The Role of Search in University Productivity

Inside, Outside, and Interdisciplinary Dimensions

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Outline of the Presentation

I. Introduction
II. Description of Knowledge-Flows
III. Knowledge Production Function
IV. Summary, Discussion, and Conclusion

Discovery and the Search for Knowledge

- Academics engage in discovery and in a search for knowledge that is useful for their work and their progress in the learned professions.
- Equilibration of expected marginal returns and costs sets the level of effort in discovery and search.
- But the schedules of returns and costs depend on field and institutional boundaries.
- Recent changes in technology and policy have altered these schedules across boundaries.

Recent Changes

- The allocation of effort to discovery and search has changed as a consequence.
- The changes are due to: (a) improved information technologies, (b) growing complexity of research, and (c) policies favoring collaborative and interdisciplinary research.
- We explore these issues using a panel of 110 U.S. universities and 12 fields observed over the period 1983-1999. This sample accounts for more than 80% of academic research spending in the U.S.

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Shift Factors: Policy Initiatives

- Recent U.S. policy initiatives favor collaborations across institutions, fields and countries. Why?
- Because the U.S. National Science Foundation (NSF) holds a strong belief that path-breaking research requires new combinations of ideas.
- In the U.S. "centers are the primary means by which NSF fosters interdisciplinary research." NSF (2009b) and the Networking Research Programmes of the ESF are a similar approach.

Shift Factors: Information Technologies

- Deployment of the Internet in the late 1980s and commercialization of complementary software in the early 1990s led to a decline in search costs.
- It seems obvious that search effort would shift beyond the institution as a result.
- But has search expanded outside the discipline as a result of this shift in technology?
- This is not clear, since IT turns distant research in the same field into a substitute for local research in other fields.

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Knowledge-Flows and Knowledge Production

- To address these issues we study knowledge-flows between U.S. universities at the end of the 20th century.
- Then we examine the knowledge production function for ideas, as captured by scientific papers.
- Ideas are a function of knowledge-flows from previous stocks of knowledge that are distinguished by institutional and field boundaries.
- Old ideas and past resources produce new ideas.

Descriptive Findings: Preparations

- We'll begin with a description of knowledge-flows across institutional and field boundaries.
- But first we need to prepare the ground a little.
- For starters, we need a definition of knowledge-flows.
- Then we need a scale-free measure of the relative size of various knowledge-flows.
- These allow for easy comparisons across fields and institutions.

Definition of Knowledge-Flows

- Knowledge-flows in this paper are defined as:

$$S_{ijt} = \sum_{F\in Q_F} \sum_{I\in Q_I} \sum_{\tau=1}^{t-1} (c_{ijt}^{FI\tau} / n_{FI\tau}) R_{FI\tau}$$

- Flows to field i and institution j at time t come from the fields in the first sum, the institutions in the second, and previous years in the third.
- Sums are taken over the citation rate $c_{ijt}^{FI\tau} / n_{FI\tau}$ times the R&D stock (roughly, the stock of ideas).
- We can choose subsets of the flows by changing the sets Q_F, Q_I, for example, flows from the same field, etc.

Shares in Knowledge-Flows

- We calculate shares in knowledge-flows to show changes in relative size.
- For instance, the share of other fields is:

$$Share^{Other\ Fields} = S^{Other\ Fields} / (S^{Same\ Field} + S^{Other\ Fields})$$

- Sometimes we call this the interdisciplinary share.
- In the same way we can define shares of other universities, and so forth.

Changes in Shares

- The interdisciplinary share of knowledge-flows stays the same or decreases in about half the fields.
- But in engineering it almost doubles from about 0.16 to about 0.28, as Figure 3h shows.
- Overall the interdisciplinary share increases by 10%, from 0.22 to 0.24, as shown in Figure 4.
- In comparison the share of knowledge-flows from outside an institution increases by 30%, from 0.62 to 0.82, and this is similar across fields. See Figure 5.

Figure 3h--Share of Other Fields, Knowledge-Flows to Engineering

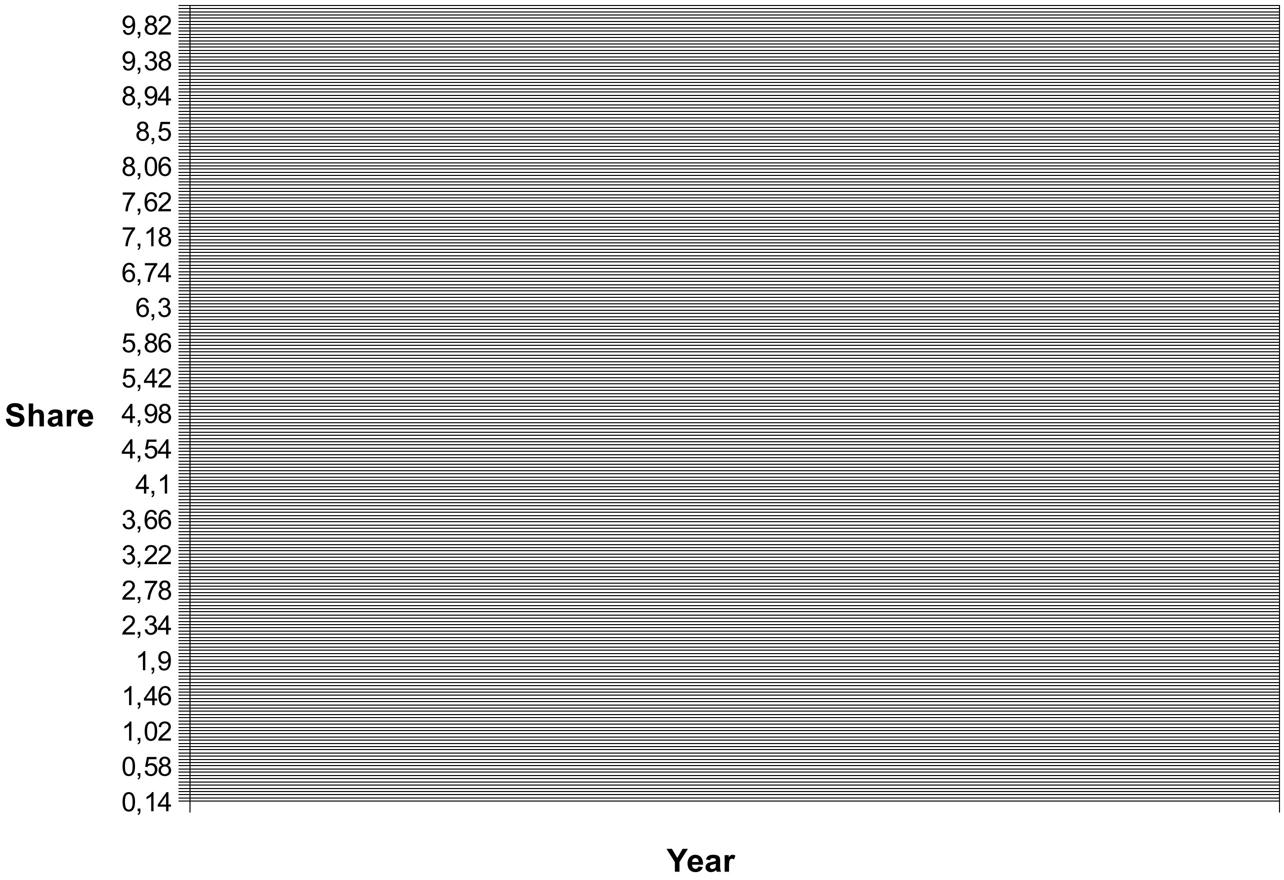

Figure 4--Share of Other Fields, Knowledge-Flows to All Fields

Figure 5--Share of Other Universities, Knowledge-Flows to All Fields

Changes within Engineering

- Engineering is a focal point of policies to increase interdisciplinary research.
- Because of this, we undertake a separate study of 13 engineering subfields.
- We break up shares of citations within the same subfield, the rest of engineering, and science.
- The share of science increases most and the share within a subfield nearly always decreases.
- The figure below illustrates this for one subfield.

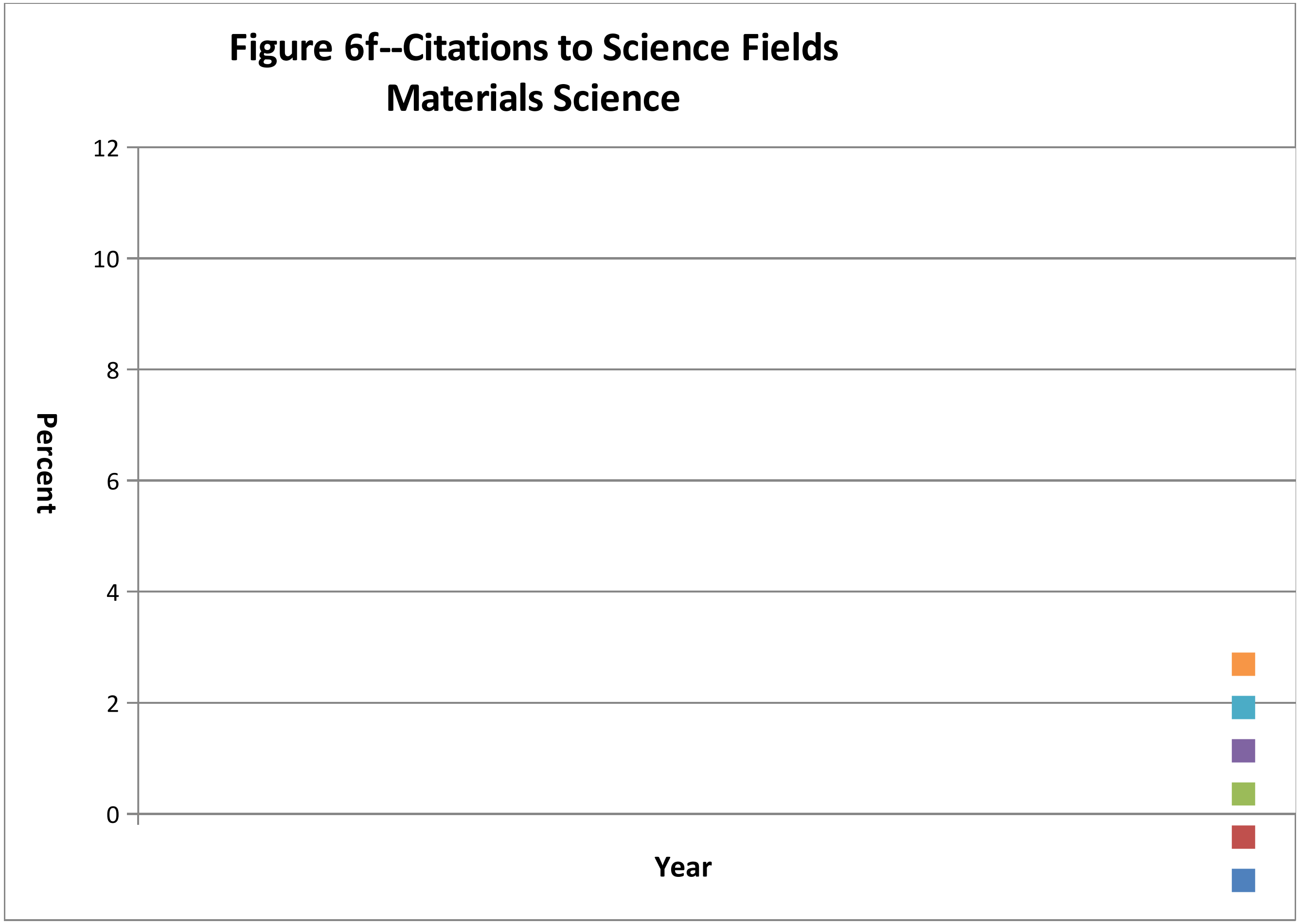

Figure 6f--Citations to Science Fields
Materials Science
12
10
8
6
4
2
0
Percent
Year

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Regression Findings: Preparations

- We turn now to a regression analysis of knowledge production with emphasis on interdisciplinary knowledge-flows.
- One contribution that this analysis can make is in distinguishing between the importance of knowledge-flows in production and the share of knowledge-flows.
- The two are not necessarily the same and this proves to be a key to understanding what the paper does.

Knowledge Production Function

- Below we report estimates of the production function:

$$\ln(n_{ijt}) = \beta + Z_D'\delta + \eta_R \ln(R_{(ij)t-1}) + \sum_{w=1}^{W} \eta_w \ln(S^{w}_{(ij)t-1}) + e_{ijt}$$

- Permanent variance components v_i, v_j, v_t are absorbed by fixed effects for field, university and time so that $Z_D'\delta = v_i + v_j + v_t$.
- As long as the transitory error e_{ijt} is uncorrelated over time, it follows that the regression coefficients will be unbiased, and identified.

Output Elasticities

- The production function includes output elasticities for the knowledge inputs.
- Their meaning is

$$\eta_i = \frac{\partial n}{\partial x}\frac{x}{n}$$

- Here x is the R&D stock or knowledge-flow.
- Thus the output elasticity is the percent change in papers per one percent change in knowledge input.
- We refer to it informally as “importance” in production.

Findings: Same/Other Universities

(Dependent Variable: Log(Papers) of Universities)

Variable	Coefficient (Standard Error)	
Log(Knowledge-Flow in Same University)	0.072** (0.019)	0.080** (0.017)
I(90)*Log(Knowledge-Flow in Same University)		-0.045** (0.016)
Log(Knowledge-Flow in Other Universities)	0.296** (0.024)	0.259** (0.024)
I(90)*Log(Knowledge-Flow in Other Universities)		0.130** (0.020)

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Findings: Same/Other Fields

(Dependent Variable: Log(Papers) of Universities)

Variable	Coefficient (Standard Error)	
Log(Knowledge-Flow in Same Field)	0.296** (0.034)	0.275** (0.033)
I(90)*Log(Knowledge-Flow in Same Field)		0.068** (0.014)
Log(Knowledge-Flow in Other Fields)	0.080** (0.011)	0.086** (0.010)
I(90)*Log(Knowledge-Flow in Other Fields)		0.014 (0.014)

Findings: “Hot” and “Cold” Fields

(Dependent Variable: Log(Papers) of Universities)

Variable	Coefficient (Standard Error)	
Log(Knowledge-Flow, “Hot” Fields)	0.020** (0.006)	0.054** (0.010)
I(“Hot”=0)*Log(Knowledge-Flow, “Hot” Fields)		-0.061** (0.011)
Log(Knowledge-Flow, Cold” Fields)	0.032** (0.006)	0.071** (0.009)
I(“Cold”=0)*Log(Knowledge-Flow, “Cold” Fields)		-0.076** (0.011)

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Summary

- During the 1990s knowledge-flows and knowledge production shifted towards outside research, from other universities and away from inside research.
- A much smaller increase is observed in inter-disciplinary knowledge-flows, but there is no shift in production towards this research.
- Instead, research from the same field became relatively more productive, because IT opened up access to ideas elsewhere, leading to a substitution of distant authors in the same field for local authors

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Time Period too Short…

- The time period may be too short relative to policies that have promoted interdisciplinary work, for these began in the 1980s.
- Growth of inter-disciplinary knowledge-flows in engineering suggests that we are starting to see an effect of the policies.
- But the results of this research may well lie in the future due to long and variable gestation lags, precisely because the research is path-breaking.

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