CONTACT INFORMATION

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Carolyn Stein

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Education

Massachusetts Institute of Technology
Ph.D., Economics — 2015 - 2021
Dissertation: *"Essays on the Economics of Science and Innovation"*
Advisors: *Heidi Williams, Amy Finkelstein, Pierre Azoulay*

Harvard University
A.B. *summa cum laude*, Applied Mathematics — 2009 - 2013

Employment

University of California, Berkeley
Assistant Professor, Haas School of Business (EAP) — 2022 -
Assistant Professor, Department of Economics — 2022 -

Stanford University
Postdoctoral Fellow, Stanford Institute for Economic Policy Research — 2021 - 2022

Bain Capital Credit
Investment Analyst — 2013 - 2015

Publications

"Internalizing Externalities: Designing Effective Data Policies" (with Ryan Hill and Heidi Williams) *AEA Papers & Proceedings* 110, May 2020: 49-54.

Working Papers

"Race to the Bottom: Competition and Quality in Science" (with Ryan Hill)

"Scooped! Estimating Rewards for Priority in Science" (with Ryan Hill)

"Adaptability and the Pivot Penalty in Science" (with Ryan Hill, Yian Yin, Dashun Wang, and Benjamin F. Jones)

Resting Papers

"Heat Check: New Evidence of the Hot Hand in Basketball" (with Andrew Bocskoscky and John Ezekowitz), August 2014.

Fellowships and Awards

Robert M. Solow Prize for Excellence in Research and Teaching	2021
Review of Economic Studies European Tour	2021
China Star Tour	2021
NBER Predoctoral Fellowship in Aging and Health	2020 - 2021
Excellence in Refereeing Award, *AER: Insights*	2019; 2020
George and Obie Shultz Fund Grant	2018; 2020
National Science Foundation Graduate Research Fellowship	2017 - 2020
MIT Presidential Graduate Fellowship	2015 - 2017
Harvard University Certificate of Distinction in Teaching	2012
Phi Beta Kappa (Senior 48)	2012
John Harvard Scholar	2010
Detur Book Prize	2010
Harvard Top Chef (with Anna Mapes Carter)	2010

Invited Presentations

IIES Stockholm, Brookings, Duke Fuqua (Strategy), UC Merced, ASSA Meetings, Wisconsin Economics, Stanford Economics, Brown, NBER Summer Institute, University of Munich (LMU) — 2021 - 2022 *(including scheduled)*

	BFI China, Peterson Institute for International Economics, Yale Economics, London School of Economics, U.C. Berkeley Haas (BPP; EAP), U.C. Berkeley Economics, Harvard Economics, Yale SOM (Economics), Duke Economics, UBC Sauder (Strategy & Business Economics), Princeton, Northwestern Economics, Chicago Booth (Microeconomics), Harvard Business School (EM; TOM), USC Economics, University of Utah Eccles (Strategy), NBER Productivity Seminar, Rutgers Institute for Quantitative Biomedicine, SUNY Albany	2020 - 2021

Professional Activites

Referee: *AEJ: Applied, AER: Insights, American Economic Review, Journal of Political Economy, Quarterly Journal of Economics, Review of Economics and Statistics*

Other Activities

MIT Cycling Team *(treasurer; recruitment chair)*	2018 - 2021
Big Brothers Big Sisters of Massachusetts Bay	2017 - 2021
Cabot House, Harvard University *(non-resident tutor)*	2014 - 2018
Harvard Blackjack Team	2011 - 2013

Citizenship

United States

Last Updated: January 2022

Completed coursework:

- Graduate microeconomic theory (full year)
- Graduate macroeconomics (full year)
- Graduate econometrics (full year)
- Labor economics I (semester)
- Labor economics II (semester)
- Applied econometrics (semester)
- Industrial organization I (semester)
- Behavioral economics (semester)
- Nonlinear econometrics (semester)
- Market design (semester)
- Advanced topics in industrial organization (semester)

RESEARCH AND INTEREST STATEMENT
Carolyn Stein

My research studies how incentives in the basic sciences shape the production of new knowledge. The market for basic scientific knowledge is unusual, because contributions are often not directly marketable. Therefore, scientists are remunerated in other ways: credit and recognition are the primary currency of scientific careers. This recognition in turn translates to promotions, pay raises, and potentially prizes. My goal is to use the tools of labor economics to study this important but unusual labor market. Methodologically, I seek to combine applied theory with empirical work and causal inference. The two are complements: empirics teach us something about the world, but theory often guides us on where to look. I plan to use these tools to better understand how researchers in the basic sciences respond to incentives, so that we can design better science policy which will promote more discovery and innovation.

My job market paper (joint with Ryan Hill) studies how the competition to publish first and claim "priority" in science impacts the quality of scientific work. In this paper, we develop a simple model where researchers decide which projects to work on, and how long to spend on them. While making these decisions, researchers take into account the payoffs of each project, as well as the risk of getting pre-empted or "scooped." The model delivers the key prediction that the most important projects will be the most competitive, and in turn will be the most rushed and lowest quality. We are able to test these predictions in the scientific field of structural biology, using data from the Protein Data Bank (PDB), a project-level data repository. Importantly, the PDB records detailed and objective measures each project's quality of execution, which allows us to test the key prediction of our model. We find that across a variety of quality measures, the most important projects are consistently the lowest quality. This relationship is mitigated when we focus on structures deposited by scientists affiliated with structural genomics groups. Researchers in these groups are less focused on publication and priority, which suggests that our quality results are directly linked to priority racing and cannot be explained by other factors such as project complexity. We show that this racing behavior – which is amplified among the most important projects – is inconsistent with a social planner's idealized first-best. However, if the social planner can only manipulate the division of credit between the winning and losing team (rather than dictating which projects researchers work on and for how long), this may represent a constrained second-best.

The unequal division of credit between first- and second-place researchers is reminiscent of the tournament-style contracts first studied by Lazear and Rosen (1981). However, in our case, researchers are competing to finish first, rather than to produce more. Therefore, the result of more lopsided rewards in our setting is faster publication at the expense of lower quality, rather than higher levels of output at the expense of worker effort. The resulting lower quality could also be thought of as a multitasking problem (Holmstrom and Milgrom, 1991): by heavily incentivizing being first, we distort incentives away from project quality.

In related work with Ryan Hill, we seek to quantify how credit is shared between winning and losing teams in priority races. Priority racing is driven by the fear that the winner will take most or all of the credit, while the loser will not be recognized for his or her contribution. Most of the theoretical literature on patent and R&D racing assumes that these competitions are winner-take-

all. Our goal is to measure the credit division empirically. We again study the field of structural biology. Using the detailed data from the PDB, we are able to re-construct project timelines and link near-identical projects to find instances where teams were competing to complete the same project first. An important feature of the PDB is that researchers upload their projects prior to publication; therefore, even if researchers abandon their work upon learning that they were "scooped," we will still have a record of it. Using these reconstructed races and linking them to publication data, we find that the winning teams get 55 percent of the credit, as measured by citations. This is a far cry from winner-take-all. We also document that this is far more equitable than scientists believe: we survey nearly 1000 structural biologists and find that they estimate the winning researcher would receive 70 percent of the total citations. We find that most of the premium is attributable to journal placement, as the winning papers tend to publish in higher-impact journals. We also find that prior reputation matters as well: the priority premium is much larger if the winning team is higher-reputation than the losing team.

Looking forward, my research agenda will continue to focus on incentives in the basic sciences. In ongoing work with Joey Anderson, we are studying how salary contracts impact the types of projects scientists undertake. In particular, we are interested in the notion of "soft money" – salary that is not guaranteed or paid by the university, but rather which must be paid out of extramural grants. Soft money is therefore contingent on successful grant applications, and places substantial salary risk on individual researchers. This type of contract has become prevalent in the life sciences. Using grant- and transaction-level data from UMETRICS, a data-sharing consortium of over 30 U.S research universities, we find that professors in the life sciences draw nearly 40 percent of their salaries from soft money on average. Many scientists have voiced concerns that this induces researchers to pursue less risky and more incremental work, because the cost of failure on a soft-money contract includes substantial salary cuts. In general, science is an inherently risky endeavor. We are interested in how researchers and universities share this risk (Holmstrom, 1979), especially when we may *want* researchers to work on innovative but risky projects (Manso, 2011).

I am excited to push this agenda forward in the coming years, because I believe it has important implications. There is growing evidence and associated concern that the pace of innovation has been slowing, while the costs have been rising. Basic science is a (if not *the*) key input into applied innovation, which in turn drives economic growth. A better understanding of what incentives govern the production of new scientific knowledge is critical to designing effective policies and institutions that will help push the scientific frontier forward in the years to come.

I am excited to be considered for this bootcamp because I believe that there is growing interest and excitement around the economics of science. The COVID-19 pandemic has illustrated the importance of science policy and has reiterated that science and scientists respond to incentives. I think it would be a fantastic opportunity to meet other junior scholars who are working in this exciting area, and I am eager to see the field grow.

Cover letter

I am writing letters for several PhD students and recent PhDs for the Innovation Research Boot Camp. So far, 2022 has been a bit of a disaster as our kids' school delayed their opening and has then been remote due to COVID. Given my reduced work hours, I hope that you will forgive me for sending letters when available that I have written for other purposes, or short letters when I have not previously written a letter for the student previously. This in no way reflects on the students, but rather just reflects the disaster of my 2022 schedule. Thank you for your understanding.

Heidi Williams (hlwill@stanford.edu)

Stanford University

HEIDI WILLIAMS
Charles R. Schwab Professor of Economics

Dear Sir or Madam,

I am writing on behalf of **Carolyn Stein**, a PhD student in economics at MIT who is on the academic job market this year. Carolyn is a brilliant, creative, mature, and hard-working student who I expect to have a very successful career. She is a unique combination of a skilled applied theorist and a careful empiricist – a combination that is all too rare in our profession. I give Carolyn my strongest recommendation, and believe her application should receive careful consideration from all schools, including those at the very top.

Last year, MIT featured Carolyn in this write-up: https://shass.mit.edu/news/news-2019-voices-mit-students-meet-carolyn-stein-economics, which I mention because I think it gives a nice summary of her background and interests. Carolyn was a Harvard undergraduate where she majored in applied math and economics, and graduated *summa cum laude*. After graduation, she spent a year or two working in finance after graduation (at Bain Capital Credit) – during which time it seems to have become abundantly clear to her that academia rather than finance was the right path for her. I remember when Carolyn visited MIT as an admitted/prospective PhD student – I was incredibly impressed by her insight and maturity even during our brief ~20 minute meeting, and since then she has only exceeded even the very high expectations I set based on that initial interaction. At the time she applied to MIT, Carolyn thought that she wanted to study labor economics, exploring why some people reach their potential in the labor force while others do not. But after taking a course of mine which covered some innovation policy topics, Carolyn chose to work with me as a teaching assistant for my undergraduate innovation policy course at MIT, and subsequently decided to shift her area of research to the economics of science and innovation.

Carolyn has a creative, original, and ambitious research agenda in the economics of science which I expect great things from in the coming years.[1] Carolyn's best completed work to date is a pair of papers joint with Ryan Hill (a classmate of hers from MIT who is now a post-doc with Ben Jones at Northwestern Kellogg) focused on priority races in the sciences. The first project is empirical, while the second is a blend of applied theory and empirical work. Both projects build on an extremely deep dive that Carolyn and Ryan made into understanding one particular scientific field – structural biology. In my view, Carolyn and Ryan have done an exceptionally good job of taking seriously their

[1] Carolyn is applying for a variety of positions, but let me include a footnote for economics departments considering her application. Economists are of course typically trained in specific sub-fields – e.g. macroeconomics, labor economics, public finance, industrial organization, economic history, econometrics, etc. Historically, the economics of science/innovation has not found a natural home in any of these "standard" sub-fields of economics. My blunt advice to you is: don't let this type of "fit" issue distract you from how remarkable Carolyn is. Rather than nit-picking about whether she is or is not a labor economist, or whether she would or would not do a good job of teaching public finance, please try to focus on her clear promise as a scholar and teacher who will be a fantastic colleague.

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task of really understanding the scientific discipline their work focuses on. While of course the natural criticism of their work is that it is specific to one discipline, in my view their work is exactly the right step forward in this area – what this area needed was thoughtful conceptual frameworks, new facts, and new empirical approaches. Carolyn and Ryan's work provides all three, and I see this pair of papers as likely to be very influential in shaping subsequent work in this field.

Let me motivate how they came to focus on the field of structural biology. Carolyn and Ryan originally dug in to a general analysis of priority races across scientific fields, but in the course of doing that a fortunate conversation with a biologist led them to switch to focus on the field of structural biology. Two things are fantastic about structural biology for the purpose of this project. First, a publicly available database catalogs essentially all research projects in the field (key: <u>including</u> projects that never result in a publication), and does so in a way that naturally allows them to identify priority races – that is, different scientific teams aiming to solve the same problem. Second, detailed data that is available for this scientific field allows them to reconstruct historical timelines to be able to observe cases where more than one team was – unbeknownst to each other – working on the same problem at the same time. I had never even *heard* of the field of structural biology when Ryan and Carolyn came to me with this idea, but it immediately became quite clear that this was exactly the right case study for them to focus on.

Carolyn and Ryan's first paper constructed a very compelling empirical design which allows them to estimate the causal effect of being "scooped" (losing a priority race). The motivation for this paper is that while many theoretical models of innovation races conceptualize the reward structure in science as winner-take-all, in practice there is extremely little empirical evidence on how scientific credit is allocated between the "winners" and "losers" of priority races. Of course, getting scooped is not randomly assigned. However, by leveraging the details of the institutional context of the field of structural biology, Ryan and Carolyn are able to construct a sample of priority races in which "who wins" looks highly unpredictable even if not purposefully random.

In this sample, they convincingly establish that getting scooped has a moderate-sized impact on the success of the scooped project: scooped projects are 2.5 percent less likely to be published, appear in a 0.18 standard deviation lower-ranked journal, and receive 20 percent fewer citations. While these effects are statistically significant and economically meaningful, they also clearly reject a winner-take-all model: focusing on citations, their estimates imply that the "losing" paper receives 45 percent of the total citations accrued to both papers (as opposed to the 0 percent implied by winner-take-all models). I find these estimates very compelling, and also find them substantively interesting. I was gratified when Carolyn and Ryan's result were written up last year in a (very flattering) feature article in *Nature* news – "Scooped in science? Relax, credit will come your way" – one of many pieces of feedback they received that scientists themselves were also quite interested in their results.

Going beyond this basic result, Carolyn and Ryan then developed a simple statistical discrimination model which provides a framework for interpreting heterogeneity in their estimated effects: for example, the cost of being scooped is much smaller when a high-profile team is scooped by a low-profile team, relative to the reverse situation. They also executed a survey of scientists to ask what scientists *think* the costs of being scooped are, to be able to compare and contrast those beliefs with their actual empirical estimates. Surveyed scientists thought that "losing" papers would receive 29 percent of the total citations, as opposed to the 45 percent that Ryan and Carolyn estimate.

In my view, the paper is just fantastic – I see it as something that will be very high-impact, and which will inspire subsequent work on this topic, but also on other related topics. Carolyn and Ryan submitted this paper to the NBER's Summer Institute Innovation/Productivity meeting, one of the main conferences in this field that is currently co-organized by Adam Jaffe, Ben Jones, and myself. Because Ryan is a post-doc of Ben's and both Carolyn and Ryan are/were PhD students of mine, both Ben and I recused ourselves from reviewing their paper. You can infer from their paper making it on to our schedule that that Adam Jaffe liked their paper!

Carolyn's job market paper is a second joint project with Ryan which is focused on how priority races impact the quality of scientific research. I think of this paper as being very representative of the types of papers Carolyn will write in the future. My sense is that she is really drawn to want to write papers that combine applied theory models with careful and thoughtfully designed empirical tests, which I think this paper is a great illustration of.

On the theory side, most theoretical models of innovation characterize inventions as binary – teams either succeed or fail. While there are a few exceptions (most notably Bobtcheff et al. 2017, which is a very nice theoretical paper published in *ReStud*), in general very little attention has been paid to the idea that inventions may vary in quality as a function of how much time or effort researchers invest. Ryan and Carolyn develop a model in which there is a deterministic relationship between the time a scientist spends on a project and the project's ultimate scientific quality, and in which scientists choose how long to spend on a given project with this deterministic relationship in mind. Scientists also face a risk of being "scooped," and therefore face a trade-off between "polishing" a project (to make it higher quality) and being more likely to be scooped the longer they polish. Unlike Bobtcheff et al. 2017, Ryan and Carolyn embed this idea in a framework where project entry is endogenous – projects differ in their expected returns, and a key prediction of the model is that in equilibrium the most important projects will be completed at the lowest quality levels (due to fears over being scooped).

Ryan and Carolyn then draw on the deep institutional knowledge they have developed around the field of structural biology in order to develop ways of testing these predictions. Measuring project quality in an objective way would be impossible in most fields of science, but in structural biology several natural metrics are available. At a high level, structural biologists try to fit three-dimensional

structure models to experimental data, implying that goodness-of-fit measures provide natural objective quality metrics. For example, refinement resolution – a measure of distance between crystal lattice planes – is not subjective, and cannot be manipulated by researchers. Similarly, in most contexts it would be hard to develop an ex ante measure of which projects were more or less "important." But in the case of structural biology, Ryan and Carolyn are able to leverage extensive protein structure-level covariates (all fixed ex ante) to predict citations, thus constructing an ex ante measure of the importance of different projects.

Using these novel empirical metrics, Ryan and Carolyn document a variety of new facts. More (ex ante) important projects are indeed more competitive – suggesting the endogenous entry margin in the theoretical framework is empirically relevant. More important projects are completed more quickly (around 2 months faster) and with lower quality (about 0.7 standard deviations lower quality). They investigate a variety of potential confounds, and their bottom line is that the predictions of their model are supported in all of the various robustness tests they have been able to develop. One particularly clean robustness exercise contrasts protein projects completed by "normal" researchers with protein projects completed by structural genomics groups – federally-funded research groups who for various reasons are much less motivated by priority races (for example, they publish much less frequently). Consistent with what the model would suggest, the negative relationships between competition and quality (and, separately, importance and quality) are less strong in the sample of structural genomics group researchers. That is, the data appear consistent with a causal negative relationship between project importance and quality.

Ryan and Carolyn close their paper by undertaking a variety of analyses – both theoretical and empirical – that explore the welfare implications of these results. For example, they explore how policies manipulating credit share affect welfare. From a practical perspective, that analysis is motivated by recent policy changes at journals such as *PLOS Biology* which have formally welcomed "scooped" studies to submit their papers for publication.

For each of these two projects, Carolyn and Ryan did a fantastic job of identifying novel and economically interesting questions, worked quickly but carefully to pull together the relevant institutional knowledge needed to construct data measuring the relevant economic phenomena, and thought extremely clearly about how to design appropriate empirical tests. The second paper also develops a parsimonious and insightful theoretical framework that I think is quite useful. Taken together, these two papers define a clear research agenda that I expect to be very productive in the coming years.

Carolyn has several very promising ongoing research projects, and is generally a fountain of creative ideas. As one example, Carolyn is collaborating with one of my PhD students at Stanford (Joey Anderson) on a project exploring the implications of so-called "soft money" in academia. Soft money refers to requirements that researchers fundraise their own salary, and is common for example among

medical school faculty at many universities. Measurement of the prevalence of soft money has been essentially impossible given that compensation contracts are confidential, but anecdotes suggest that soft money has become more prevalent over time. For example, in 2017 Tufts Medical School changed their salary policy to require that faculty pay 40% of their salary from grants. A *Boston Globe* article summarized interviews with affected faculty claiming this change induced large changes in their research. Carolyn and Joey had the idea to leverage the UMETRICS data – a new compilation of internal administrative records from 32 member universities covering 2001-2020 – to try to develop systematic measures of soft money at the individual level. So far, their empirical work has focused on documenting descriptive facts about soft money that have been able to validate or reject various "folk wisdom" in this area: for example, Bourne and Vermillion (2016) used internal data from one university (UCSF) to document that more junior faculty were more likely to be paid on soft money contracts – a fact that appears to be true in the broader set of universities measurable in the UMETRICS data – but the long panel available in UMETRICS is able to shed light on this trend being driven by age (year of tenure) versus cohort effects. Carolyn and Joey are working on applying this soft money measure to explore both the determinants of soft money contracts, and the effects of soft money contracts on research outcomes. This will be, to the best of my knowledge, the first empirical paper exploring the implications of soft money in academia – a hugely controversial phenomenon – and I view this project as both innovative and important. I would expect a basic descriptive paper summarizing their soft money measure to be published in a general-interest journal like *Science*, and have hopes that a paper exploring either the causes of or consequences of soft money will have a good shot at a top-tier general interest journal in the field of economics.

Since I moved from MIT to Stanford, I've often invited Carolyn to join group advising meetings with my Stanford students, and she almost immediately developed a strong reputation for giving constructive and supportive feedback to peers and younger scholars. When she participated in the NBER Summer Institute Innovation/Productivity meeting where Ryan presented their joint work last spring, I was thrilled to see her chime in multiple times with thoughtful and on-point questions (to the large group – several hundred participants!) that highlighted substantive challenges facing some of the other papers, but again always in a constructive way. All of that is to say, in addition to her having several excellent completed papers and a clear pipeline of research, I feel even more confident in my assessment of her potential for future contributions (in a broad sense) to the profession based on my observations of her interactions with a broad cross-section of students and colleagues. She is really exceptional.

Let me also say that Carolyn has a proven track record of being a dedicated and well-liked teacher in a variety of courses (labor economics, competitive strategy, and an undergraduate microeconomic theory course). She received really top teaching ratings in all of the courses she TA'd (including one of my undergraduate courses at MIT, where I was able to directly observe what a phenomenal teacher she is). Let me also take this opportunity to point out that Carolyn had full funding for her PhD work at MIT – as an MIT Presidential Scholar, followed by an NSF Graduate Research Fellowship, followed

by an NBER Pre-Doctoral Fellowship in Aging and Health – so she had no requirement nor financial reason to teach; she selected into wanting to teach these courses because she has a genuine love for teaching and working with students, and her teaching evaluations were excellent.

On a personal level, Carolyn is a really wonderful person. She is a supportive and thoughtful mentor of younger scholars, and a fantastic role model and mentor for women in particular. I hope you will give her your most serious consideration. Please do not hesitate to contact me if I can be of further assistance.

Sincerely,



Heidi L. Williams