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Women in academia: Why and where does the pipeline leak, and how can we fix it?

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HIGHLIGHTS

- Across all academic disciplines, women hold a minority of professorships, even in those disciplines where the majority of college students is female. The percentage female at the professorship level is lower than the percentage female at the Ph.D. and college graduate levels in all disciplines.
- Many factors might contribute to women dropping out of academic careers more frequently: A lack of role models, different challenges due to parenthood, limited funding and mentorship opportunities, or implicit bias in credit giving and co-authorship.
- Universities seeking to address the leaky pipeline can choose from a plethora of strategies with varying benefits and risks.
- The leaky pipeline in academia is not exclusive to women; other historically underrepresented groups can face distinct challenges that may require different policies in order to be addressed.

Women advance along the academic career ladder at lower rates than men. This phenomenon, dubbed the "leaky pipeline," is pervasive across all academic disciplines and leads to lower levels of female representation in academic leadership positions despite gender parity at the college level. Higher drop-out rates by women from academic careers can be explained by various supply-side factors – women choosing to leave academia due to a lack of role models or different family responsibilities – and demand-side factors – expecting more volunteer and committee work from female researchers, giving less credit to women's contributions to scientific teamwork, citing women's work less often, giving women less access to mentorship and funding opportunities, and perceiving women as less competent and brilliant overall. Policies that seek to remedy one of these factors might have negative side effects when the broader societal and institutional context is disregarded.

Leaky pipes are a nuisance to many homeowners. Although you funnel a lot of water in, the faucet only spits out a few droplets. What is lost on the way is wasted. It is seldom one big leak, like a burst pipe, that causes the loss, but rather many seemingly negligible leaks working together.

Perhaps this is why the "leaky pipeline" is such a powerful metaphor for a phenomenon observed in the professional and academic world – that although a large number of women enter a profession, few of them are represented in the upper echelons of that same profession. In academia, this phenomenon is particularly pronounced: Although women make up the majority of college graduates, only a few end up holding professorships. While obstacles faced by women, including harassment and discrimination, exist across the labor market, this article emphasizes the challenges more commonly experienced by women in academia. Still, women are not the only group facing a leaky pipeline in academia. Representation at the end of the academic pipeline is similarly lower than at the beginning for racial minorities, individuals from lower socioeconomic status backgrounds, and first-generation academics. Of course, these groups are not homogeneous and might face different leaks. Because of the large scope of this topic, the focus of this article is on the leaky pipeline faced by women in U.S. academia, where the leaks are, and what possibilities exist to fix them. Coauthors Schultz and Stansbury, as well as coauthors Morgan, LaBerge, Larremore, Galesic, Brand, and Clauset review current representation of minorities, individuals from lower socioeconomic status backgrounds, and first-generation academics at the Ph.D. and faculty levels [1, 2]. In the present discussion, the author adopts the term "women" for simplicity but does not intend to mask the diverse and intersectional identities that this word encompasses. In some cases, this article also contrasts "men" and "women," but this is not to be understood as implicitly stating there are only two genders. Unfortunately, there is little scholarship on the leaky pipeline faced by non-binary, intersex, and transgender individuals. These limitations should be kept in mind with respect to the policies discussed in this work.

This article will first offer a brief description of the leaky pipeline by contrasting it with another well-known metaphor, the glass ceiling. It will then elucidate possible explanations for this phenomenon using a *supply* – women leaving academia – and *demand* – academic institutions creating higher barriers for women – framework. In the final section,

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current policies to address the leaky pipeline in academia will be reviewed briefly.

Metaphors...

Readers might be familiar with a different term, the *glass ceiling*, which refers to an invisible barrier that prevents women and minorities from rising in a profession. Applied to academia, however, the metaphor suggests that there are no women and minority professors at all. Such an impression might arise from a history of science that has mostly been written as a history of great men, but this has never been true. For example, recent research by Iaria, Schwarz, and Waldinger [3] documents the presence of female professors throughout the 20th century. Employing the metaphor of a leaky pipeline can help us take a more holistic view of this stepwise phenomenon rather than assuming there is one large and late-stage barrier.

To inform policy, it is crucial to understand where the points of attrition in the multi-stage process of becoming an academic lie as well as what causes them: voluntary or involuntary exit, demand or supply. To shed light on this question, the next section examines female and male participation at each stage in the academic career ladder: college, doctorate, and different levels of faculty positions.

...and measurement

The most common path to a professorship is a college degree, followed by a doctorate, possibly a postdoc, and then a (tenure-track) assistant professorship, which, conditional on academic achievements, can progress into a tenured associate, and subsequently full professorship. Breaking up the pipeline into these stages can help us identify where there are leaks. Using data from the Digest of Education Statistics (provided by the Department of Education), the Survey of Earned Doctorates (SED, conducted by the National Science Foundation, or NSF), and the National Survey of Postsecondary Faculty (also conducted by the Department of Education), we can assess the representation of women at each stage of the academic career path.

Figure 1 plots the share of women at different points in time for different career stages. Two patterns are immediately apparent: The share of women decreases at each step of the career ladder – with the exception of assistant professorships. However, the share of women at each stage has also increased over time.

How many women, though, are actually leaving academia, and at what stage in the path to professorship does this occur? To answer this question, we would ideally be able to follow all college graduates along their academic careers. Unfortunately, these data do not exist. Comparing percentage point changes as we have here can give us a first, albeit imperfect, estimate. Indeed, this metric as a window into

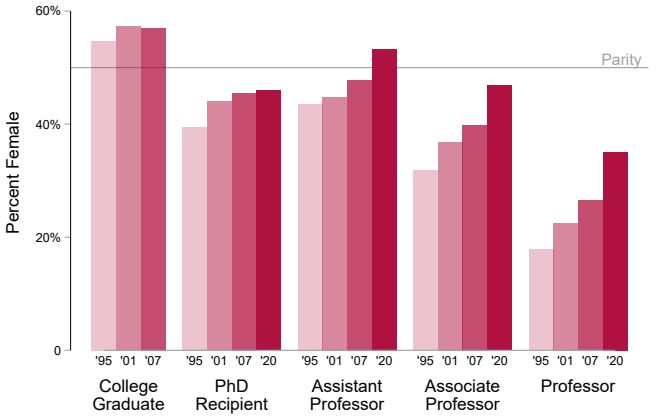

Figure 1: Share female at different points on the academic career ladder, for selected years. Source: Digest of Education Statistics, Survey of Earned Doctorates. Own calculation.

the leaky pipeline has several limitations. Given that college graduates do not become Ph.D. recipients, and Ph.D. recipients assistant professors, instantaneously, it would thus be more helpful to compare the female share of a stage in any year with the share at the next stage in a later year that accounts for this delay between career stages. In addition, disciplines differ in the duration of career steps. For example, while it is common for postdoctoral positions in biology to last up to eight or even ten years, Ph.D. recipients in economics more often receive their first faculty position immediately, or one to two years after graduation.

An additional limitation of the currently available data is that while college graduates and Ph.D. recipients are measured as the number of people *becoming* college graduates and Ph.D. recipients respectively (known as a flow variable), all faculty positions are measured as the number of people currently *holding* a position (a so-called stock variable). In the above data, then, professors in 2007 may thus reflect individuals who became professors in both 2005 and 1980. This complicates the interpretation of changes in female representation over time, as we may be counting the same individuals multiple times in the later career stages who hold professorships across years. This could present as an apparent improvement in “fixing leaks" in the pipeline, when it instead is an artifact of how the data are defined and collected differently between the earier and later steps along the academic pipeline. For example, an increasing share of female professors in the later career stages could reflect better retention of female junior faculty or more men retiring, which have different interpretations when assessing policy success in mending the leaky pipeline.

Finally, for a complete picture of when women exit academic careers, it would be necessary to have data for the number of women beginning and finishing a step. This would help to clearly pin down which stage or stages of the academic pipeline contribute the most significant leak(s), aiding policymakers in crafting policies tailored to patching one

specific leak or another. Indeed, for the design of policy, it is crucial to understand if the policymaker would need, for example, to invest in making a Ph.D. more attractive to women, or in retaining more women in Ph.D.s, e.g. by improving their experiences during the Ph.D.

While these data limitations make it difficult to define an exact value for the magnitude of "leaks," the rough location of leaks is apparent: Women move from college to Ph.D. at lesser rates. The step between a Ph.D. and a first faculty position as an assistant professor does not seem to "leak" women. However, female representation then decreases again from assistant to associate and full professorships, suggesting that most women are lost at the start and finish of the academic race.

What explains these patterns? The demand and supply of female academics

To inform policy, it is first necessary to determine why women advance along academic career paths differently than men. As suggested by Figure 1, the literature does not find a single determining factor, but rather a multitude of compounding individual and institutional factors acting at various stages along the pipeline. For the purpose of this review, these explanations will be grouped into *supply-side* — i.e. women entering academia — and *demand-side* — i.e. institutions not retaining women — factors. In reality, these factors might intersect, since anticipating exclusion can lead to pre-emptive self-exclusion. For example, a recent study of employees in Sweden indicates not only that employees who experience gender discrimination or sexual harassment themselves switch workplaces, but that people avoid employers where they believe they might face discrimination [4].

The supply of female academics

Different interests: One possibility is that women prefer to work on topics and in disciplines that are less likely to lead to a faculty position. This hypothesis posits that the leaky pipeline for women in academia is an outcome of academic field composition. It is known that different disciplines have different transition rates up the academic job ladder. So, if women disproportionately study and work in disciplines that have lower student-to-Ph.D. and/or Ph.D.-to-professorship quotas, while men typically select disciplines with higher quotas, on average, it will seem as if academia as a whole has lost women. Figure 2 repeats the same exercise as Figure 1, but now within academic disciplines. Because data on the gender composition of disciplines is not available by faculty rank, the share female for the entire faculty is shown.

Figure 2 suggests that leaky pipelines exist within all disciplines. Contrary to popular associations between women and humanities and men and STEM, female shares decline at higher levels in the profession across both discipline groups. Clearly, the idea that women have different, less promotable interests does not explain the leaky pipeline in academia, given that female shares are lower among faculty in so-called "female" subjects.

Still, Figure 2 raises another question: Why do some disciplines experience drastic declines in the female share (e.g. education) while some declines are more modest (e.g. engineering)? While this question could greatly inform policy design, it is sadly underexplored. It is equally possible that female college students who enter a male-dominated field are especially motivated by an interest in the subject that leads them to pursue an academic career despite barriers, that female-minority subjects have enacted better retention policies in response to a more readily perceptible problem, or that differing professional cultures perpetuate detrimental norms about female academics. The section *Credit-Giving, Citations, and Notions of "Genius"* below discusses one example of such a detrimental norm: The belief that women are less brilliant than men.

Role models & mentors: Historical underrepresentation can perpetuate itself even if all the institutional barriers that make an academic career more challenging for women than for men have been removed. This occurs when advancement, or, even more profoundly, the desire to be in a profession, depends highly on the availability of role models and mentors. Role models are different from mentors – role models can inspire without repeated, close interactions, whereas mentorship is longer-term and involves specific guidance. They also appear to matter at different stages: Research suggests that mentorship is crucial to advancing in academia for women who have already decided on or expressed an interest in academia [5, 6]. Role models appear to be more crucial for the initial "spark": whether a student can identify with an academic or scientific career, i.e. "is this a profession for someone like *me*?" In a study of students at the United States Air Force Academy, coauthors Carrel, Page, and West show that female students profit substantially from being assigned to a female professor in introductory STEM classes. These students not only finish their classes with better grades, but also are more likely to graduate with a STEM major [7]. So, there is evidence that exposure to a senior female researcher retains women in that discipline. However, it remains unclear how this works: Are women better at teaching other women? At motivating them? Are female professors able to create a more welcoming, stereotype-free environment for female students? Furthermore, the degree of proximity required for a person to constitute a role model is unclear. Is reading a biography about Marie Curie enough, or would one have to have personally encountered her in some capacity?

Success in a career often depends on informal information that is transmitted through mentors, who also provide guidance. Although it is unclear whether a mentor has to have the same gender as the mentee, women might find it harder to connect with a male mentor or have less access to

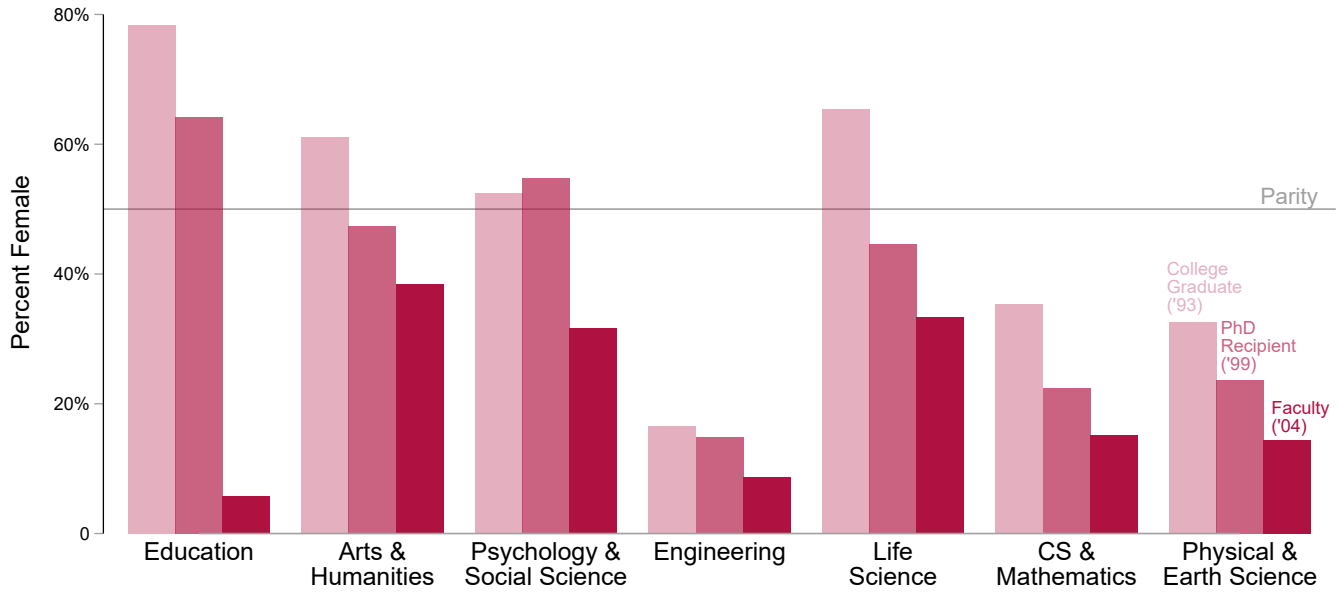

Figure 2: Share female at different points on the academic career ladder for selected years, split by broad field. Years selected based on data availability (earliest year for college graduates: 1993; latest for faculty: 2004) and reasonable time lags. Source: Digest of Education Statistics, Survey of Earned Doctorates. Own calculation.

networks in male-dominated fields. This is a potential lever for policy, since structured female mentoring initiatives that match female assistant professors to female senior professors as mentors have been shown to boost women's careers. In a randomized control trial, coauthors Blau, Currie, Croson, and Ginther find that program participants have more grants and publications, as well as publications with higher quality [8]. However, this type of initiative might come at the cost of putting excess time burdens on female faculty (discussed in greater detail under *Tasks with Low Promotability*.).

Challenges of parenthood: Recent studies suggest that the gender pay gap is a motherhood gap [9]. While norms around motherhood and childcare impede mothers across the labor market, specific institutional features of academia potentially magnify those challenges. A crucial step in the academic career ladder is achieving tenure. During tenure review, an academic's achievements as an early career professor – usually the duration of an assistant professorship of six years – are evaluated, and the decision to retain an academic as tenured faculty is made. These years often coincide with the time in which many women choose to have children. In response to the challenges of pregnancy, childbirth, and early childrearing, universities have adopted tenure-clock-stopping policies. These policies grant an extra year on the tenure clock for each child that is born to (or adopted by) faculty during the pre-tenure period. Tenure review is subsequently conducted after providing more time for these faculty to fulfill their tenure requirements. However, there are caveats to this policy: First, it only grants extra time for "new" children (births/adoptions). Therefore, any children born before a faculty member starts a tenure-track position are not taken into consideration, despite the fact that toddlers and small children also require large time commitments. Moreover, evidence from Antecol, Bedard, and Stearns shows that gender-neutral tenure-clock-stopping policies, which grant extra years to both new mothers and fathers, might have an adverse effect on women. They find that women are less likely to receive tenure at their university after a gender-neutral tenure-clock-stopping policy is adopted, whereas men are more likely to. Their findings also indicate that new fathers, rather than using the extra time for childrearing as intended, instead increase their publication output. Although women in their sample do not leave academia at higher rates than men, they take longer to receive tenure and do so at different institutions than those at which they were first hired [10].

The demand for female academics

With the introduction of Title IX in 1972, overt discrimination on the basis of sex in education programs has been prohibited. Still, many facets of conscious and unconscious bias against women lead to a de facto lower demand for female academics. This is often due to women being perceived as less competent than men with equal qualifications, or to women having less access to opportunities and thus seeming less qualified on paper.

Tasks with low promotability: University academics perform many tasks. Research and teaching are the most apparent, but service to the profession, such as committee work, can take up a substantial amount of time. Most research universities largely base tenure decisions on an academic's research record, with some weight placed on teaching quality. While teaching loads are usually contractually determined, service to the profession is largely a volunteer activity. As service activities are rarely decisive in tenure review, they are

considered tasks of low promotability. Yet, numerous surveys have shown that female academics tend to spend more time than men on service activities, such as serving on faculty committees [11, 12]. This would not be a cause for concern if women simply enjoy these tasks more and efficiently trade off the pleasure of being on a university committee with more time for research. However, coauthors Babcock, Recalde, Vesterlund, and Weingart provide evidence that this is not the case [12]. In a series of experiments, they show that women receive more requests for tasks with low promotability because women are expected to volunteer more often. Anticipating this, women also volunteer more in mixed-gender groups. Interestingly, the propensity to volunteer does not differ between men and women in single-sex groups. Put differently, men expect women to volunteer and thus volunteer less when a woman is a member of a group [12]. This dynamic has implications for policy considerations at academic institutions. For example, a popular "quick fix" to gender imbalances in academia has been to adopt gender parity in tenure or grant review committees, but when the initial share of women in a department is low, this may lead to undue time burdens placed on female faculty members. Some might consider this a worthy price to pay if the benefits of balanced committees to female academic careers outweighed the costs of this work being borne by too few shoulders, but there is no clear evidence that a higher share of women on a committee benefits female applicants [13]. Nevertheless, universities that implement gender-balanced-committee policies might consider experimenting with how to relieve the gender-specific consequences of unequal service burdens. Possible paths of action could include rotating tasks more frequently between senior researchers, reducing teaching loads for those on committees, or rewarding service to the profession more in hiring decisions. The additional "volunteering" burdens on female faculty also have consequences for the design of female mentoring initiatives (discussed in the "Supply" section), especially those that involve mentoring by junior faculty. Namely, although beneficial for female students, these initiatives place additional time demands on female junior faculty.

Access to mentoring and funding opportunities: Although women participate in more non-promotable tasks, they often receive fewer career opportunities. This applies to all steps of the academic career ladder. Disparities in academic opportunities can already arise at the undergraduate level. Coauthors Moss-Racusin, Dovidio, Brescoll, Graham, and Handelsman show that science faculty of any gender perceived male applicants to a laboratory manager position as more competent and hireable, and they offered these applicants higher starting salaries and more mentoring. To obtain these data, the authors employed an audit study: They sent faculty participants fictitious applications that were identical in all respects except the applicant's name, which was randomly varied to signal a particular gender to the reviewer. For example, if John Smith received higher scores than Jane Smith despite an identical résumé, then this would indicate gender bias on the part of the reviewer [5]. In a similar experiment, coauthors Milkman, Akinola, and Chugh show that professors respond to emails from prospective graduate students requesting a 10-minute meeting at significantly higher rates when the fictitious student has a name that is interpreted as belonging to a white male. This pattern is particularly pronounced in higher-paying disciplines and at private universities but, interestingly, does not vary by faculty gender or racial identity [6].

Given that based on name alone, women are perceived as less competent and receive less mentoring, why not remove the name from applications and perform blinded review? Unfortunately, blinded review is no panacea. By examining National Institutes of Health (NIH) and Bill & Melinda Gates Foundation grant applications, coauthors Kolev, Fuentes-Medel, and Murray provide evidence that "female" applications receive lower ratings, even when reviewers do not know an applicant is female. Using text mining, the authors show that this phenomenon is mediated by gendered communication styles: Applications from women use less positive language for research (terms such as "novel"), score higher on readability and concreteness, and focus less narrowly on a subdiscipline of medicine. How harmful these differences in communication style are for female applicants depends on the type of grant proposal: Longer NIH grant proposals are more successful if they narrowly focus on a subdiscipline of medicine, while shorter Gates Foundation proposals profit from concreteness [14]. It is an open question whether gender gaps in these settings arise because biased reviewers use lexical differences to (unconsciously) screen for women or the language men tend to use aligns more with funding institutions' goals. If it is only a preference for a certain type of language, and reviewers can consciously de-bias when they know an application has been written by a woman, then blinded review may actually hinder rather than help female applicants.

Credit-giving, citations, and notions of "genius": Whether or not a person succeeds in academia, especially at prestigious institutions, depends on how innovative and important their research is. Assessments of innovativeness and importance are highly subjective and often mirror deep societal stereotypes. Research has shown that women tend to receive less credit for their work. For example, coauthors Ross, Glennon, Murciano-Goroff, Berkes, Weinberg, and Lane analyze administrative data from 36 universities. In their sample, female research group members – identified by receiving payments from a grant – appear less often as authors on the publications and patents produced by these grants. This applies to women at every academic rank, and particularly for high-impact publications [15].

Even when women are coauthors on a project, their contributions are often overlooked. A paper by Sarsons provides evidence from economics, a discipline in which

authors are commonly listed alphabetically and not in order of contribution. Keep in mind that the latter, although providing more information on the specific contributions of each author, could itself be an outcome of discrimination. The evidence shows that an additional coauthored publication increases female reseachers' probability of receiving tenure less than a similar coauthored publication does for male researchers. However, this difference is less pronounced when women coauthor with other women. This suggests that review committees undervalue a woman's contribution to group work. While women and men profit similarly from single-authored works [16], in many disciplines, especially those that require costly infrastructure, single-authored publications may not be attainable for early-career researchers.

Recognition for work also takes the shape of citations. In turn, citations provide an important indicator for a paper's, and consequently a researcher's, quality. Critically, tenure review boards not only assess the number of a researcher's publications, but also their quality. This is a further dimension in which women are often overlooked. A study by Koffi uses publication and citation data, including the text of publications, to construct an omission index, which measures which papers should have been cited by another paper and contrasts this with the papers that were in fact cited by the index paper. All-male-authored papers are the least likely to be omitted, mixed-gender-authored papers are significantly more likely to be omitted, and all-female-authored papers are the most likely to be omitted, even when publishing in similarly high-quality outlets. Women thus face a double bind: When coauthoring with men, they receive less credit for their contributions, but when only coauthoring with women, their work is less cited [17].

In addition to the undervaluation of women's academic contributions and accomplishments, survey evidence from coauthors Leslie, Cimpian, Meyer, and Freeland suggests that a broad pattern of stereotyping women as less brilliant and possessing less raw, innate talent gives rise to differential representation of women across academic disciplines. They surveyed faculty, postdoctoral researchers, and Ph.D. students across a range of disciplines and institutions in the U.S. and elicited agreement with statements such as "being a top scholar of [discipline] requires a special aptitude that just can't be taught" to measure expectations of brilliance. In addition, they surveyed respondents on their hours worked on and off campus as well as their beliefs about the selectivity of disciplines at the Ph.D. level. The authors demonstrate a strong negative correlation between a discipline's beliefs about the importance of brilliance and the share of female researchers in that discipline: the more brilliance the members of a discipline deem necessary, the lower the share of female academics [18]. In contrast, work load – as a proxy for barriers to people with more family responsibilities – and the selectivity of Ph.D.'s – as a measure of competitiveness, which studies have found to be a less desirable feature of careers for women [19] – do not explain the variation in female share by discipline. The association between brilliance and maleness also extends to the way letters of recommendation for female and male candidates are written. Examining letters of recommendation written for applicants to faculty positions in chemistry and biochemistry, coauthors Schmader, Whitehead, and Wysocki find that letters written for men contain more standout adjectives and words that are associated with ability rather than grit [20].

Mending the leaks

As outlined in the previous sections, the leaky pipeline for women in academia is multifaceted and multi-causal. In order to begin mending these leaks, relevant stakeholders such as policymakers at the federal, state, and/or institutional level will need to consider these varying sources and features to craft effective policy. For example, at each stage in the academic career, different leaks may require different fixes, i.e. inspiring female students to major, providing research and mentoring opportunities at the undergraduate and graduate level, addressing higher time demands on female junior faculty due to motherhood and service to the profession, providing grants to female researchers, and recognizing women's scientific contributions. It is important to note that reducing the barriers that women as well as other historically underrepresented groups face in academia is not only a question of fairness. Research also indicates that when a discipline lacks representation of a group, research agendas tend to disregard topics that predominantly affect this group. For example, all-female inventor teams are substantially more likely to focus on women's health [21], and lower-income inventors develop more products that are accessible to lower-income individuals [22]. Thus, academia is missing out on ideas when it misses out on people.

In the context of investigating the causes of the leaky pipeline, this article has briefly highlighted popular and potential policies to fix leaks: Mentoring initiatives, tenure clock-stopping policies, female quotas on committees, increasing the promotability of service to the profession, or blinded review. As we have seen, each of these policies comes with risks and benefits. When considering implementing any of these, it is important to ascertain how such interventions interact with the broader societal and institutional context. Well-intended policies such as blinded review, having female representatives on every faculty committee, and tenure clock stopping might have adverse side effects if interactions with other institutional features are disregarded. This need for careful evaluation and experimentation with policies is reflected in the National Science Foundation's (NSF) ADVANCE program. For 20 years, the NSF has awarded more than $360 million to support research into increasing gender equity in STEM, as well as to projects at institutions to determine best practices. The stratEGIC Toolkit developed at the University of Colorado Boulder summarizes findings from the NSF ADVANCE program for practitioners and university administrators [23]. In light of the recent Supreme Court

ruling against affirmative action, universities will have to reassess their Diversity, Equity, and Inclusion policies. The ruling poses unique challenges, but might also present an opportunity for universities to experiment with and evaluate other policies to increase equity in academia. The NSF's toolkit might provide a worthwhile starting point.

The institutional context of higher education in the U.S. provides both challenges and opportunities. In contrast to countries with mostly public universities that can implement systemic changes top-down, the U.S. university landscape will likely exhibit more heterogeneity in universities' approaches to fostering women's career trajectories. This can be beneficial if legislation responds too slowly, but detrimental if some universities lag behind. Unfortunately, a lack of systemic data at the national level, in particular for faculty, somewhat impedes the investigation of these issues for women as well as other minority groups across all academic levels and disciplines. Good policy requires good data – in particular, where multiple levels of identity intersect. This article has focused on the leaky pipeline as faced by women, but women are not the only group that drop out of academia. Future research – and MIT SPR articles – is needed to understand and address the leaks faced by historically underrepresented minorities, such as people of color, first-generation academics, individuals from low socioeconomic status backgrounds, and academics with disabilities.

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