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Essays on Learning and Strategy in Research and Development

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ABSTRACT

This dissertation investigates how research organizations learn from and adapt to new knowledge. In particular, I examine how news about scandals, stigmas and failures influences the direction of research and development efforts. I investigate how these negative information events impact decisions in the settings of scientific publishing and drug development. In the first essay, I study the impact of scientific retractions on citation patterns and funding in the retracted paper's intellectual field. The second essay evaluates how retraction scandals damage individual scientists' reputations. In the third essay, I analyze how late-stage drug development failures alter competitor's project continuation decisions.

Categories: Technology & Innovation; Firm & Industry Dynamics; Strategy
Keywords: Research and Development; Spillovers; Organizational Learning; Research Direction

Overview

This dissertation investigates how research organizations learn from and adapt to new knowledge. In particular, I examine how negative information shocks influence the direction of research and development efforts. Just as exciting new discoveries can redirect the evolution of a scientific or technological field, revelations about failures, mistakes or scandals may influence the direction of subsequent knowledge production and product development. In fields where new ideas and technologies build cumulatively (Mokyr, 2002; Aghion et al., 2008), these negative information shocks force research organizations to pause, interpret external signals, reassess their own approach, and apply any lessons to their project portfolios.

Performance in innovation-based industries relies on managers' ability to navigate and exploit environmental signals (Cockburn et al., 2000). Therefore, variation in how individuals, firms and funders react to these negative information shocks is a potential source of competitive advantage. Re-prioritizing among different uncertain projects and assigning credit to competing ideas requires heeding external warnings, updating beliefs, and redistributing resources. Do some types of organizations make better decisions in the wake of relevant failures and scandals? Is a willingness to adjust R&D paths in response to new revelations an important element of a firm's overall R&D strategy? Furthermore, any tendencies to under- or overreact to information shocks may unsettle the system of incentives that encourage R&D productivity and discourage herd behavior. The delicate balance between exploration and exploitation (March, 1991) is essential for advancing scientific and technological knowledge frontiers forward, while maintaining intellectual diversity and standards of quality.

To address how research organizations learn from these events, this dissertation explores how negative information shocks impact decisions in the settings of drug development and scientific publishing. In particular, I study how competitor failure news alters portfolio investment decisions in drug development, and how scientific retractions damage intellectual fields and individual reputations. While these settings are distinct, they are linked by their reliance on experimentation, cumulative knowledge and high degrees of uncertainty. Both settings also share the features of slow progress (long lead times) and high labor intensity, but large societal impact. Each of the three essays focuses on a different level of analysis (e.g., drug development project, intellectual field, or scientific career), but Bayesian updating provides a common framework for decision-making in response to the negative information shocks. The information spillovers and ripple effects of these

revelations are empirically measurable thanks to the constant stream of R&D investment decisions and the "market" for academic credit (i.e., citations).

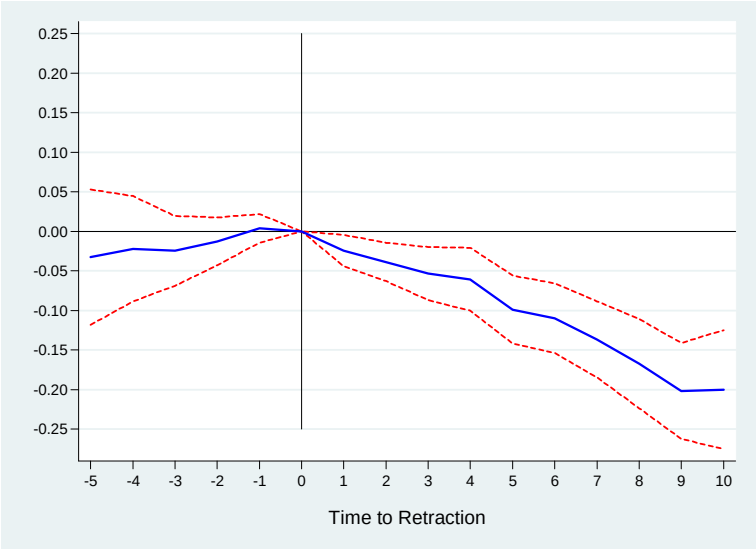
1 "Retractions"

In the first essay, I study how "false science" changes the evolution of intellectual fields. Since knowledge production requires "standing on the shoulders of giants,"[1] scientific retractions provide a unique window into the process of cumulative knowledge production. Retraction events reveal to a research community that the foundation of its intellectual "shoulders" is weaker than previously believed. How does the disclosure of a retraction change how scientific teams allocate credit and aim the direction of their research efforts? This essay, coauthored with Pierre Azoulay, Jeffrey Furman, and Fiona Murray, evaluates how these events alter the citation trajectories of articles intellectually related to the retracted papers, as well as production and funding in the affected scientific fields. We find that related articles experience a 5% to 10% reduction in the rate of citation, compared to the citation histories of control articles not related to retraction events (Figure 1, Panel A). This field-level penalty is more severe when retraction events involve fraud (rather than "honest mistakes"), and when the affected field is more competitive. Furthermore, we find that industry researchers are less responsive to retraction events than academic scientists, who might be more sensitive to matters of stigma and able to redirect efforts towards other (untainted) lines of research. Finally, we show that the production of new articles and funding opportunities within these affected fields also decline after retraction events (Figure 1, Panels B and C).

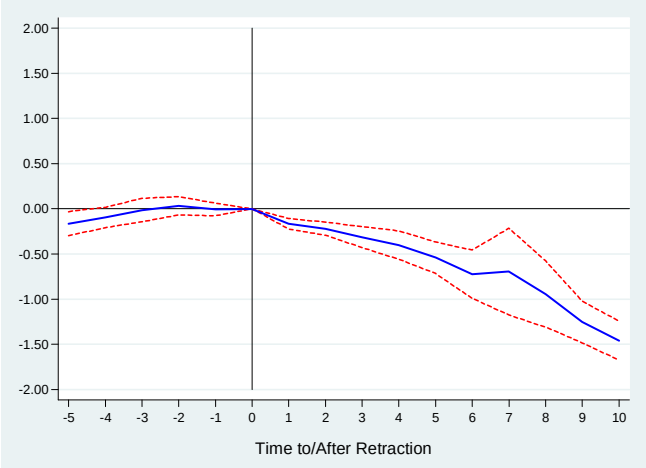
[1] This famous maxim, usually attributed to Sir Isaac Newton, is integral to the modern approach to scientific research. Google's academic search engine, Google Scholar, even has the phrase "stand on the shoulders of giants" as the sole decoration on its homepage.

Figure 1: Retractions' effect on related subfield (relative to controls)

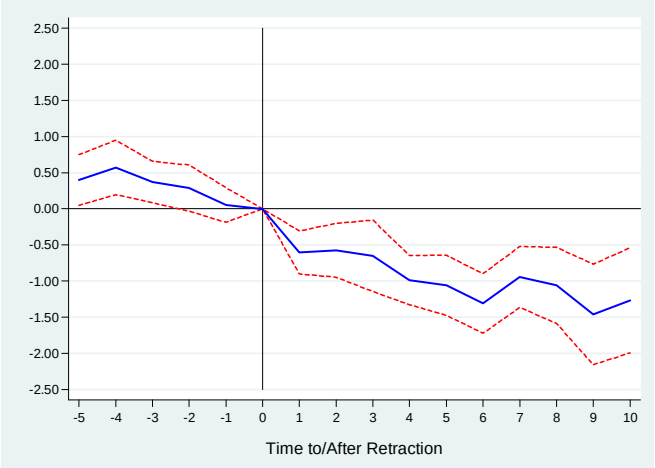
A. Retraction Effect on Forward Citation Rates



B. Article Frequency



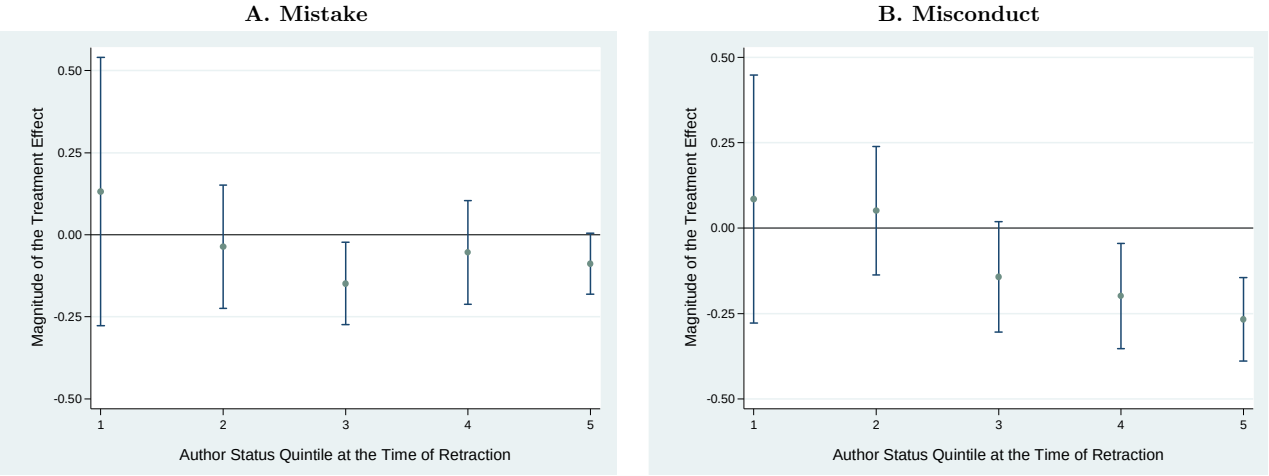
C. NIH Funding



2 "The Career Effects of Scandal: Evidence from Scientific Retractions"

The second essay (coauthored with Pierre Azoulay and Alessandro Bonatti), studies the impact of retraction scandals on individual scientists' reputations. In the "Republic of Science," individual reputations serve like a currency, and the scientific incentive system is built on the ability to reward quality and productivity, weed out errors, and punish misconduct (Dasgupta & David, 1994). In this study, we develop a theoretical model that includes two key components in a community's assessment of a scandal: (i) the individual's prominence at the time of the negative disclosure, and (ii) the nature of the revelation (misconduct vs. honest mistake). Empirically, we measure how retractions change the citation rate to authors' earlier, non-retracted articles, relative to the prior work of control authors. We show that faculty members involved in a retraction event experience an 10% decrease in citations to their prior work (relative to controls), on average. We find that more prominent faculty experience a harsher citation penalty when retraction cases involve fraud or misconduct, but experience no (statistically) differential penalty when retractions are due to "honest mistakes." Consistent with the model's predictions, the empirical results show that eminent scientist are not immune from the community's punishments in the wake of scandals, and that the research market does respond swiftly to disclosures of scandal—adjusting it's beliefs and allocation of credit based on both individual career history and interpretations of intent.

Figure 2: Citation punishment by type of retraction and author status



3 "Trials and Terminations: Learning from Competitors' Failures in Drug Development"

In the final essay, I investigate the spillover effects of a different type of negative information shock: drug development failures. I study how news of failure in late-stage clinical trials impacts continuation decisions for competitors' related development projects. While in the first two essays I examine information spillovers by intellectual distance and authorship connections, here I focus on drug markets (disease) and technology (drug target) as the key dimensions of relatedness. I develop a theoretical model for project continuation decisions, in which firms update their beliefs about a project's value based on their own experimental results, as well as their competitors' outcomes. I show how the potential to learn from same-technology competitors may increase a project's continuation value, by providing additional information and earlier decision points. Furthermore, I analyze how different levels of competition may moderate the impact of competitor failure news on continuation decisions.

I use a detailed data set on drug development pipelines to analyze how different types of competitor failure news alter competitors' exit decisions. Figure 3 shows the effect of each type of competitor failure news on exit rates (as estimated in a difference-in-difference survival model). I find that the rate of project exits more than doubles following a competitor failure in the same market and technology area. I also find that different market, same technology competitor failure news leads to a significant (17%) increase in exit rate. However, lumping all types of competitors together, would erroneously show no average change to exit decisions. Next, I use the overall success rates of remaining projects to evaluate overreaction to competitor failure news, and I find evidence that firms overreact to failure news from closely related competitor projects. Finally, I grade continuation decisions in the wake of competitor exits, and find persistent decision-quality differences across firms—implying that firms approach these decisions with different decision-making styles.

Figure 3: Change in exit rates following competitor failure news

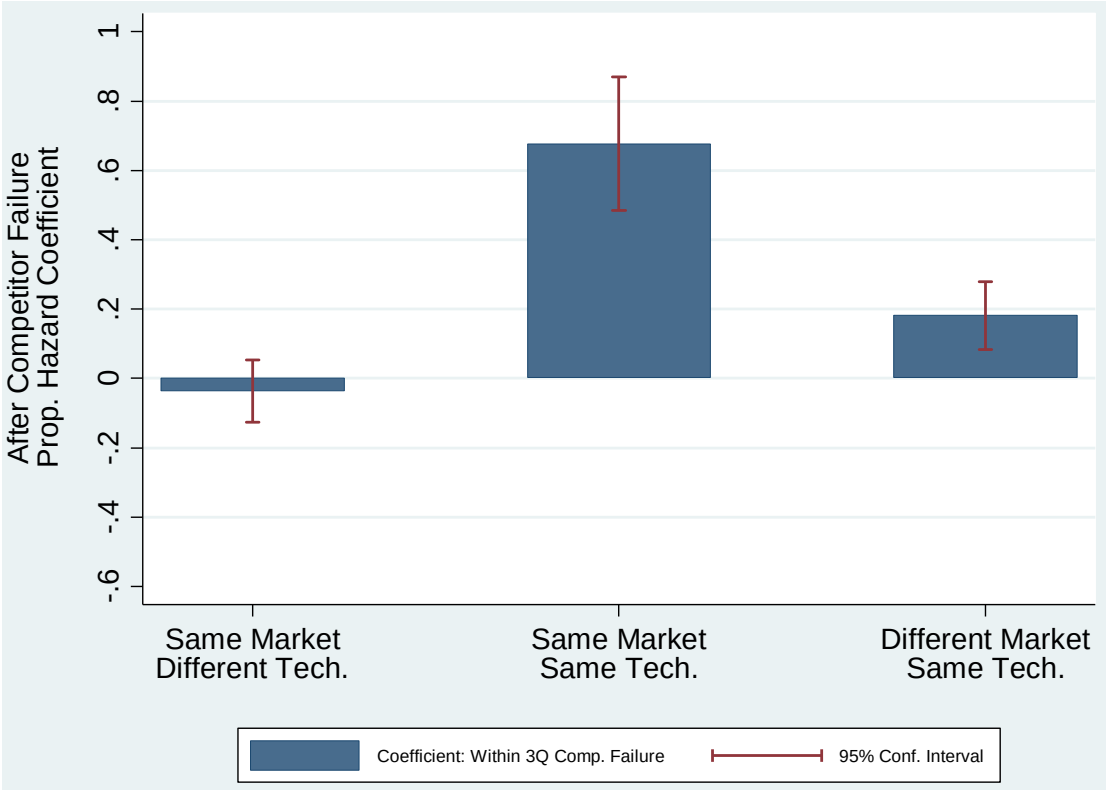
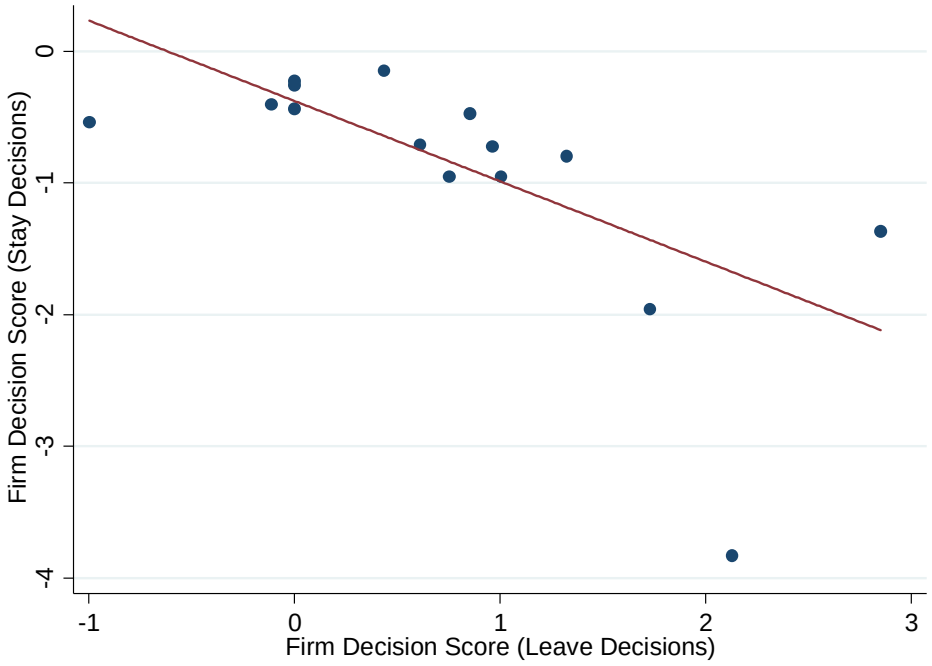


Figure 4: Scoring firms' stay vs. leave decisions (binned scatterplot)



4 Conclusions and Future Directions

The patterns I find in these studies suggest knowledge production is responsive to negative information—whether cautiously correcting course for more productive routes, or fleeing from stigmatized territory. The timing, content, and context of these disclosure events influence the magnitude of their ripple effects on subsequent research efforts. A priori, the extent and direction of these responses were not obvious. Unlike financial markets, where participants can quickly redeploy capital to new endeavors, R&D efforts often require burdensome investments in specialized knowledge, commitment to research agendas, and long lead times. That researchers do, in fact, react to negative external signals and adjust their decisions (in allocating credit or switching research projects) is good news for cumulative learning and maintaining the checks and balances of the "Republic of Science." These adjustments imply that R&D decision-makers are capable of avoiding the traps of sunk cost, tunnel-vision, and hubris—even though such biases may still come into play. But this responsiveness also means that researchers are vulnerable to overreaction by allowing the salience of recent stigma and scandal to steer their focus away from potentially fruitful lines of inquiry and development.

What can organizations do to avoid such herd behavior? While selecting and updating their R&D portfolios, how can organizations take advantage of information about their competitors and prepare for the inevitable shifts in scientific understanding? What types of information should managers have at their fingertips in order to achieve their desired balance of exploration and exploitation? And how should managers evaluate their own organization's performance in adapting to shifting knowledge and competitive landscapes?

This dissertation hopefully provides examples of the type of data and analysis needed to answer these questions. Ultimately, understanding the drivers of R&D productivity requires many studies of incentives, competition and information flows across different settings and types of organizations. A "one size fits all" approach would simply not fit the creative spirit and complicated coordination inherent to innovative sectors. In my future work, I plan to continue to use real-world data to uncover how firms can improve their R&D portfolio selection, and how industries and policy-makers can encourage truly novel, diverse and high-value research efforts.

References

Aghion, Philippe, Mathias Dewatripont, and Jeremy C. Stein. "Academic Freedom, Private-Sector Focus, and the Process of Innovation." *The RAND Journal of Economics* 39, no. 3 (September 1, 2008): 617–35. doi:10.1111/j.1756-2171.2008.00031.x.

Cockburn, Iain M., Rebecca M. Henderson, and Scott Stern. "Untangling the Origins of Competitive Advantage." *Strategic Management Journal* 21, no. 10–11 (October 1, 2000): 1123–45. doi:10.1002/1097-0266(200010/11)21:10/11<1123::AID-SMJ130>3.0.CO;2-R.

Dasgupta, Partha, and Paul A. David. "Toward a New Economics of Science." *Special Issue in Honor of Nathan Rosenberg* 23, no. 5 (September 1, 1994): 487–521. doi:10.1016/0048-7333(94)01002-1.

March, James G. "Exploration and Exploitation in Organizational Learning." *Organization Science* 2, no. 1 (February 1, 1991): 71–87. doi:10.1287/orsc.2.1.71.

Mokyr, Joel. *The Gifts of Athena: Historical Origins of the Knowledge Economy*. Princeton University Press, 2002.