CHAPTER 16: ACADEMIC LABORATORIES AND THE REPRODUCTION OF PROPRIETARY SCIENCE: MODELING ORGANIZATIONAL RULES THROUGH AUTOCATALYTIC NETWORKS*

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The introduction to this volume emphasizes the origins and emergence of new forms as a collective blind spot in the social sciences.

Few analyses capture the relationship among all three features of social and economic life—the origin of new practices, their emergence as broader self-reproducing structures, and the form that they take as a result of this process.

Our approach to this question examines how disparate elements of the social organization of academic science were assembled, transposed, and recombined to define a new regime of public and proprietary science.

We combine detailed archival analysis with computational agent-based modeling to examine the introduction and adoption of proprietary science in the academy, specifically as a set of routines that shaped the production and disclosure of university-based research.

We emphasize the transformative aspect of self-reinforcing processes in recasting networks, shaping organizational routines, and potentially guiding science.
One of the most salient transformations that has taken place in recent decades is the introduction and spread of commercial practices in the academy, particularly in the form of patenting.

Technology transfer was initially unfamiliar to universities and scientists, but eventually became legitimate and expected.

Many argue that this change reflects the mixing of once disparate domains of public (university) and proprietary (industry) science:

- The nature of the goals accepted as legitimate
- Features of the reward system
- Norms of disclosure

The adoption of patenting by academic scientists, initially in the 1970’s and in greater force in the 1990’s, reflected a contrasting norm of disclosure:

- It conferred the right to exclude others from using a research finding and
- It permitted scientists and universities to make money from those findings.
From our perspective, understanding this transformation requires

- situating practices in the social and organizational system of academic science,
- and recognizing how the features that give rise to an institution can be different than those that reinforce it once in place.
OUR ANALYSIS

- Our aim is to illuminate the feedback dynamics of crossing boundaries and emergent institutional change.

- As the “amphibious” life scientists described in previous chapters came into contact with the world of commerce, how did their experiences reverberate into the conservative halls of academia? How were commercial practices, like patenting adopted, and in what form?

- We explain this process through the recombination of meanings and practices within the existing social structure of science.

- We also demonstrate how patenting practices originated in labs, rather than through policy incentives or regulative controls.

- We demonstrate how scientists efforts to maintain autonomy and expand the reach of one’s research program fueled change, despite the fact that these actions were part of concerted struggles to preserve the academic system.

- Our analysis shows that efforts to operate within the social structure of science generated the mechanisms that transformed it.
Emergence is a bottom up process as repeated social interactions give rise to vocabularies of motives that come to define what is standard and appropriate.

New forms are built by participants situated in the cultural routines of their past.

Opportunities and constraints, both new and old, make some participants receptive to alternatives from other domains, which remain invisible to others.

When transposition happens, new practices are assembled selectively rather than adopted wholesale, and as they become integrated into the social order, these practices can also alter the domain in which they are transposed.

Emergence is built on scaffolding of networks that transform rather than transmit.
DATA AND METHODS

Archives
- Administrative and invention records of Stanford University
- Focus on life science invention disclosures 1968-1982
- 42 inventions linked to a basic life science department, classified by lab, inductively examined points of intersection between commerce & academia

ABM*
- Advantage of clarity in forcing a precise translation of qualitative findings into “runnable” code
- Providing a platform to explore counterfactuals that are otherwise impossible to investigate

Process
- Begin with core question about the emergence of proprietary science
- Derive insights from the archives
- Translate insights to ABM
- Conduct controlled tests of mechanisms that can explain our outcome

* ABM developed using NetLogo, Wilensky 1999.
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## Correspondence Between Research and the Agent-Based Model

### Theoretical and Empirical Claims

#### Characterizing the Knowledge Production Process
- Science is based on cumulative production of knowledge & relies on distributed skills.
- Lab success relies on others using the science they produce.
- Labs reproduced their practices by training doctoral graduates.

#### Characterizing Forms of Disclosure
- Commerce developed in labs, linking opportunities to change & to produce.
- Patenting was contingent, depended on findings, & could change at each disclosure.

#### Characterizing the Adaptation of Labs
- Scientists learned from others patenting downstream developments of their work.
- Scientists reacted to patenting among peers.

### Operationalization in the Model

#### Characterizing the Knowledge Production Process
- **Scientific production routine**: labs are comprised of skills that transform scientific products.
- Lab survival depends on having skills that are replicated when knowledge advanced to another lab.
- Each lab is given a reproduction routine where new labs are "hatched" with some random mutation.

#### Characterizing Forms of Disclosure
- Knowledge disclosure routine activated by the knowledge production process.
- Labs have different patenting thresholds & products have different science value (1-100).

#### Characterizing the Adaptation of Labs
- Participatory adaptation routine: labs update PT as weighted avr. of their’s & successful colleagues’.
- Premptive adaptation routine: labs update PT based on the existence of more liberal colleagues.
INSIGHTS FROM THE ARCHIVES

- Despite extensive scholarship emphasizing national and local incentives, approaches toward commercializing research emanated more from labs than government, legal, or university sources.

- Variation in approaches and rationales for commercializing:
  - Threshold of what was patentable
  - Distribution of potential resources given back to science
  - Debates hinged on control over science & the ability to direct the resources rather than appropriate them personally.

- Engagement in commercial science was shaped by the production process and reward system of science.

- Approaches in labs were not fixed, but changed over time.

- These observations prompted us to think about the emergence of proprietary science as the shift in a threshold from few to many adopters; and willingness to patent few things to mostly anything.
“Although many of us are not in a position to exploit our discoveries, we do feel that universities and university-based research should benefit from profitable applications of our findings. I had hoped that an industry so recently spawned by university research would be enlightened in its recognition of who is responsible for its existence….Your comments leave me and other[s] no alternative but…to patent or make exclusive arrangements for whatever we develop. I can assure you that I will alert my colleagues throughout the world to guard against what I consider exploitation…”
“...It is not infrequent that inventors will...forego their personal share...There is a strong feeling by many, if not most inventors, that as they are responsible for bringing in the royalty funds, they should have a strong (if not the only) voice in controlling distribution of income...A royalty income fund under control of a PI would allow the PI to get a piece of equipment for general laboratory use, to send people to important technical society meetings for which grant or other funds are not available, etc...”
“I can accept a view that it is **more reasonable for any financial benefits** derived from this kind of **scientific research** carried out at a **non-profit university** with public funds to go to the university, rather than be treated as a **windfall profit** to be enjoyed by profit-motivated...[organizations]; I agreed to cooperate with Stanford for that reason... [but]...on the understanding that it would be made **perfectly clear to all concerned** that I would receive no personal gain from the patent.”
MECHANISMS

- Guided by the experiences of the observed labs, we included three mechanisms that explained the emergence of proprietary science.

- **Lab Reproduction:** a means of population-level learning that reflected a key way in which the social structure of science is reproduced, which in turn can play a role in emergence. This mechanism was also inspired by the instrumental role of graduate students and postdocs as they left their advisors to establish their own labs.

- **Participatory Adaptation:** a means of social influence that incorporated the ways in which scientist’s engagement in transferring their knowledge to more commercially-minded partners prompted the rethinking of their practices.

- **Preemptive Adaptation:** a form of adaptation for scientists that captured the ways in which the prospect of others patenting, and incurring the right to exclude others from further developing their area of science, provoked them to take up patenting themselves.
We drew on these insights to develop an agent-based model to examine the shift from a few labs willing to patent a narrow range of findings to most labs willing to patent a broad range of findings.

From an ABM perspective, we characterized the emergence of this activity as a reference pattern representing this shift in a patent threshold distribution.
DESCRIPTION OF THE MODEL

- Our model is made up of three parts: scientific products, skills, and scientific labs.

- Scientific labs use skills to transform scientific products.

  1 → 2 → 3 → 4 → 1

- Following Padgett’s* chemistry-inspired model, this transformation process can result in self-reinforcing chains of production. This is the evolutionary engine.

- Labs are rewarded when using skills in a successful transaction by the replication of their skills.

- We layered a process of patenting on top of this production: scientific labs also own decision-making routines that determine whether to patent.

*Padgett, 1997; Padgett, Doowan, and Collier, 2003; Padgett, McMahan, and Zhong, 2009
EXPLAINING REWARDS IN THE MODEL

- Scientific products represented as balls sitting in an urn with three attributes
  - **Type**, indicated by a number 1 to n.
  - **Scientific Value**, indicated by a number 1-100
  - **Patent Status**, indicated by whether or not it is patented in a transaction

- Labs are arrayed spatially on a grid with wrap-around borders, and connected to each other via collegial ties (i.e. Moore neighborhood).

- Labs are rewarded based on relative benefit in successful transactions.
  - In successful **publication-publication** transactions, the sender’s knowledge advancement routine is duplicated.
  - In successful **publication-patent** and **patent-publication** transactions, the receiver’s knowledge advancement routine is duplicated.
  - In successful **patent-patent** transactions, both the sender’s and receiver’s knowledge advancement routines are duplicated
LABS CAN ADAPT
- **Reproduction**: specifies the patentability threshold of the offspring, with an exogenously determined parameter that governs the amount of random mutation; also specifies the likelihood that the offspring will inherit any given link to a parent’s network, including the parent themselves.

- **Participatory Adaptation**: lab updates its patent threshold when it’s transaction partner was rewarded more than they were; recalculated as the weighted average of its current threshold and the threshold of the more successful transaction partner.

- **Preemptive Adaptation**: lab updates its patent threshold if a lab has a network neighbor whose disclosure routine would lead to the patenting of the product; adjusts its patent threshold to the minimum level that allows it to patent the product itself.

LABS CAN DIE (WHEN THEY RUN OUT OF SKILLS)
- When a routine is duplicated, another routine chosen at random is killed off.
A "DAY" IN THE LIFE OF A LAB

* Knowledge advancement routine
chosen at random
"ready for action"

* Labs with that routine draw a ball
(scientific product)
from the urn

* Labs with scientific product
apply knowledge advancement
routine: Does this lab have the
skills to transform the idea?

* Apply disclosure routine:
Is this scientific product
something the lab is willing to patent?

* Return scientific product
to urn

* Labs with scientific product
apply preemptive adaptation
routine: Is there a network
neighbor who would be willing
to patent this kind of product?

* Keep the lab's patentability
threshold the same

* Update the lab's patentability
threshold

* Produce Knowledge
Published not patented

* Transform product into
new scientific product
* Pass product to neighbor

* Labs apply their participatory
adaptation routine:
Did the receiver get the
relative reward in this transaction?

* Keep the lab's patentability
threshold the same

* Update the lab's patentability
threshold

* Produce Knowledge
Patented and published

* Transform product into
new scientific product
* Pass product to neighbor

* dotted lines represent adaptation routines that can be turned on or off.
EVO LUT ION O F A G E N T - BASED M O D E L O V E R T I M E
MULTILEVEL SCIENTIFIC PRODUCTION NETWORKS

Figure 16.3 Multilevel scientific production networks. A. Social network. B. Skill level scientific production network.
TRANSACTION TYPES OVER TIME

A. Transaction Types Over Time with Preemptive Adaptation On

B. Transaction Types Over Time with Preemptive Adaptation Off
CHANGE ROUTINES

B. Final Time Period

Even Reward Structure

Mean Patentability Threshold

Favor Patents Reward Structure

Favor Publications Reward Structure

Basic Scientific Importance (patentability threshold)

Mean Patentability Threshold

Number of Labs
INSIGHTS FROM THE MODEL

- Even when the environment favors publishing over patenting, the preemptive adaptation mechanism can lead to the shift in the patent threshold distribution.

- Small, incremental adjustments at the level of labs and at individual instantiations of scientific findings can lead to a dramatic change. You really just need neighbors that are slightly different from you.

- This finding compliments accounts of the expansion of patenting activity and provides one instantiation of how the features that give rise to commercializing science are different than those that support them once settled.

- By adapting the autocatalysis framework to the setting of proprietary science, we extend an existing model of the emergence of economic “life” to the emergence of disclosure regimes that govern the production of knowledge.

- We demonstrate accommodations to the model to address the production of science.
By examining life scientists at the origins of patenting, we demonstrate how commercializing academic science was a contingent and relational decision and not only a matter of whether scientists willing to accept the practice of patenting in their labs.

Inventions that culminated into patents were the result of multiple factors: the process by which scientists conducted their work, their perceptions about appropriate ways to relate to colleagues in both universities and firms, and particular research findings under consideration.

Debates emerged at point of contradiction between science and commerce, prompting seemingly similar problems of control over resources and organizational survival despite different rationales.
Even without centralized control—such as external laws or policies—we demonstrate ways proprietary science can emerge, without top-down coordination or control.

Moreover, we demonstrate the difficulty in achieving this through basic processes of selection and reproduction.

Stated differently, in order to get self-reinforcement and reproduction of new routines, labs have to interact and be willing to change their rules and conceptions about invention.