On a per capita basis, the cities with the largest number of per capita Bachelors degrees are State College, PA, College Station, TX and Bloomington, IN. The ranking of metropolitan areas with the share of S&E in total Bachelors degrees includes Lafayette, IN, Rochester, NY Palm Bay-Melbourne-Titusville, FL, and Rapid City, SD.

Figure 3.1 shows the difference between using per capita versus aggregate levels of the Bachelors degree variables in 1980. In this graph, the horizontal axis measures per capita Bachelors degrees, and the vertical axis measures logarithm of total Bachelors degrees. From these graphs it is clear that college towns such as College Station, Texas, State College, Pennsylvania, Urbana-Champaign, Bloomington-Normal, Lafayette, Gainsville Florida, have higher per capita values but moderate on totals while, the New York, CMSA, Boston CMSA have higher aggregate values than per capita values.

In 1980 (1990 and 2000) there were 2,874 (3,208 and 3,159) universities and colleges in the sample. Using the zip code of each college and university I match universities to their metropolitan areas. Restricting the sample to universities and colleges in a metropolitan area, leaves a sample of 2,058 (2,396 and 2,401) universities and colleges in 1980 (1990 and 2000) and these institutions awarded 753,025 (864,705 and 1,035,436) Bachelors degrees and 210,619 (215,213 and 267,985) Bachelors degrees in S&E given from all the universities and colleges in the sample.
The dataset on Academic R&D Expenditures comes from National Science Foundation by school, field and source for 1980, 1990 and 2000. In 1980 (1990 and 2000) there were 520 (554 and 614) universities and colleges, of which 413 (440 and 511) universities and colleges are in metropolitan areas in for 1980 (1990 and 2000)\textsuperscript{24}. The NSF reports R&D for universities and colleges for a much smaller population than National Center for Education Statistics. Matching these schools to the Carnegie Classification ([2002]), 93% of these universities and colleges are Ph.D. granting research schools, or they are mining and engineering schools. Total R&D from all universities and colleges is 5,422,888 (14,649,223 and 27,902,825) thousand dollars.

The largest total R&D expenditure in all the three years 1980, 1990 and 2000 comes from Johns Hopkins University, with 253,204 (668,915 and 901,156) in thousands of dollars, followed by Massachusetts Institute of Technology (MIT), University of Michigan, University of Wisconsin Madison, University of Washington at Seattle, and University of California, Berkeley, Stanford University, Harvard University. These schools also get the most funding from the federal sources. The large state universities like Texas A&M, the Ohio State University, Louisiana State University, and University of Georgia receive the most state funding. The universities that have the biggest funding from industry are Duke University, MIT, Stanford, Harvard, The Ohio State University, North Carolina State University, and Penn State University.

\textsuperscript{24} In my data analysis I use total R&D which contains R&D of natural as well as social sciences. I do not include the R&D of research laboratories since they are not academic institutions. R&D is measured in thousands of dollars.
Aggregating the R&D data to the metropolitan area levels we find that the largest metropolitan areas that have the most R&D are the big cities like New York, Los Angeles, Boston, Chicago, and San Francisco. On per capita basis R&D is highest in College Station, State College, PA, and Urbana Champaign, IL. There are 157 (159, 181) metropolitan areas in 1980 (1990 and 2000). Table 3.1 gives the list of metropolitan areas that have large volumes of R&D in per capita and aggregate levels. I also create a list of universities associated with the cities who lead the nation in greatest amount of R&D.

A rich set of non-university control variables for metropolitan areas like population, crime rates and public school attendance is taken from *State and Metropolitan Data Set* for the years 1980, 1990 and 2000. In the same vein I also use data of utilities mortgages and taxes to measure the difference in standard of living in each metropolitan area from *Places Rated Almanac* of 1972, 1980, 1990 and 2000.

I use the 1% sample of the 1980, 1990 and 2000 Census to estimate individual earnings and employment as the local labor market activity data. There is a larger sample i.e. the 5% Census sample available but it is state specific. Since metropolitan areas often overlap state boundaries, it is not the ideal sample for this work. The census sample is restricted to people of working age (18-65) who are not institutionalized or in school\(^{25}\). Local labor markets are defined by the Consolidated Metropolitan Statistical Area (CMSA), New England County Metropolitan Area

\(^{25}\) In income regression I drop the observations for which wage information is not available. In the employment regression I drop the observations for which I do not have any employment data. The employment sample is larger than the earnings regression sample.
(NECMA), or Metropolitan Statistical Area (MSA). People were matched to university data from their metropolitan area of residence.

Data on degrees is available for substantially more cities than have reported R&D. Most cities with no reported R&D probably have very low R&D. The observations for which R&D is unknown are deleted. The resulting sample has 1,223,224 observations total, with 349,450 (399,751 and 474,023) observations for 1980 (1990 and 2000) which captures 126 (139 and 141) metropolitan areas for the earnings regression. The resulting sample has 462,107 (502,531, 604,635) observations for 1980 (1990 and 2000) which captures 126 (139 and 141) for employment regression.

Table 3.2 shows the changes in the mean and standard deviations of the earnings and employment of individuals from 1980 to 2000. We find that the mean of log earnings have increased from $9.17 in 1980 to $9.78 in 1990 and increased further to $10.19 in 2000. The mean employment rate has gone up from 68% in 1980 to 73% in 1990 and to 75% of working age adults in 2000. While the standard deviation of both increase over time, the coefficient of variation for these variables indicate that inequality across city over time has decreased.

Table 3.2 gives the summary statistics of the regression sample for the earnings and employment regressions. Between 1980 -2000, the mean of Bachelors degrees granted by universities and colleges per capita have increased by over 13%. Interestingly, the standard deviations go up as well. The coefficient of variation in this

\[ \text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Mean}} \]

...
time increased from 72% to 82%, which tells us that inequality in the flow of Bachelors degrees cities increased. The mean of Science and Engineering degrees fell, but this is more a result of adding a few cities to the data set in 1990 and 2000 which lacked in S&E Degrees. The mean of per capita R&D expenditure has risen from $33.30 in 1980 to $93.35 in 2000. The coefficient of variation has increased across cities over time—signifying an increase in the dispersion of this variable.

The mean of the share of people with Bachelors degrees increased from 10% in 1980 to 20% of the working population aged 18-65 in 2000. The standard deviation has increased between 1980 and 2000 suggesting increases in regional inequality in distribution of the stock of college educated population in different cities.

### 3.3 Fixed Effects Regression Results

The effects of universities are estimated by employing a variety of strategies. The panel structure of my data is used to include city level fixed effects with year dummy variables.

At the individual level, I estimate an equation like:

\[
y_{ict} = \alpha + \beta UNIV_{ct} + \gamma Z_{ct} + \phi X_{ict} + \theta_t + \nu_c + \omega_{ict}
\]  

(3.1)

Where, \(i\) stand for an individual, \(c\) stands for city and \(t\) stands for time. When \(y_{ict}\) represents the logarithm of annual wage and salary earnings of individual \(i\) in city \(c\) and time \(t\), equation 3.1 becomes an earnings regression. When \(y_{ict}\) represents the employment
status of individual $i$ in city $c$ and time $t$ i.e. this variable takes a value of 0 (1) if the person is unemployed (employed), equation 3.1 is an employment regression.

A vector of university variables (like per capita Bachelors degrees, per capita R&D, the share of science degrees in total Bachelors degrees and the share of Bachelors degree holders in a city)\(^{27}\) is denoted by $UNIV_{ct}$ while $Z_{ct}$ represents a vector of city level controls like (population, a dummy variable for year ($\theta_t$) and an interaction between population and the year dummy variable). Both $UNIV_{ct}$ and $Z_{ct}$ vary across cities. $X_{ict}$ is a vector of individual characteristics that vary across individual, time and city including year of schooling, experience, gender and marital status of individuals.

As indicated, to make cities with different size similar, I standardize university data by dividing them by population of that city. To allow for a correlation between observations in a city over time the standard errors are clustered within each city across time.

**Results for Annual Earnings**

Table 3.3 reports the effect of universities on the annual earnings of individuals in their local labor markets. The first four columns report the effect of per capita Bachelors degrees, per capita R&D, the share of S&E degrees and the stock of Bachelors degrees on the logarithm of earnings independently. Each variable is positively related to earnings. The share of S&E degrees is statistically significant at the 10% level

\(^{27}\) The correlation between the flows of Bachelors degrees to the stock of Bachelors degrees is 0.18 in the regression sample dispelling doubts that they are collinear.
while per capita R&D and stock of Bachelors degree holders are statistically significant at the 5% level. T-test fails to reject the hypothesis that per capita Bachelors degrees are 0. The stock of Bachelors degrees has the largest independent impact on earnings.

Columns 5-7 report the estimates where the stock of Bachelors degree holders is used along with the other variables, the share of S&E degrees and stock of Bachelors degrees continue to be positively and significantly related to earnings. The coefficients of per capita Bachelors degrees and the share of S&E degrees increase and that of per capita R&D decrease. The levels of significance of S&E degrees increases, while that of per capita R&D falls. Per capita of Bachelors degrees has a positive coefficient but is never statistically significant.

Columns 8-10 show different combinations of per capita Bachelors degrees, the share of S&E degrees and per capita R&D without the stock of Bachelors degrees. Column 9 stands out where both per capita R&D and the share of S&E are significant at the 5% level. The rest of the parameter values and levels of significance match the results presented in columns 1-4. Column 11-13 report results of specification in column 8-10 with the stock of Bachelors degree variable. Not surprisingly the coefficients behave almost like those reported in columns 4-6. In Column 12 all the variables are positive and significant.

The last two columns report the estimates where all the university variables are present with and without the stock of Bachelors degree holders. Per capita R&D, the share of S&E degrees and the stock of Bachelors degree holders all are positively and
significantly related to earnings. The joint F-tests of the whole model in each case reject that the university effects are any different from 0. All these results reflect that universities are important determinants of earnings, over and above the direct effect of individual education.

The difference of these results from the literature can be driven home by considering the economic significance of the effects of university activities on individual earnings. Using the standard deviations in Table 3.2, we get that if the stock of Bachelors degrees per capita R&D and the share of S&E degrees increases by 1 standard deviation, log earnings increase by 7% (1% and 1.6%). From a local government standpoint, it suggests policies that attract Bachelors degree holders in a city, or retain Bachelors degree holders in a city can have large effects on earnings. An increase in the share of S&E degrees or an increase in R&D would also have large positive effects on earnings.

Another way to gauge the importance of the university variables on earnings is to consider that between 1980 and 2000, the share of R&D has increased by 300%. This increase is estimated to have raised the average earnings by 19% to 33% over the last two decades, after controlling for the direct effect of individual education on earnings. These large effects are markedly different from the literature, which often find no effect of universities on earnings (Beeson and Montgomery [1993], Wang [2005], Goldstein and Drucker [2006]).
There are two interesting points about the fixed effects estimation results. First, the flow of Bachelors degree holders is perhaps less important. This variable is dropped from subsequent analysis. Second, including the stock of Bachelors degrees in the regression decreases the value of the coefficient on per capita R&D and increases the coefficients of per capita Bachelors degrees and the share of S&E degrees.

*Results for Employment Status*

Table 3.4 reports the results of the employment regressions. Employment is a discrete variable, which takes the value 1 if the person is employed, and it takes the value 0 if an individual is not employed. I fit a linear probability model to facilitate comparison with instrumental variables estimates in the next section. The specifications in Table 3.4 are organized in the same way as those in Table 3.3. The first four columns report the individual effects of per capita Bachelors degree, the share of S&E degrees and the stock of Bachelors Degree holders, all of which are positively related to individual employment status. The coefficient for per capita R&D is close to 0 and is not statistically significant. Only the stock of Bachelors degree holders and the share of S&E degrees are statistically significant at the 5% and 10% levels respectively.

Columns 5-7 report specifications that include the stock of Bachelors degree holders. The coefficients increase for S&E degrees and per capita Bachelors degrees but the sign of per capita R&D variable reverses and the coefficient becomes smaller in magnitude. Per capita Bachelors degrees and the share of S&E degrees become significant at the 10% level. Columns 8-10 present combinations of the university
variables without the stock of Bachelors degrees, which are similar. Columns 11-13 show
the change in the estimates from column 8-10 when the stock of Bachelors degree holders
is introduced. The coefficients of the share of S&E degrees and per capita Bachelors
degrees increase, but that of per capita R&D change signs but stays insignificant, its
value being close to 0.

The last two columns report the estimates where all the university variables
are all included together with and without the stock of Bachelors degree holders in a city.
The share of S&E degrees and stock of Bachelors degrees continue to be positively and
significantly related to employment.

The coefficient on per capita R&D is close to zero and insignificant. Thus,
while R&D has a large impact on income, its effect on employment status is insignificant.
On the other hand, a one standard deviation in increase in the stock of Bachelors degrees;
per capita Bachelors degrees; and the share of S&E degrees increases the probability of
employment by 1.4% .05% and 0.03%. Together, their influence would increase the
probability of individual employment by 2.2%. It is noteworthy that the variables that are
related to employment are degree variables for the local economy and that these estimates
control for individual education.

Another way to gauge the importance of the university variables on
employment is to consider the impact of recent increases. Between 1980 and 2000, the
share of the workforce with Bachelors degrees increased by 15%. This increase is
estimated to have raised the average probability of employment by 18% over the last two
decades (again controlling for the direct effect of education on employment). These large effects are consistent with the literature which often finds greater effects on employment than on earnings (Beeson and Montgomery [1993], Wang [2005], Goldstein and Drucker [2006]).

Robustness

I have used a variety of other specifications to check the robustness of the results. Polynomials of the variables already used were included. A common concern is R&D takes time to impact local labor markets. Similar concerns surround degrees – spillovers from degree recipients may increase over time. To allow for gestation periods, values of university variables were measured at a 5 year lag. Lastly, R&D expenditures at federal laboratories were included in the already existing R&D measure and aggregate science and engineering Bachelors degrees were used instead of per capita values. None of these robustness checks, the results of which are available upon request, changed the results qualitatively\(^{28}\).

3.4 Instrumental Variable Regression Results

City fixed effects account for time-invariant unobserved determinants of labor market conditions that are related to universities, but they do not control for time-varying unobserved factors. To deal with this issue, I use instrumental variables. Two different

\[^{28}\text{While estimated the fixed effects model at the metropolitan area level as well. The results were similar. There are some econometric problems because of which I am not reporting them. City level regressions do not include individual characteristics. So, individual heterogeneities are not captured. To circumvent this problem, I used metro specific fixed effects and then estimated these fixed effects on the university variables. This is a two step procedure which might lead to biases in standard errors depending on which metro was used as the baseline for fixed effects.}\]
sets of instruments were used: 1) Historical values of Bachelors degrees, the share of
degrees in science and R&D interacted with year dummy variables and 2) a shift share
index for R&D. The historical values of the degrees are from 1969-1970 and the
historical values of R&D are from 1973.

The First Stage equation is

\[ UNIV_{it} = \varphi + \sum \delta_i \text{HistoricUNIV}_{i1970} + \mu Z_{it} + \tau X_{it} + \theta_t + v_i + \epsilon_{it} \]  \hspace{1cm} (3.2)

The Second Stage Equation is

\[ y_{it} = \alpha + \beta UNIV_{it} + \gamma Z_{it} + \phi X_{it} + \theta_t + v_i + \omega_{it} \]  \hspace{1cm} (3.3)

The historical variables are expected to be related to current university
variables, but not directly to current labor market conditions. Table 3.5 shows the partial
\( R^2 \) for the excluded instruments. The partial \( R^2 \) of the historical values of Bachelors
degrees was 5%, that of the share of science and engineering was 23% and the partial \( R 
\) squared for R&D is 62%. Similarly, I find out the F statistics for the excluded
instruments, which are also reported in Table 3.5. For example, the value of the F statistic
for the historic value of per capita Bachelors degrees is 26897.83 for the earnings and
32687.90 for the employment sample. This indicates that the instruments are not weak.

I use a second set of IV for R&D – a shift share index of R&D. Total R&D is
broken down into 14 categories based on field of and source. The fields are life science,
physical science, psychology, social science, geology, math and computer science,
engineering and other sciences. The sources are total, federal and non federal. The
instruments are constructed finding the average share of R&D in each city in an initial year, which in my case is 1973. The weights vary across cities. The share shift index for each city is then calculated by constructing weighted averages of aggregate trends in spending in each of the 14 categories, where the weights vary across cities as a function of the initial specialization. Formally the instrument is

\[
S_{cft3}^j = \frac{E_{cj}^f}{\sum_{f_j} E_{cj}^f} \quad (3.4)
\]

\[
IVRD_{ct}^j = \sum S_{cft3}^j * E_{cj}^f \quad (3.5)
\]

Here \( S_{cft3} \) denotes the initial weights (for 1973 in this case) field \( f \) in city \( c \) for R&D source \( j \). Equation (4) gives the share of expenditure on say medicine among total expenditure in all other fields in 1973. \( E_{cj}^f \) is the weight of expenditures in field \( f \) in city \( c \) in time \( t \) for R&D source \( j \). In this case, \( E^f_j \) represents the average expenditure in a certain type of R&D in field \( f \) over three decades. \( E^f_{ct} \) is the R&D from the source \( j \) in city \( c \) in field \( f \) and in time \( t \).

The intuition is the following. Different universities in USA specialize in one or more of these fields. For example, San Francisco and Baltimore are two of the top places in USA for expenditure in life sciences (including medical sciences). The federal government is a large part of such expenditures. Through the decades, there have been variations in the federal government budget expenditure to universities in life sciences.
These changes in life sciences expenditure provide a source of exogenous variation in R&D in San Francisco and Baltimore relative to places that are less specialized in life sciences. The shift share index is a weighted average of spending trends, where the weights vary across cities according to initial shares in each category, this exogenous variation gives us identification. The partial R² for the shift share index is 5% - so there is a strong relationship between the shift share index instrument and per capita R&D variable.

There is a concern that the stock of Bachelors degrees in a city may be endogenous – affected by the current demand and supply shocks which also affect current incomes. To address this, I use an interaction term between the presence of a land grant university and year. Land grant schools were developed under the Morrill Act of 1875. Given that they were founded a century before the labor market conditions we measured, they should have no influence on current conditions beyond their effect on current university variables. The presence of a land grant institution has been used by others as the instrument for the share of college graduates in the population (see Morretti [2004a, 2004b]).

The instruments are missing for some individual observations and city-year pairs. Deleting these observations yields a data set with individual observations and 373 city-year pairs. The means and standard deviation for this sample is similar to the full sample descriptive statistics as reported in Table 3.2. The fixed effects results for this sample are similar to those reported above.
Results for Annual Income

These results are given in Table 3.6. In column 1, column 2 and column 3, I instrument for R&D by the historic R&D variable, the shift share index with total R&D and by both historic R&D and the shift share index. The specification with historic instruments, and the specification with historic and the shift share instruments together leave the second stage estimator positive and significant. The specification where only the shift share instrument is used, the coefficient is positive but not significant. So the shift share instruments are not strong, they produce insignificant results. Similar pattern is seen when we insert the stock of Bachelors degree holders are included in the estimation. Column 4 and column 6 shows that per capita R&D is significant at the 10% level, but it is not in column 5 where only the shift share index was used as the instrumental variable.

The share of S&E degrees are instrumented by the historic values of S&E variable. This is reported in column 7. The share of science and engineering degrees is not significant but positive. Also the value goes down by almost 40%. It suggests that S&E degrees are not as important as the fixed effects regression would suggest, but R&D increases earnings significantly. In all these specifications the stock of Bachelors degree holders is still positive and significant and the value of its coefficient is the same as in the fixed effects regression.

Column 8-10 has the instrumental variable results for specification 9 from the fixed effects model. Once again, for R&D, three different sets of instruments are tried, while for the share of S&E degrees I only use the historical value of the variable. The
share of S&E degrees is not significant, as they were in the fixed effects regression. Column 11-13 shows the result of the instrumental variables for per capita R&D and the share of S&E degrees controlling for the effects of stock of Bachelors degrees in a city. We find that R&D is significant at 10% instead of being significant at 5%. Since the point estimates are close to the fixed effects numbers, the economic impact of these variables is going to be the same as before.

In all these regressions, the first stage results are as expected. For example, the historical R&D variable positively influences per capita R&D, and the shift share index positively influences R&D as well. The level of significance is positive of all the instruments. In the same vein, the first stage signs for the share of S&E degrees indicate that they positively influence the current S&E degrees. As before, the results suggest that the universities are important determinants of annual earnings of the people living in metropolitan areas with R&D being one the main factors.

Results for Employment

From Table 3.4 from the fixed effects section, it is evident that R&D does not play a large role in determining employment. The indication was that per capita Bachelors degree or the share of S&E degrees can have a large role to play apart from the stock of Bachelors degrees. It was also noticed that employment effects of the university variables was significant in the presence of stock of Bachelors degrees. The instrumental variable results are summarized in Table 3.7. The columns report the second stage estimates of the regressors.
Column 1 reports the instrumental variable estimates of per capita Bachelors degrees. I use the historic values of per capita Bachelors degrees as instruments along with the land grant year dummy as another instrument. The coefficient for per capita Bachelors degrees increases nearly twice as much as in Specification 5 of Table 2.4 and the significance increases as well. The results for the share of science and engineering degrees in column 2, shows that it is not significant and the coefficient has the unexpected sign. Column 3 instruments for both per capita Bachelors degrees and the share of S&E degrees with their historical values and land grant. In the end, only per capita Bachelors degrees have a positive sign. The stock of Bachelors degree holders keep on being positive and significant in all three columns regressions. The main lesson learnt is that only Bachelors degrees, either the stock or the flow have the real power in affecting employment status of individuals.

3.5 Conclusion

This paper estimates the economic effects of universities on their local markets. It extends and enriches the existing empirical work, which answer if the universities have important impact on local economies. I use panel data at the level of universities and colleges. City fixed effects and two different instrumental variables are included to find that universities and colleges have significant impact on their local economies. In contrast to the literature, universities and colleges are found to affect individual incomes and employment significantly. A one standard deviation of the share of Bachelors degrees in science and engineering, R&D and the stock of Bachelors degrees individually can
increase the mean earnings in a city by 2%-7%. The university activities together increase the probability of employment by 2.2%. The instrumental variables show that R&D still positively and significantly affects earnings and the stock of Bachelors degrees always affects earnings and probability of employment positively. The other implication of the study is that R&D and the share of S&E degrees are important for earnings, while per capita Bachelors degrees are important for employment. It implies the importance of academic science in general and suggests policies for university presidents to make universities have larger effects on their communities.
### Table 3.1: Comparison of leading cities in Total Versus Per Capita R&D in 1980

<table>
<thead>
<tr>
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</tr>
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<tbody>
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<td>New York</td>
<td>Bryan College Station</td>
<td>New York</td>
<td>Bryan College Station</td>
<td>New York</td>
<td>State College</td>
</tr>
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<td>DC</td>
<td>DC</td>
<td>State College</td>
<td>DC</td>
<td>Bryan College Station</td>
</tr>
<tr>
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<td>Iowa City, IA</td>
<td>San Francisco, Boston</td>
<td>Urbana Champaign Athens</td>
<td>San Francisco, Boston</td>
<td>Urbana Champaign</td>
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<td>4</td>
<td>Boston Lafayette</td>
<td>Lafayette</td>
<td>Lafayette</td>
<td>Athens</td>
<td>Urbana Champaign Bloomington, IN</td>
<td></td>
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<tr>
<td>5</td>
<td>Los Angeles Urbana Champaign</td>
<td>Los Angeles, CMSA Houston</td>
<td>Urbana Champaign Athens</td>
<td>Iowa City, IA</td>
<td>Los Angeles Bloomington, IN</td>
<td></td>
</tr>
<tr>
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<td>Chicago Athens</td>
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<td>Madison</td>
<td>Raleigh Durham Houston</td>
<td>Athens</td>
<td>Lawrence, KS</td>
</tr>
<tr>
<td>7</td>
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<td>Madison</td>
<td>Bloomington IN</td>
<td>Lawrence, KS</td>
<td></td>
</tr>
<tr>
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<td>Madison, WI Columbia, MO</td>
<td>Chicago</td>
<td>Columbia, MO Lafayette</td>
<td>Chicago Gainesville, FL</td>
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<td></td>
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<td>Detroit Gainesville, FL</td>
<td>Detroit</td>
<td>Lafayette</td>
<td>Detroit</td>
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<td></td>
</tr>
<tr>
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<td>San Diego Bloomington, IN</td>
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<td>Gainesville, FL</td>
<td>Philadelphia</td>
<td>Lafayette</td>
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Table 3.1: Comparison of leading cities in Total Versus Per Capita R&D in 1980
<table>
<thead>
<tr>
<th></th>
<th>Mean (Standard Deviation)</th>
<th>Mean (Standard Deviation)</th>
<th>Mean (Standard Deviation)</th>
<th>Mean (Standard Deviation)</th>
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<tr>
<td></td>
<td>1980</td>
<td>1990</td>
<td>2000</td>
<td>Panel</td>
</tr>
<tr>
<td>Log Wages</td>
<td>9.1726 (1.0440)</td>
<td>9.7876 (1.0227)</td>
<td>10.1964 (0.9890)</td>
<td>9.7707 (1.0977)</td>
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<tr>
<td>Bachelors Degree Per Capita</td>
<td>0.0044 (0.0033)</td>
<td>0.0047 (0.0041)</td>
<td>0.0050 (0.0041)</td>
<td>0.0047 (0.0039)</td>
</tr>
<tr>
<td>Share of S&amp;E Degrees</td>
<td>0.2830 (0.0622)</td>
<td>0.2515 (0.0509)</td>
<td>0.2582 (0.0445)</td>
<td>0.2631 (0.0537)</td>
</tr>
<tr>
<td>R&amp;D per Capita</td>
<td>0.0342 (0.0432)</td>
<td>0.0869 (0.1313)</td>
<td>0.1470 (0.2073)</td>
<td>0.0952 (0.1580)</td>
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<tr>
<td>Stock of Bachelors Degree</td>
<td>0.1102 (0.0197)</td>
<td>0.1667 (0.0310)</td>
<td>0.2053 (0.0368)</td>
<td>0.1656 (0.0494)</td>
</tr>
<tr>
<td>Observations (earnings sample)</td>
<td>352385 (401704)</td>
<td>401704 (479167)</td>
<td>479167 (1233256)</td>
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<tr>
<td>Employment status</td>
<td>0.68 (0.46)</td>
<td>0.73 (0.44)</td>
<td>0.75 (0.43)</td>
<td>0.72 (0.44)</td>
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<tr>
<td>Observations (employment sample)</td>
<td>462,107 (502,531)</td>
<td>502,531 (604,635)</td>
<td>604,635 (1,569,273)</td>
<td></td>
</tr>
</tbody>
</table>

Table 3.2: Descriptive Statistics: Labor Market and University Activities

Note: The descriptive statistics for the earnings and employment samples are very similar for all other variables.
Table 3.3: Earnings Regressions: Fixed Effects Estimates

<table>
<thead>
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<th>Columns</th>
<th>1</th>
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<td>Bachelors Degree Per Capita</td>
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<td>3.7</td>
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<td></td>
<td>1.96</td>
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<td></td>
<td>(3.80)</td>
<td></td>
<td>(3.28)</td>
<td></td>
<td></td>
<td>(3.79)</td>
<td></td>
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</tr>
<tr>
<td>Share of S&amp;E Degrees</td>
<td>.20 *</td>
<td></td>
<td>.31**</td>
<td></td>
<td></td>
<td>.205*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(.12)</td>
<td></td>
<td>(.12)</td>
<td></td>
<td></td>
<td>(.124)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D per Capita</td>
<td></td>
<td>.12**</td>
<td>.06 *</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>(.04)</td>
<td>(.03)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Stock of Bachelors Degree</td>
<td></td>
<td>1.46**</td>
<td>1.47**</td>
<td>1.53**</td>
<td>1.39**</td>
<td></td>
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<tr>
<td>Holders</td>
<td></td>
<td>(.280)</td>
<td>(.28)</td>
<td>(.27)</td>
<td>(.277)</td>
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<tr>
<td>R Squared</td>
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<td>.361</td>
<td>.361</td>
<td>.361</td>
<td>.361</td>
<td>.361</td>
<td>.361</td>
<td>.361</td>
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</tbody>
</table>

Continued

Note: Stock of Bachelors Degree Holders indicates the share of Bachelors degree holders in a metropolitan area.

Note: Observations: 1209570 Clusters: 373* - Significance at 10% and **- Significance at 5% The individual controls include years of education, experience, experience squared, experience cubed, experience raised to the power of four, interaction between gender and marriage and race. The city controls include logarithm of population, population squared, total crime rate, mortgage payment with taxes, utilities and public school enrollment in K-12 system in a city. Include time dummy variables and city level fixed effects. The second stage estimates are reported.
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Table 3.4: Employment Regressions: Fixed Effects Estimates

Note: Stock of Bachelors Degree Holders indicates the share of Bachelors degree holders in a metropolitan area.

Note: Observations: 1209570 Clusters: 373* - Significance at 10% and **- Significance at 5% The individual controls include years of education, experience, experience squared, experience cubed, experience raised to the power of four, interaction between gender and marriage and race. The city controls include logarithm of population, population squared, total crime rate, mortgage payment with taxes, utilities and public school enrollment in K-12 system in a city. Include time dummy variables and city level fixed effects. The second stage estimates are reported.

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R Squared 0.144 0.144 0.144 0.144 0.144 0.144 0.144 0.144

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Table 3.4 Continued

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Table 3.5: Instrumental Variables: Partial R Squares and F Statistics

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<td>Residual of Per Capita Bachelors</td>
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<td>[77846.53 (&gt;9999)]</td>
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</table>

Note: Stock of Bachelors Degree Holders indicates the share of Bachelors degree holders in a metropolitan area.

Note: Observations: 1209570 Clusters: 373* - Significance at 10% and **- Significance at 5% The individual controls include years of education, experience, experience squared, experience cubed, experience raised to the power of four, interaction between gender and marriage and race. The city controls include logarithm of population, population squared, total crime rate, mortgage payment with taxes, utilities and public school enrollment in K-12 system in a city. Include time dummy variables and city level fixed effects. The second stage estimates are reported.
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Table 3.6: Earnings Regressions: Instrumental Variables

Note: Stock of Bachelors Degree Holders indicates the share of Bachelors degree holders in a metropolitan area.

Note: Observations: 1209570 Clusters: 373* - Significance at 10% and ** - Significance at 5% The individual controls include years of education, experience, experience squared, experience cubed, experience raised to the power of four, interaction between gender and marriage and race. The city controls include logarithm of population, population squared, total crime rate, mortgage payment with taxes, utilities and public school enrollment in K-12 system in a city. Include time dummy variables and city level fixed effects. The second stage estimates are reported.

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| IV Used           | Historic Value of | Historic Values of | Historic Value of |
|                  | per capita        | S&E degrees        | per capita        |
|                  | Bachelors Degrees | and Land Grant     | Bachelors Degrees | Bachelors Degrees | and Land Grant |

Table 3.7: Employment Regressions: Instrumental Variables

Note: Stock of Bachelors Degree Holders indicates the share of Bachelors degree holders in a metropolitan area.

Note: Observations: 1209570 Clusters: 373* - Significance at 10% and **- Significance at 5% The individual controls include years of education, experience, experience squared, experience cubed, experience raised to the power of four, interaction between gender and marriage and race. The city controls include logarithm of population, population squared, total crime rate, mortgage payment with taxes, utilities and public school enrollment in K-12 system in a city. Include time dummy variables and city level fixed effects. The second stage estimates are reported.
Figure 3.1: Per Capita versus Aggregate Bachelors Degrees for 1980
3.8 List of References


Hill, Kent “University Research and Local Economic Development, (2006)” Center for Competitiveness and Prosperity Research, Arizona State University, August


Moretti, Enrico (2004b) "Human Capital Externalities in Cities" *Handbook of Regional and Urban Economics*, North Holland-Elsevier


BIBLIOGRAPHY


Hill, Kent “University Research and Local Economic Development, (2006):” Center for Competitiveness and Prosperity Research, Arizona State University, August


Moretti, Enrico (2004b) "Human Capital Externalities in Cities" Handbook of Regional and Urban Economics, North Holland-Elsevier


Stokes, Donald E. (1997): *Pasteur’s Quadrant*, Brookings


Wikipedia http://en.wikipedia.org/wiki/Bayh-Dole_Act