

The Rise of Research Teams: Benefits and Costs in Economics

Benjamin F. Jones

Economics research is increasingly a team activity: economists increasingly coauthor their papers, and these coauthored papers have a large and increasing impact advantage. This “rise of teams” raises issues for individual researchers and for the field. On the one hand, coauthorship brings benefits, allowing individuals to combine perspectives, knowledge, skills, and effort in fruitful ways. But it also imposes costs; for example, coauthorship divides and obscures credit among the participants, which can undermine individual career progression. This paper synthesizes recent literature to weigh the benefits and costs of research teams. The findings provide guidance to individual researchers themselves, and the institutions that support them, in fostering high-impact research and productive research careers.

The paper begins by documenting the rapid rise of team authorship in economics. For example, while papers with two or more authors constituted only 19 percent of economics journal articles in 1960, this share rose to 44 percent in 2000 and 74 percent in 2018. Moreover, team-authored papers in economics have increasing impact advantages over solo-authored papers. By 2010, a team was three times more likely to produce a highly cited paper than a solo author, an advantage that has grown steadily with time. These shifts appear not only within every subfield of economics, but also in virtually all fields of science, social science, and patenting.

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This shift to teamwork brings both advantages and problems. The multi-disciplinary literature on creativity emphasizes that creativity is a process of combination—a novel mixture of existing material and methods (for example, Schumpeter 1939). Viewed as “combinations of ideas,” high-impact research turns out to combine prior knowledge in distinctive ways. Moreover, teams are more likely to produce these distinctive creative combinations. For example, teams appear to navigate extant knowledge to produce more novel combinations of ideas (Uzzi et al. 2013).

Meanwhile, one individual can only know so much. As scientific knowledge accumulates with time, individuals appear restricted into ever-narrower subspecialties of expertise. This increasing specialization can help explain the rising relative advantage of teams or, put another way, the declining impact of solo researchers (Wuchty, Jones, and Uzzi 2007; Jones 2009). Beyond aggregating differentiated knowledge, however, teams may also reflect vertical differences in the productivity of the coauthors. These differences may in turn have performance implications. For example, one might imagine that the quality of team output follows from the strongest member of the team, who might be the creative engine or otherwise drive the enterprise. On the other hand, team output may follow from the weaker members of the team, perhaps due to bottlenecks at certain tasks. Perhaps surprisingly, team impact in economics, as in all other fields, is weighted toward the lower-impact rather than higher-impact team members (Ahmadpoor and Jones 2019). Consistent with this finding, scholars engage in positive assortative matching when forming teams, in all fields.

Overall, striking empirical regularities emerge when considering the rise of teams. Echoing how Zipf’s Law describes the size distribution of cities (Gabaix 1999), or the Kaldor (1961) facts discipline macroeconomics, a substantial surprise of the innovation literature is that the production of ideas—which might seem to be a messy and opaque creative exercise that defies ready description—is given to strong empirical regularities.

These same regularities, however, also point to particular costs. For one, teamwork obscures credit. Teamwork can thus put stress on the reward system of science, where tenure and promotion, prizes, and status more generally all depend on the community’s assessment of individual scholars. Teamwork seems to undermine this system, at least in the community’s capacity to rely on objective indicators. For example, consider the career implications now that almost all work, and an even greater share of the high impact work, is coauthored. When work is coauthored, each paper provides less of a signal about the individual authors. Yet tenure clocks have not lengthened. Should lifetime tenure contracts be awarded based on a short series of increasingly intertwined signals? Moreover, economics (like many fields) continues to award prizes to individuals rather than teams. But do early-career prizes like the John Bates Clark medal, which is awarded by the American Economic Association to a prominent American economist under the age of 40 (described at <https://www.aeaweb.org/about-aea/honors-awards/bates-clark>), which have traditionally celebrated individuals, make sense when more and more work—and the highest-impact work—is done in teams? If economics is increasingly relying on

subjective assessments of credit within a group effort, given the rise of teams, do tenure committees, funding panels, and prize committees increasingly impose a series of biases related to gender, personal relationships, institutional eminence, or other features that lead to discrimination? These concerns are not hypothetical: recent work in economics suggests that women, unlike men, are less likely to receive tenure when their work is coauthored (Sarsons et al. 2021). While economics is shifting sharply toward teamwork, it's far from clear that the institutions that support research are keeping up with the rise of teams.

The Rise of Teams

A large literature has studied “team science” through the perspective of coauthorship (for example, Adams et al. 2005; Wuchty, Jones, and Uzzi 2007). Although teamwork and collaboration in research can extend beyond formal coauthorship, benefits of a coauthorship orientation include its ease of measurability with large databases and its direct relevance to career progression. Authorship records form central measures of scientific careers, as in academic curricula vitae, and are a primary basis for community evaluations of scholars, including in tenure decisions, as will be discussed further below. This section charts the rise of teams in economics through the lens of coauthorship.¹

The Rising Frequency of Teams

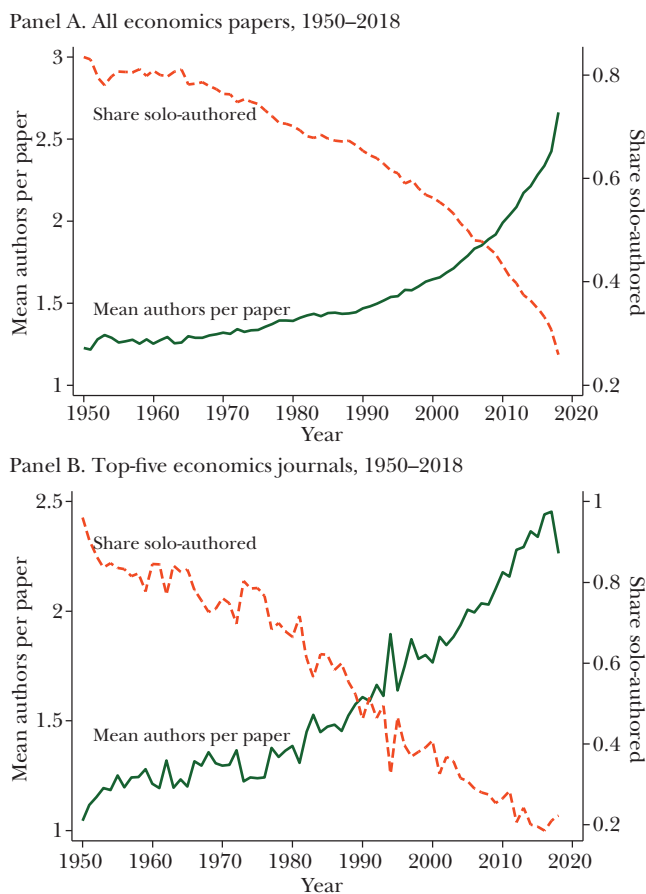
Publications in economics were once largely a solo author's game. Examining economics papers published before 1900, about 90 percent were solo-authored. This pattern holds true in my own calculations using the 1.7 million economics papers indexed from 1816–2018 in the Microsoft Academic Graph (data described in Sinha et al. 2015), and similar patterns appear using the Web of Science™ data published by Clarivate (Wuchty, Jones, and Uzzi 2007). The fraction of solo-authored work declined in the first half of the 20th century, but only modestly, when about 80 percent of economics papers were solo-authored. The dominance of solo-authorship was even starker looking among today's top five journals—following common practice, these are defined here as the *American Economic Review*, *Econometrica*, *Journal of Political Economy*, *Review of Economic Studies*, and *Quarterly Journal of Economics*—where 98 percent of articles were solo-authored before 1950.²

But then the pattern began to change. Figure 1, panel A presents some trends. Solo authorship represented 80 percent of economics papers in 1960 and 65 percent

¹Research on “team science” further embraces co-invention in technology, including patenting and software development (for example, Wu et al. 2019). Alternative constructs of teamwork and collaboration in the sciences can extend from non-coauthor research assistants to those who provide comments and advice, where the “invisible college” of science suggests potentially open collaborative boundaries (Oetli 2012).

²Perceptions of the top journals evolve over time. This set of journals is meant as one benchmark using prominent journals.

Figure 1

The Rise of Team Size in Economics

Note: Data are from Microsoft Academic Graph, which indexes 1.7 million papers in economics from 1816–2019. For details, see the online Appendix available with this article at the *JEP* website.

in 1990, but then solo-authorship fell out of the majority in 2005 and represents only 26 percent of economics papers today (as measured by the right-hand axis). To put it another way, in 1950, there were 1.2 authors per economics paper. Average team size reached 2.0 for the first time in 2010. By 2018, team size averaged 2.7 (as shown on the left-hand axis). The jump in average team size in economics papers over the last ten years is greater than the jump over the prior half-century.

Figure 1, panel B shows the trends for the top five economics journals. Here we see similar patterns, albeit with a more linear dynamic. In 1950, solo authorship was more common among these journals (96 percent) than among economics

publications overall (83 percent). Now, solo authorship is less common in these top-five journals (22 percent) than in economics overall (26 percent). This reversal leads us toward the second set of facts: the relationship between team-authorship and high-impact work.

The Rising Impact of Teams

As a measure of success, define “home-run” papers in a given year as those in the top N percentile of citations received among all publications that year: thus, home-run papers may be defined as those in the top 10 percent, 5 percent, and 1 percent of citations received. The home-run measure is normalized by year of original publication, so it is not affected by time trends in total number of citations. We can then define the relative team impact (RTI) as

$$RTI = \frac{\text{team home run rate}}{\text{solo home run rate}}$$

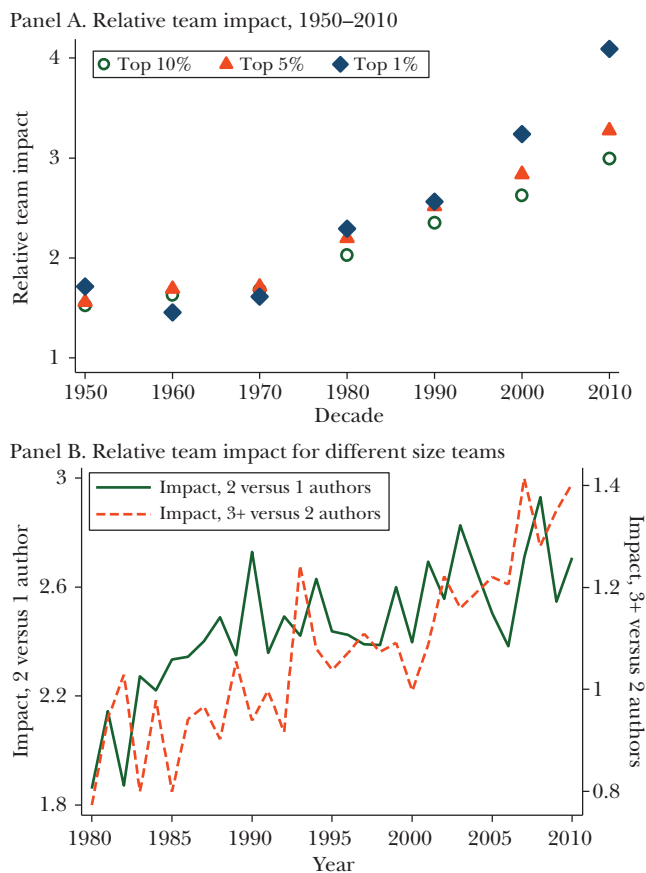
where the numerator is the fraction of team papers that turn out to be home runs, and the denominator is the fraction of solo-authored papers that turn out to be home runs (Wuchty, Jones, and Uzzi 2007).

Figure 2, panel A presents the relative team impact over time. Teams have a growing impact advantage. In addition, this growing advantage is stronger when one looks at higher thresholds of impact. From the 1950s through the 1970s, a team-authored paper was 1.5 to 1.7 times more likely to become a home-run than a solo-authored paper, with the modest variation depending on the impact threshold. By 2010, the home-run rate for team-authorship was at least 3.0 times larger than for solo-authorship. From the 1980s onward, the team-impact advantage is increasing as the impact threshold rises. By 2010, team-authored papers are 3.0 times more likely to reach the top 10 percent of citations, 3.3 times more likely to reach the top 5 percent of citations, and 4.1 times more likely to reach the top 1 percent of citations than solo-authored papers.

The impact advantage of teams appears strongly at even higher impact thresholds, as well (not shown in the figure). The data thins at higher thresholds of impact but also shows a rising advantage of teams. For example, defining home runs at the top 0.1 percent in citations received in a given year, the relative team impact was below 1.0 in the 1950s and 1960s, 1.4 in the 1970s, 2.9 in the 1980s, and over 3.0 in each decade since 1990. This pattern is also evident if one looks at eminent individuals. For example, consider the highest impact work by winners of the Clark medal, utilizing each work’s citation impact in Google Scholar. For Gary Becker, who won the award in 1967, all five of his top five and nine of his top ten publications are solo-authored. By contrast, for Clark medalists in the last decade, the median case shows one of the top five and two of the top ten publications being solo-authored.

One might imagine that the team advantage is increasing because teams are getting larger and larger. Perhaps more authors simply mean more citations. To address this possibility, Figure 2, panel B presents the “relative team impact” holding the number of authors fixed. This figure uses the 5 percent definition of home

Figure 2

The Rise of Team Impact in Economics

Note: Relative team impact is the percentage of team-authored papers that achieve a given citation threshold divided by the percentage of solo-authored papers that achieve a given citation threshold. For details, see the online Appendix available with this article at the *JEP* website.

run papers, but similar trends appear using different thresholds for defining home runs. In the first comparison (measured on the left axis) we consider two-authored papers versus solo-authored papers, and we see a sharply increasing impact advantage over time. In other words, the upswing is not about adding more authors, but rather a given number of team authors has an increasing impact compared to solo authors.

Figure 2, panel B also compares larger author teams to two-author teams. Three-author teams were substantially less than 5 percent of economics papers prior to 1980, so we focus on post-1980 data to increase sample size. By 2018, three-author teams represent 23 percent of all economics publications. Interestingly, teams with

at least three authors initially underperformed two-author teams: in the 1980s, these larger teams' papers were about 10 percent less likely than two-authored papers to become home runs. This pattern has now reversed. The home-run rate for the larger teams has risen consistently compared to two-authored teams. By 2010, the larger-team papers were 1.4 more likely to be home runs than two-author papers and vastly more likely to be home runs than solo-author papers.

Generality across Research Areas

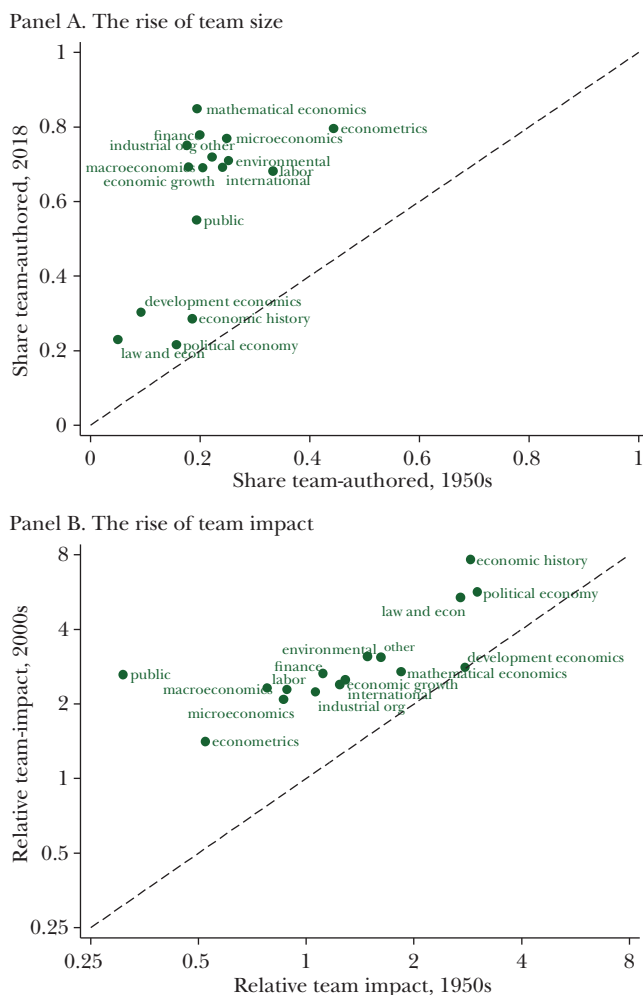
One might imagine that the rising frequency of teams in economics, or the rising impact advantage of teams, may be confined to a few large subfields. However, these patterns instead appear to be systematic across sub-branches of economics research.

Figure 3, panel A presents the shift toward team authorship, with economics organized into 16 different subfields. For all subfields, team authorship has been more prevalent since 2015 than it was in the 1950s. Four fields—economic history, law and economics, political economy, and development economics—continue to show substantial solo authorship, but nonetheless exhibit increased teamwork with time. Moreover, leading journals within these fields show a greater team orientation today. For example, looking at top field journals in development economics (here taking the *Journal of Development Economics*, *Economic Development and Cultural Change*, and *World Development*), one sees that 75 percent of papers have been team-authored since 2015, which is much more in line with the broader trends. To further explore field level generality, Table 1 narrows the focus to some top field journals for many prominent economic subfields and shows a systematic shift to teams.

Figure 3, panel B presents the relative team impact within each subfield, taking the 1950s as a baseline and comparing the relative team impact for papers published in the 2000s. Specifically, we look at all publications in the years 2000–2009, which gives a large sample for each field and substantial time after the publication year to count citations to each paper. The home-run rate is now measured at the subfield level: specifically, a home run is a paper in the upper 5 percent of citations received among all papers published in the given subfield and year. The relative team impact has gone up over time in every subfield. Notably, for about one-third of subfields, the relative team impact was below one in the 1950s. That is, solo authors substantially outperformed team authors in producing home runs. These were large and central fields: macro, micro, econometrics, labor, and public. However, after 2000, these fields have experienced a reversal, showing substantial team advantages.

The Microsoft Academic Graph data used here does not specifically denote a “theory” subfield within economics. However, one can look at theory-oriented journals. For example, the rise in teams appears strongly when studying *Econometrica*, *Games and Economic Behavior*, and the *Journal of Economic Theory*. Team-authored work in these journals has risen from 39 percent in the 1980s to 71 percent of papers in 2018. The relative team impact measure for these journals averaged 4.1 from 2000 to 2009. Generalizing to some top journals in each field, Table 1 shows the impact advantage of teams is systematic.

Figure 3

Generality across Economic Subfields

Note: The sixteen different subfields of economics are developed from the field coding in the Microsoft Academic Graph. For details, see the online Appendix available with this article at the *JEP* website. Data points above the 45-degree line indicate a shift toward teamwork (panel A) and rising impact of teams (panel B).

That these results generalize within economics should not be surprising in light of broader literature in the sciences, social sciences, and patenting. Regarding the frequency of collaboration, economics is following in the footsteps of the hard sciences, where the majority of papers were already team-authored in the 1950s (Wuchty, Jones, and Uzzi 2007). But far more broadly, the rising frequency of teams, and the rising impact advantage of teams, extend across virtually all fields of scientific inquiry and

Table 1

Recent Team Prevalence and Impact Advantage, Top Field Journals

<i>Top field journals</i>	<i>Share team-authored, 2018</i>	<i>Share team-authored, 1980s</i>	<i>Relative team impact, 2000s</i>
Development	0.72	0.25	1.92
Econometrics	0.86	0.41	1.63
Finance	0.81	0.55	3.96
Economic geography	0.64	0.50	3.11
Industrial organization	0.78	0.43	1.68
International	0.78	0.27	2.09
Labor	0.75	0.44	1.12
Law and economics	0.80	0.43	4.06
Macroeconomics	0.74	0.34	4.71
Public	0.69	0.41	2.60
Theory	0.71	0.39	4.12

Notes: This table considers the frequency of team-authored papers and the relative impact advantage of teams, studying the top journals in each field. The journals are the top three by field according to current citations metrics (SCImago Journal Rank) and where the Microsoft Academic Graph data has substantial coverage. For details, see the online Appendix.

all technology classes of patenting (Adams et al. 2005; Wuchty, Jones, and Uzzi 2007; Jones 2009). This generality notably extends not only to distant fields throughout science and engineering, but also to “nearer neighbors” to economics, such as political science, sociology, and psychology. For example, comparing the late 1990s to the late 1950s, the fraction of team-authored papers had risen by 270 percent, 90 percent, and 115 percent in political science, sociology, and psychology, respectively, and the relative team impact in these neighboring fields has become as large or larger than in economics (Wuchty, Jones, and Uzzi 2007).

The generality in the “rise of teams” suggests very broad forces are at work. While one can consider mechanisms that may affect particular sub-fields in certain ways, what is happening in economics and across its many sub-fields, is happening across the entire landscape of the social sciences, hard sciences, and engineering as well as in patenting. The universality of these changes, despite different field-level norms and institutions, including the different research settings of universities, government labs, and for-profit businesses, suggests that very general forces are at work. With that generality in mind, we can examine where the rising advantage of teamwork may come from, emphasizing empirical evidence and perspectives that apply across the landscape of research.

The Benefits of Teams: Dimensions of Advantage

Teamwork as Knowledge Aggregation

The rising team advantage can be framed on one dimension as rooted in the accumulation of scientific knowledge. Further research often builds on prior

knowledge—as Isaac Newton said, “[I]f I have seen further, it is by standing on ye shoulders of giants” (Inwood 2003). But this progress of science can create a problem for the individual scholar, where the cumulateness of knowledge can make it increasingly difficult for an individual to be broadly expert across the knowledge frontier (Jones 2009). In Albert Einstein’s (1941) words: “[K]nowledge has become vastly more profound in every department of science. But the assimilative power of the human intellect is and remains strictly limited. Hence it was inevitable that the activity of the individual investigator should be confined to a smaller and smaller section.”

Einstein’s “inevitable” specialization in turn naturally leads to teamwork. As individual researchers become increasingly narrow, teams allow the aggregation of specialized knowledge and thus offer a line of continued attack on problems of wider application (Jones 2009). This force—cumulateness leading to increasing narrowness—provides one inroad to explaining the increasing tendency to work in teams across all fields and, more particularly, the declining impact of solo authors compared to teams.

To put some empirical content around this conceptual perspective, consider that John Harvard’s collection of approximately 400 books was considered a leading collection of his time, and its bequest in 1638, along with small funds for buildings, helped earn him the naming right to Harvard College (Morrison 1936). One hundred seventy-five years later, Thomas Jefferson’s renowned library of 6,487 books formed the basis for the US Library of Congress. That library’s collection had risen to 55,000 books by 1851 (Cole 1996). Today, the US Library of Congress holds 39 million books (as described in <https://www.loc.gov/about/general-information>).

Looking instead at journal articles, the flow rate of new papers grows at 3–4 percent per year. In 2018, peer-reviewed, English-language journals published three million new papers (Johnson, Watkinson, and Mabe 2018). In total, the Web of Science™ now indexes 53 million articles from science journals and another 9 million articles from social science journals (as described at <https://clarivate.com/webofsciencelibrary/solutions/web-of-science>). In economics alone, the Microsoft Academic Graph counts 30,100 economic journal articles published in the year 2000. This publication rate was twice what it was in 1982 and half what it is today. The number of high-impact papers has also become very large; for example, among publications in the year 2000 alone, 2,849 economics articles have received at least 100 citations. To Einstein’s point, it would seem increasingly difficult for an individual economist to stay on top of the flow of new ideas, or even the flow of relatively impactful ideas, let alone the stock of existing ideas.

Jones (2009) denotes the ensuing challenges as a “burden of knowledge,” where individuals respond to cumulateness along two dimensions. The first is the length of training: individuals can engage in longer training phases, like pre-doctoral programs, lengthening the time of the PhD program, and then post-doctoral programs, to acquire expanding stores of knowledge (Jones 2009, 2010). The second is the increasing narrowness that Einstein described, confining

researchers in the reach of their ideas. This rising narrowness can also be quantified in data. For example, individual researchers are less likely to switch subfields with time, including economics, which is consistent with increased specialization (Jones 2009; Schweitzer and Brendel 2019). Looking at a point in time, researchers are also less likely to switch subfields when in deeper areas of knowledge (Jones 2009).

The organizational implication—teamwork—then follows naturally as a means to aggregate expert knowledge. In the history of aviation, for example, the Wright brothers designed, built, and flew the first heavier-than-air aircraft in 1903. This pair of individuals successfully embraced and advanced extant scientific and engineering knowledge. Today, by contrast, the design and manufacture of airplanes calls on a vast store of accumulated knowledge and engages large teams of specialists; today, 30 different engineering specialties are required to design and produce the aircraft's jet engines alone.³

The role of teams in aggregating knowledge appears in diverse empirical contexts. For example, large literatures in psychology emphasize the value of teams in aggregating diverse information to solve problems. A meta-analysis of 72 psychology studies indicates that team performance is strongly increasing when individuals bring distinct information sets and share their information across the group (Mesmer-Magnus and DeChurch 2009). In research teams, survey evidence also links teamwork to specialization. When asked about the primary reasons for collaboration—which could include access to funding, data, physical tools and laboratories, communications advantages, the joy of working together, or specialized skills—by far the dominant answer scientists gave was access to individuals with unique knowledge, expertise, or capabilities (Freeman, Ganguli, and Murciano-Goroff 2015). A separate survey of researchers in 20 fields of science and social science links increased team size with an increasing division of labor and the aggregation of diverse fields of expertise (Lee, Walsh, and Wang 2015). A natural experiment in mathematics also links increased teamwork to exogenous shocks in access to specialized frontier knowledge (Agrawal, Goldfarb, and Teodoridis 2016).

In short, the greater the stock of knowledge in an area, the narrower the expertise of the individual investigator becomes, and the greater the role of teamwork in attacking broad problems. In fact, teams are not only larger with time but also larger at the same point in time when looking at deeper areas of knowledge, which can be measured by the size of the stock of referenced information (Jones 2009). From this perspective, economics can be seen as lagging the hard sciences, where teams are larger and the rise of teams began much longer ago. To the extent that the sciences have accumulated more knowledge historically, scholars in the social sciences may naturally have remained comparatively less specialized and less team-intensive for longer. The rise of teams in economics can then be seen as a sign of the progress of the field. In any case, teams have now come to economics and, as in the sciences, the frequency and impact advantages of research teams only appear to grow.

³This point is discussed in Jones (2014); Joseph Palladino of General Electric Aircraft Engines provided this specific estimate in personal correspondence.

Teamwork as Creative Combination

Creativity is widely seen as a process of *combination*, where existing material is drawn together in fruitful, new ways (Schumpeter 1939; Fleming 2001). This perspective appears in economics, psychology, sociology, art history, and histories of science of technology among other fields (Usher 1954; Becker 1982; Weitzman 1998; Schilling 2005; Uzzi and Spiro 2005; Rothenberg 2015). This viewpoint also motivates policies and funding mechanisms devoted to interdisciplinary research (National Research Council of the National Academies 2015), which can be construed as a search for advantageous combinations by combining people across disciplinary boundaries.

Recent research has found ways to bring data to bear on this combinations perspective. The research shows that high-impact work combines prior knowledge in distinctive ways. Moreover, teams are more likely to produce these distinctive creative combinations. For example, Uzzi et al. (2013) study the reference lists of 18 million papers. Kim et al. (2016) study the technology code combinations in 8.8 million US patents. These papers define whether any given pairing (of referenced journals, or of technology codes) is relatively “conventional” or “novel.” Each new work contains a distribution of such combinations, and two findings emerge: high-impact work is distinctive for 1) the extreme conventionality of most of its combinations, yet 2) the presence of “tail novelty”—a small set of highly unusual combinations. The highest-impact work thus appears simultaneously to be exceptionally heavily grounded in convention, while introducing a truly unusual pairing of prior work. Absent either this depth in conventional combination or the novel combinatorial edge, the chance the paper or patent becomes high-impact falls in half.

Another combinatorial perspective examines mixtures of old and new ideas. Here again there are striking regularities. Mukherjee et al. (2017) study the age profile of references in 28 million papers and five million patents. The highest-impact papers are found to draw 1) exceptionally heavily on recent work yet also 2) relatively widely through time across the corpus of prior knowledge. Absent either element, the chance the new work becomes high-impact again falls in half.

These “combinations of ideas” findings are virtually universal across fields, appearing as general descriptive rules that locate high-impact work. The findings also suggest that the creative combinations problem is not easy. Researchers appear to achieve high-impact when accessing knowledge widely across time and beyond convention—suggesting the creative search problem extends across an enormous landscape of knowledge.

Teamwork, in turn, is strongly associated with these particular creative combinations. Teams are far more likely to achieve the mixture of hyper-recent and older-standing knowledge. Also, team papers are substantially more likely to contain tail novelty. Notably, these combinatorial rules also appear among solo authors. In particular, a solo-authored work that contains these distinctive combinatorial features tends to be much higher impact than solo-authored work that is missing these features. What is distinctive about teamwork, then, is not that teams operate according to different underlying combinatorial rules. Rather,

teamwork is associated with a sharply higher tendency to achieve these fruitful creative combinations. Where tested, these findings also appear net of individual fixed effects, even among notable scientists. For example, a given Fields medalist in mathematics is more likely to achieve the distinctive mixture of old and new, and associated higher impact, when working in a team (Mukherjee et al. 2017).

Finally, teams of different size appear to do different things. Based on citation networks, one can measure the extent to which a paper develops or disrupts prior ideas (Funk and Owen-Smith 2016). Applying these measures systematically in large datasets, smaller teams prove more likely to produce disruptive ideas, while large teams are more likely to develop and consolidate existing ideas (Wu, Wang, and Evans 2019). These measures have been cross-validated in several ways. For example, surveys of scholars across fields have identified disruptive versus developmental papers, and these independent categorization efforts prove highly correlated with the citation-network measure (Wu, Wang, and Evans 2019). These findings, which generalize across papers, patents, and software innovations, as well as when comparing among the works of a given author, suggest a subtler interpretation of the nature of creativity in teams. Namely, disruption—or more revolutionary forms of creativity—appears difficult to manage or produce among large sets of people, and thus appear as the domain of small teams. By contrast, the developmental (and still highly impactful) fruits of “normal science,” which advances and refines existing paradigms, appear to be the domain of larger teams, consistent with an ability to aggregate extant knowledge and apply differentiated expertise to advance against known problems.

Teamwork as Vertical Combination

Beyond “horizontal” combinations of people with diverse expertise, recent work also investigates teams as “vertical” combinations, where relatively high-impact and low-impact individuals collaborate. A primary question is whether the joint output reflects the typical output of the higher- or lower-impact team members. At one extreme, team output might follow a “max” process, where the only person who matters is the top person, perhaps because this person generates the creative ideas and/or determines the overall research direction of the group. At the other extreme, the output might follow a “min” process, where the weakest member of the team determines the joint outcome, perhaps because this person creates bottlenecks at certain important tasks.

Ahmadpoor and Jones (2019) examine this question by tracking millions of individual authors and inventors through their collaboration networks. The outcome studied is the citation impact of each individual paper or patent produced. Because the same individual will typically work with different sets of collaborators, and may also occasionally work alone, one can identify an individual fixed effect for each researcher. Simultaneously, one can examine the functional form for the collaborative outcomes for researchers with different fixed effects. The universal finding is that team output is predicted more by the lower-impact members rather than the higher-impact members of the team. This finding appears in all fields of

the sciences and social sciences, including economics as well as in patenting. The joint output typically follows the harmonic or geometric average of the individual fixed effects, which heavily weight lower values when averaging.

Despite this “averaging down” pattern, there is simultaneously a large advantage to teamwork. This advantage appears net of the individual fixed effects. For two people of the same measured quality, their team will typically achieve approximately double the citation impact as when these same individuals work alone. This benefit means that teams, even with some diversity in the vertical quality of the team members, still tend to produce papers (or patents) with more impact working together than working separately.

While it may be surprising that team output tends toward the lower-impact member, these findings are consistent with substantial complementarity in the tasks each team member performs. With teams aggregating diverse expertise through complementary skills or a division of labor (Jones 2009; Freeman et al. 2015; Lee et al. 2015), production functions that emphasize bottlenecks are natural. Conceptually, a top member of the team may still provide creative direction, and elevates the team potential, but to the extent that implementation requires complementary tasks, joint output becomes ultimately and more strongly determined by limited success at specific tasks.

Such within-team complementarities also have organizational implications. Namely, the efficient organizational form then features individuals of similar vertical quality working together (which is referred to as positive assortative matching). Not surprisingly, if perhaps for a variety of reasons, this organizational tendency is also seen in the data, where positive assortative matching is the norm in every field of science and social science, including economics and in patenting (Ahmadpoor and Jones 2019). This is the opposite of what a “max” like function would imply, in which case the efficient organizational form would be to spread the best people around into independent teams.

Teamwork as a Laboratory

Vertical and horizontal components of teamwork can also help inform the “laboratory model” of research, which is common in the hard sciences and, anecdotally, appears to be increasingly common within economics. This research model includes principal investigator(s) as project leader(s) and a variety of tasks executed across a hierarchical team. Field experiments in economics, which can require many researchers to execute, as well as empirical projects that rely on the creation, integration, or heavy computational analysis of large datasets, provide examples within our field. The laboratory model takes on distinct organizational forms and draws on distinct skills. The research team may extend beyond the coauthor list on the ultimate research article, and team leaders typically have substantial overarching control—in designing the project, hiring team members, assigning individual roles, communicating the results, and managing funding. The principle investigator(s) must also monitor the potentially difficult-to-observe execution by each team member and engage in substantial coordination efforts.

In understanding the rise of teams in economics, note that laboratory models in economics still appear quite rare, and the model applies less to many economics subfields, such as theory, that are nonetheless also experiencing the rising frequency and impact advantage of teams. Looking broadly at Nobel prizewinners and Clark medal-winners over the last decade, one is struck by the prevalence of theoretical contributions. Nonetheless, laboratory models do appear increasingly prominent in economics. For example, the 2019 Nobel prize, which was awarded to Abhijit Banerjee, Esther Duflo, and Michael Kremer, summarizes their contributions as being “for their experimental approach to alleviating poverty.” Among the last decade’s Clark medal-winners, several awardees appear to have leveraged laboratory-like research models, which further hints at the success of the approach. More generally, both field experiments and big data analyses are on the rise, with the former deploying potentially large data-collection teams in the field and the latter often requiring substantial data infrastructure work and often deploying methodological advances, including network methods, text analysis, and machine learning techniques, that have extended researchers’ tool-kits in computationally-intensive ways (Currie, Kleven, and Zwiers 2020). These approaches can all lend themselves to laboratory models.

As with teamwork in general, the advent of laboratory models in economics suggests another way in which economics is following in the footsteps of the hard sciences. One implication is that funding becomes an increasingly important input for research, as these models are resource-intensive. Funding constraints can then be especially impactful, and these models may already be substantively constrained in the economics field where US federal research expenditure for the economics and the social sciences, both in total and per researcher, remains tiny compared to the hard sciences.⁴ Funding constraints may, in turn, raise equity issues, where a small number of elite researchers, or elite institutions, may be privileged with better funding opportunities and seize upon the advantages of high-scale laboratory teams. As we will consider below, the hard sciences may provide useful models for how economics can navigate these issues.

Teamwork and Communications

Finally, the rise of teams may be viewed in light of the advance of information and computing technologies, which has made collaboration easier. This appears especially true for geographically distant collaboration, which has substantially

⁴The social sciences as a whole received 1.8–2.9 percent of US annual federal funding since 1990, but social science PhDs are typically 8.6–9.5 percent of US PhD recipients over this period. This indicates that not only is federal funding for social sciences tiny in total, it is even lower compared to the sciences when measured per PhD in the field. Further, the federal research funding share of the social sciences and of economics has been declining with time, even as the PhD shares have been steady. From this perspective, resource-intensive research in economics appears both uncommon and relatively constrained (National Center for Science and Engineering Statistics, Science and Engineering Indicators 2018 Appendix Table 4–25; Survey of Earned Doctorates, Table 12).

increased (Agrawal and Goldfarb 2008; Wagner, Park, and Leydesdorff 2015). In fact, multi-university teams are the fastest growing authorship structure (Jones, Wuchty, and Uzzi 2008). In addition, distant collaboration is one teamwork feature where economics and the social sciences appear ahead of the hard sciences: Collaborators in the hard sciences and engineering are more likely to remain co-located, perhaps due to a greater reliance on capital equipment (Jones et al. 2008).

A rising frequency of teams also follows naturally from declining collaboration costs. Declining communications costs provide less direct reasoning for why one collaborates in the first place or why the impact of teams is rising, especially in dominating the upper tail of scientific and social scientific work. This suggests that one should understand the evolution of teamwork as a mix between the costs of collaboration and its innovative benefits, where easing collaboration through technology makes it easier for individuals to seize these advantages. Relatedly, much of the early Internet itself was developed through the National Science Foundation to facilitate research, so that the reduction in communication costs has followed in part from the fruits of collaboration that researchers perceived (for example, Greenstein 2010).

A separate dimension of “communication” is that teamwork may provide promotional advantages. That is, the diffusion of an idea may be increasing in the number of authors who presumably extend the promotional opportunities for a given paper. This “marketing” advantage may be an additional, longstanding benefit of working in a team. However, it seems less useful for explaining the rising impact advantage of teams of a given size or the sharply increasing advantage of teams among the very highest impact work.

Summary

Integrating across these perspectives, several interrelated themes emerge. In part, teamwork is an exercise in accessing horizontally differentiated information. The aggregation of expertise can in turn improve creative search and implementation amidst the large and expanding landscape of existing knowledge. These perspectives are consistent with various empirical evidence, from direct surveys of why people form research teams to psychology experiments around team function to big-data descriptive findings. These perspectives also correspond to straightforward conceptual reasoning, linking the cumulativeness of ideas to inevitable individual narrowness. At the same time, teamwork is increasingly advantaged by how improved communication technologies reduce collaboration costs. This advance has allowed teamwork not only to increase locally but also to draw together researchers working at large geographical distances. While these considerations are not a comprehensive picture of the underlying forces in the rise of teams, they engage the remarkable generality in the rise of teams across economic subfields and virtually all scientific, social scientific, and engineering research disciplines. These dimensions also point to a specific series of challenges facing the economics field, to which we turn next.

Team Costs: Challenges for Individuals and Challenges for the Field

Given the increasing impact advantage of research teams, one might conclude that the shift toward teamwork is a fruitful development for the field. However, the rise of teams can also create costs, especially for the development of scientific careers. Here we consider key dimensions of these costs as well as interventions that might lessen the challenges.

Teamwork and the Academic Reward System

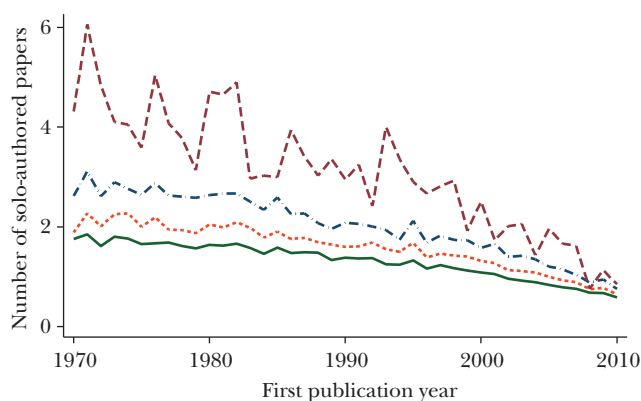
The progress of scholarly careers depends on community perception. And the key input to community perception is the scientific work that scholars produce. Merton (1957) describes the “thin” property right of scientific ideas, where authors place their work in the public domain and are rewarded especially strongly according to community-level assessment, both about the quality and originality of the idea and the role of the specific scientist in its creation. As Merton writes, “In short, property rights in science become whittled down to just this one: the recognition by others of the scientist’s distinctive part in having brought the result into being.” In the academic reward system, high-stakes decisions on tenure, grant funding, journal placement, presentation opportunities, the awarding of prizes, the attachment of one’s name to an idea (eponymy), and status itself all rely on formal and informal evaluation by the community. During the era of solo research, crediting individuals for their work was a relatively straightforward exercise. The rise of teams clouds community inference, which raises difficult and potentially pernicious issues.

Consider the tenure decision. Lifetime contracts are typically awarded, or not, based largely on publications in a handful of years after the PhD, with the duration specified by the institution’s “tenure clock.” What publication information is available to make this decision? Figure 4 charts the evolution of early-career publishing, drawing from all economics articles indexed in the Microsoft Academic Graph and focusing on individuals who publish multiple papers. We define cohorts of economists based on their first publication year and count their publications through the ensuing seven years. Further, we consider publication counts for individuals who achieve different percentiles of lifetime citations. Again, the percentile thresholds for lifetime citations are determined within cohorts: for example, the “upper 10 percent” for the year 1970 considers, among all the people who first published in 1970, the 10 percent of individuals with the highest citation counts through 2018.

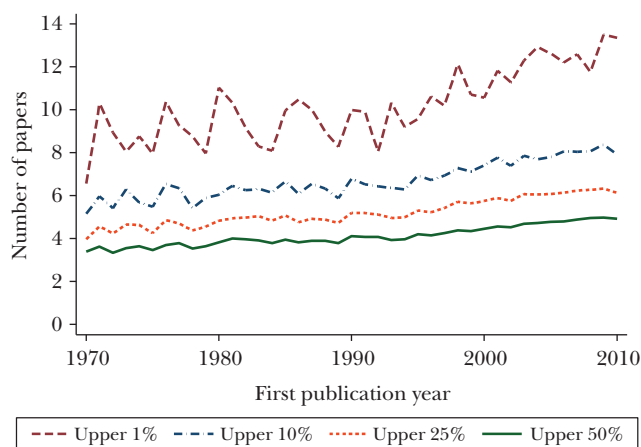
Figure 4, panel A shows that solo-authored work in the early career has become extremely rare. By 2010, the typical early publication record shows just one solo publication. This (new) regularity appears across economists of different impact profiles and regardless of how prolific they are in general. The decline of solo-authored work comes despite an increase in overall publication counts shown in Figure 4, panel B. The early-career publication record of economists can thus provide a number of signals, but these signals are increasingly intertwined. When the single solo-authored work is a job-market paper, the individual’s additional

Figure 4
Authorship in the Early Career

Panel A. Count of solo-authored papers in first eight years of career



Panel B. Count of all papers in first eight years of career



Note: Cohorts are defined by the individual's first publication year. The "Upper N%" subgroups are defined according to each person's career total citations, with comparisons made within the cohort. See text for further detail. For details, see the online Appendix available with this article at the *JEP* website.

pre-tenure publication signals are entirely mixed with their coauthors. Tenure decisions must now rely on credit assignment within teams.

Next, consider scholarly prizes. Individual prizes are highly sought after in many fields, including economics, where the Nobel prize and the Clark medal are extremely prominent.⁵ However, the more work that is done in teams, and the

⁵The Nobel prize can be awarded to up to three people in a given year and can, in principle, be given to a research team. While this happens in the sciences, where the award is typically given for a particular breakthrough, in economics the Nobel is typically given to selected individuals for their broader bodies

more impactful this work becomes, the less obvious the decisions become on whom specifically to reward. By contrast, “best paper” prizes, such as the Frisch medal given by the econometric society, do not require a parsing of credit. Prizes for “best paper” may then be increasingly appropriate reward mechanisms as the nature of economics and science more broadly continues to shift.

Overall, community evaluators are left in the high-stakes but increasingly untethered role of assigning credit. To some extent, one might make additional, individually informed inferences to help settle the matter. For example, perhaps a series of papers look like one author’s agenda, as opposed to another’s agenda. Or perhaps the paper mixes techniques (say, theory and empirical work), where each author can be assigned to particular techniques, and these techniques can be evaluated separately within the paper. But often such inferences are difficult. With nearly all work being team-authored, it is increasingly difficult to identify the contribution of each individual author. It is even more challenging in the early career before tenure—before individuals have known agendas or technical strengths.

Credit and Bias

More pernicious problems may also fester within the informational voids. In assigning credit across team members, community members may consciously or subconsciously weight their views based on gender, race, or other group characteristics, including the institutional affiliations of the authors. When individual signals are weakened, the role of people’s priors or group preferences are comparatively strengthened. These issues are not just theoretical in economics: Sarsons et al. (2021) consider the high-stakes outcome of tenure promotion comparing female and male economists. They find that women are penalized for coauthored work in tenure decisions, while their male counterparts are not. The rise of teams may thus, inadvertently, worsen well-known problems of underrepresentation and discrimination within the economics field (Bayer and Rouse 2016; Allgood, Badgett, and Bayer 2019).

The assignment of credit at one point in time also has future career implications. If one person receives too little credit for a given work, someone else receives too much. In addition, the more the community believes one person deserves credit, the more advantages that person may receive in the future. This idea, coined the “Matthew Effect” in science (Merton 1968), emphasizes a success-begets-success or rich-get-richer and poor-get-poorer dynamic within research domains.⁶

Bias in credit can translate into bias in funding resources and access to top journals, prizes, and the academy’s other attendant rewards. Natural experiments in a variety of settings outside economics show that eminence, including both personal

of work. Similarly, the Clark medal can, in principle, be awarded jointly to two people, where their work is intertwined, but to date this has not been done.

⁶The Matthew Effect is named in accordance with the Biblical passage, “For to everyone who has will more be given, and he will have abundance; but from him who has not, even what he has will be taken away” (Matthew 25:29, Revised Standard Version).

eminence and institutional eminence, draws favorable attention by reviewers and in the diffusion of one's ideas (for example, Simcoe and Waguespack 2011; Azoulay, Stuart, and Wang 2014; Hill and Stein 2020) and that early funding advantages in the sciences lead to later funding advantages (Bol, de Vann, and de Rijt 2018). Moreover, teams do not share credit equally. For example, in the context of scientific retractions across the sciences, Jin et al. (2019) find that more eminent coauthors see little decline in future citations to their work after a retraction, but the junior coauthors do; in fact, eminent authors are protected more strongly when junior coauthors are involved in the project.

Teamwork thus has the potential to worsen bias, potentially in ways with long-run effects. These issues are not just consequential for individuals, but also for the progress of ideas, especially to the extent that resources are misallocated, and talented individuals receive fewer opportunities, depart the field, or, anticipating bias, do not enter in the first place (Phelps 1972; Arrow 1973; Buckles 2019; Hsieh et al. 2019).

The Access Problem

The credit problem arises once a work has been produced. Related challenges also come before work is produced as part of a team. In hitching one's production (and hence career progress) to other individuals, scholars may be highly concerned about the quality of specific teammates and the effort they will provide (Holmstrom 1982; Ahmadpoor and Jones 2019). Especially with complementary tasks (Jones 2009; Lee, Walsh, and Wang 2015), one has to be careful in the choice of coauthors. Mistakes become very costly.

Various evidence indicates that individuals do take care in forming teams. Rather than random selection of team members, scholars in all fields engage in positive assortative matching (Ahmadpoor and Jones 2019). They also rely on close personal contact. For example, while collaboration at a geographic distance is rising, the large majority of such collaboration occurs between individuals who were previously co-located in the same institution (Freeman, Ganguli, and Murciano-Goroff 2015).

In this context, the same forces that drive "credit bias" for work that has already been published can appear again as "access bias" in team assembly. Confronted with potential teammates, prior beliefs about the PhD institution, gender, race, or some other characteristic believed to inform the distribution of quality may strongly influence the demand for that person as a coauthor. These external characteristics will likely play stronger roles when that person is new to their career or when they are not personally known by the other team members.

An increasing division of labor may worsen these issues. When individuals bring differentiated skills or expertise, it is hard for one specialist to evaluate the quality of an individual in a different specialty. In this setting, people may increasingly rely on external signals (like the research institution) to locate collaborators. In fact, we see trends in this direction across the sciences and social sciences amidst the growth in long-distance collaborations. Long-distance collaborations are dominated by elite

institutions, where authors increasingly collaborate with each other and increasingly do not collaborate with authors at lower-ranked institutions (Jones, Wuchty, and Uzzi 2008). The American Economic Association's recent survey found widespread concerns about elitism in the field and summarized key findings as follows: "There is a strong sense that the AEA, the NBER, and the top journals—and de facto the profession—are controlled by economists from the top institutions. Many comments (about 60) reference that there is a network, and you are either in or out, and if you are out, your chances of success in the profession are greatly diminished" (Allgood, Badgett, and Bayer 2019).⁷

Ultimately, teamwork has proven to be a highly stratified activity. While positive assortative matching can be efficient in some static models, obstacles to career access and progression built on discrimination suggest a much more negative view. Discriminatory losses from misallocating talent can be vast (Hsieh et al. 2019). Separately, from efficiency issues, the inequities of discrimination are first-order concerns. Overall, limiting the prospects for groups of talented people, or losing them entirely, can be especially consequential for both individuals themselves and for the collective progress of economics research.

Institutions and Opportunities

The rise of teams is a powerful shift in economics. The choice to work in teams appears natural given its rising impact advantage, and, as discussed above, there are a number of reasons to see the collaborative form as an increasingly important way to drive successful economics research. At the same time, teamwork strains the reward system of science. The decline of transparent signals about individual-level output leaves the community with an increasingly murky challenge in deciding whom to promote and reward. It may also further stratify the field, and the informational voids can interact especially badly with discriminatory preferences or beliefs.

Given this tension, policy interventions must proceed with care. If returning to solo work in economics would reduce research productivity and slow the progress of ideas, solutions will ideally work within the rise of teams. The institutions of economics—universities, journals, funders, and professional associations—all have some power to experiment with interventions that may ameliorate the problems that teams impose.

First, economics journals can consider publication rules that help clarify individual contributions. Outside economics, author order is often used to signal relative contributions. For example, the first and/or last position in the author list, depending on the field, can be used to communicate elevated roles within the

⁷Initial discrimination in team assembly can also naturally have dynamic consequences, continuing to limit individuals in the set of coauthors that are willing to match. Team production makes it increasingly difficult to develop a signal of one's talent and change community perception. To the extent that team output follows the harmonic average of the individual productivities (Jones and Ahmadpoor 2019), the fact that an individual may be more talented than their teammates becomes muted in the joint output. This further reduces the community's ability to detect the individual's talent and can leave the community to its prior and potential biases.

team. Further, certain leading science journals now require authors to assert (in a front-page footnote) each person's specific contributions to the work, which might include statistical modeling, formal theory, conceptual development, data acquisition, and writing. If coauthors overlap on many tasks, which may often be the case in economics, stating this fact can still be informative. Such policies may be useful for economics to consider. To put it more strongly: the reasoning for why economics should do things differently from the hard sciences, which have actively engaged these issues, is not obvious. One caveat may be that, within hierarchical teams where PhD students or post-docs work for their advisor or employer, or where junior faculty work with senior colleagues, the junior authors may feel pressure to be overly generous in crediting the senior author. Studies of the effects of these author order systems will be helpful.

Second, funders should be mindful about maintaining access, especially for junior scholars. The more that economists work in teams, the longer it takes to establish an independent reputation and the harder it may be to convince a funder (and the reviewers of grant proposals) that the investment is worthwhile. As a cautionary tale, consider biomedicine, where team sizes have grown large and it is difficult to develop an independent record. The average age at first grant from the National Institutes of Health rose to 43 in 2016, up from age 36 in 1980 (Mann 2017). Former NIH director Elias Zerhouni saw the trend against younger researchers as a major crisis, caused by bias within peer review, that would choke off the pipeline of talent (Kaiser 2008). To the extent that grants become increasingly important to fund team-based economics research, similar concerns may apply. This concern may be especially germane for resource-intensive "laboratory model" style research, which, as discussed above, appears to be increasingly prominent in economics research. Targeting grants at younger scholars may encourage career development and access to these models: indeed, the NIH has responded with quotas to support younger principal investigators. Even if such grants are less-informed bets, they may be important dynamically for the health of the field.

Third, proactive steps can strengthen individual-level assessment opportunities. Seminar and conference presentations can give greater visibility to less-established authors on a team. To the extent that coauthors have all made large contributions to a paper, inviting the less established authors would presumably provide the same valuable research interactions. Similarly, even short visiting opportunities can extend networks for less established scholars. For conference organizers, including discussants can become a universal norm, motivated not just by its benefits for addressing the ideas, but as an opportunity for individuals—and especially less established individuals—to showcase themselves. As team-authored work takes over, such individual-level opportunities become especially useful.

Finally, amidst the rise of teams, economics should work toward objective methods for assessing individual performance of those working in teams. For example, some review panels "divide by N" when crediting team-authored works to individuals, while others wholly credit each author for the work, and still other institutions do not use explicit rules. Reviewers may engage a kind of "fixed effects"

reasoning, attempting to assess an individual by looking at what happens when that individual joins projects, and adjudicate credit based on how the coauthors perform in their other work. In all cases, the concern is that when procedures are typically done non-transparently and in an ad hoc manner, reviewers are more likely to find themselves drawing on personal biases. Ahmadpoor and Jones (2019) develop an explicit method for calculating individual fixed effects, using the citations each paper receives to estimate individual fixed effects, based on the entire collaborative network of the field and looking at all fields in the sciences and social sciences, including economics. Using publication records, the algorithm produces a measure of the citations each author would be expected to produce should that author write alone. In out-of-sample tests, the method is substantially more accurate than other existing approaches for rating individuals. Advancing this type of method may better ground community assessments and limit credit bias (if not access bias), given the rise of teams.⁸

Beyond explicit assessment methodologies to confront the rise of teams, training and procedures to avoid implicit bias may be very important, as one should be mindful of the limits of one's capacity to apportion credit fairly when making judgments about individuals. When serving on review committees, the committee can be explicit about how the group is apportioning credit amidst team-authored work. It should be standard for reviewers to ask each other to explain the basis for their judgments. This kind of "peer review within peer review" can help the reviewers perceive and limit any bias.

Finally, there is the training aspect for team members themselves. Working in teams in economics is currently a learning-by-doing affair. But teamwork engages collaborative and communications skills and technological platforms that are distinct from the methodological tools and domain knowledge one is formally taught in a PhD program. Hierarchical teamwork and laboratory approaches further engage management skills and, often, skills at acquiring funding. PhD training to advance these skills would provide increasingly valuable inputs to economists' careers, and various team-skill schematics and training efforts in the sciences can provide models (see National Research Council 2015).

Conclusion

The traditional image of economic research involves someone working alone: one pictures Adam Smith writing *An Inquiry into the Nature and Causes of the Wealth of Nations* in the 18th century, Karl Marx sitting in the reading rooms of the British

⁸By focusing purely on the publication record, the method avoids direct consideration of characteristics that may be discriminatory. However, to the extent that citations themselves reflect community biases, this method may still indirectly imprint bias onto the individual measure. Assessing and correcting for any such indirect bias (which can be relevant in machine learning and other statistical prediction approaches) is an important additional step.

Museum in the 19th century, or Joan Robinson writing *The Economics of Imperfect Competition* in the 1930s, all as solitary endeavors. The evidence presented in this paper suggests that the traditional view was once largely accurate but has become increasingly outdated. Economics, like many other areas of academic research, has been moving to a team-based approach. A modern view of academic research in economics would focus on how research teams are formed, how the teams evolve over time, how they are funded, how they function, how they are managed, and how the economics community ascribes credit to the individuals who participate in them. This shift in perspective from individual to team-based research should have implications for what it means to train an economist, what the career path for an economics researcher looks like, and how a research trajectory will be rewarded.

Maintaining the benefits of teamwork while managing the challenges is not simple. A broad view is that the economics profession can look to the sciences, given their longer-standing team orientation, for policy ideas. Several policy innovations that may manage the challenges have been articulated here. Improvements in institutional design will also greatly benefit from careful experimentation and further study. It is certainly time to address these issues, especially given the issues of bias in economics, and as the prevalence and impact of teamwork in economic research continues to rise.

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