*The Journal of Law, Economics, and Organization*, 2026, 1–36
https://doi.org/10.1093/jleo/ewag025
**Article**

OXFORD

# Rewarding failure

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**Research is a messy enterprise, fraught with dead ends and missed opportunities. When research is successful, intellectual property law offers market-driven rewards. When research is unsuccessful, however, the investment is treated as a waste—an unlucky gamble in the horse race of innovation. But failed research investments are not valueless. Instead, they generate useful information that increases the odds of success on subsequent research efforts. From a social perspective, then, firms should disclose information about research failures so that other firms can avoid duplicative, fruitless lines of inquiry. Unlike with successful research investments, however, firms have no easy opportunity to capture the value of information generated by their unsuccessful research. Indeed, the law offers no coherent approach for harvesting the social value of the information generated by failed research efforts. As a result, discoveries of what "does not work" are not optimally disclosed. In this paper, we develop a simple sequential-stage model to identify the shortcomings of this one-sided reward system. We explore possible legal and institutional solutions to the problem, focusing on informal bankruptcy alternatives, patent-like "propertization" mechanisms, and prizes. Our results shed light on the potential and limits of these mechanisms for aligning private and social incentives for research.**

**JEL classifications** K11, O34, O31

"*I haven't failed, I've just found 10,000 ways that won't work.*"
Thomas Edison

"*It's fine to celebrate success but it is more important to heed the lessons of failure.*"
Bill Gates

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## Introduction

Research can be thought of as the pursuit of knowledge or truth about something. The modern economy rewards successful research in many ways. One of the most important rewards is intellectual property. Through patents and copyrights, the legal system grants protection for the economic utilization of valuable information. By granting discoverers of valuable information exclusive rights in the exploitation of such information, the legal system allows parties to internalize the benefit of their research, thus creating efficient incentives for conducting research.

Not all research, however, leads to successful discoveries. Sometimes, research shows that a seemingly promising opportunity is not viable. Even though researchers do not reach an exploitable discovery in these scenarios, they nonetheless generate valuable information for other researchers, helping them avoid unproductive paths and focus on more promising alternatives. Contrary to the case for successful research, the legal system does not have effective instruments for firms to internalize these informational externalities. The asymmetric treatment of success and failure has been openly rationalized by legal scholars: A "patent is not a participation trophy. One does not receive a patent for an invention one tried and failed to create, and the patent reward is based on success, rather than failure" (Feldman 2023: 286). In this paper, we develop a model to identify the shortcomings of the existing, one-sided reward system and investigate potential solutions to the problem.

We distinguish two sources of value associated with information generated by unsuccessful research. The first is that such information helps avoid duplicative pursuit of the same dead ends. This information increases the expected value of subsequent research by allowing firms to focus on fewer paths of research, increasing the likelihood that they may reach a successful result in the future. We will refer to this informational benefit as the "value of failure." The second is that findings from unsuccessful research can percolate to other lines of inquiry and possibly contribute to the general knowledge of an industry or scientific field. We will refer to these broader informational benefits as the "value of learning."

In the subsequent analysis, we develop a model that focuses on the underexplored value of failure problems, showing how the value of failure creates a discrepancy between private and social incentives for research. The identified wedge in research incentives adds to the learning externalities discussed in the existing literature.

The distinctive contribution of our model lies in capturing, in a simplified manner, the value of failure for innovation. The value of failure yields two important distortions. The first follows from the fact that the information generated by one firm's failure increases the expected value of subsequent research in the same field. This creates strategic incentives for researchers to delay investment so that they may take advantage of the negative information generated by prior research. This leads to socially sub-optimal *timing* in research investments. The second arises because firms do not fully internalize the value of the information they create. This leads to socially sub-optimal *levels of investment* in research.[1]

The insights derived from the model yield the following additional contributions. The leading proposals in the legal literature focus on mechanisms to increase the dissemination of negative information that firms inevitably acquire on the path to positive information (Parchomovsky and Mattioli 2011; Seymore 2012). But our model indicates that firms will wait too long and invest too little in generating negative information at all. As a result, it is

[1] Although the timing problem may be more significant in conjunction with information externalities arising from the finding of dead-ends (value of failure), suboptimal investment problems may also be significant in the presence of information externalities that benefit other lines of research (value of learning).

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not enough to encourage firms to disclose negative information they (inadvertently) produce in response to incentives to produce positive information; instead, we need mechanisms that encourage firms to invest sooner and more in the pursuit of negative information. Nevertheless, such mechanisms will not produce optimal outcomes unless they also encourage disclosure. We thus identify three paths for doing so and identify key implementation challenges that remain.

This paper is structured as follows. In "The value of failure" section, we carry out a brief review of the literature and build a sequential-stage patent race model to analyze how the information spillovers of research failures impact decisions regarding both timing and levels of research investments, deriving the socially optimal timing and levels of research investments. In "Incentivizing success and failure: protection vs. rewards" section, we consider the strengths and practical limitations of various protective and rewarding mechanisms as possible solutions to the value of failure problem. We summarize our results in two overarching propositions comparing the impact of protective and rewarding remedies on fostering optimal timing and aggregate investments in research. In "Market and legal solutions" section, we contemplate how legal and market instruments might foster the production and spread of negative information through an industry. "Conclusions" section concludes with final considerations and suggestions for future research.

## The value of failure

### Literature review

Innovation is a learning process where researchers rely on past results to inform their investment decisions. The vast theoretical literature on research and development ("R&D") and technological innovation, as well as recent empirical research on spillovers in R&D processes, has explored how firms build on their own and each other's failures and successes. A brief review of this literature will aid our understanding of the academic framing of the innovation process.

Very early in this literature, Tarde (1903) identified the initial steps of the innovation-decision process as "first knowledge" and "forming an attitude." Several studies have dealt with the first point, seeking to understand how firms learn from prior positive or negative experiences. Moreover, prior studies highlight how both positive *and* negative experiences hold important lessons for innovators. To elaborate on this point, it seems perfectly reasonable that, to learn the secrets of success, it would be efficient to study successful people and organizations. Thus, for example, authors of popular business books describe successful companies that have focused on one key product and argue that such focus caused the companies' success. However, organizational behavior research carried out by Denrell (2003) suggests that studying successes without also looking at failures tends to create a misleading, if not entirely wrong, picture of what it takes to succeed. Indeed, Denrell (2003) highlights Kodak and Xerox as examples of mono-focused companies that performed poorly over time.

While scholars generally acknowledge the potential learning benefits of failures (Lant and Montgomery 1987; Sitkin 1992; Marcus and Nichols 1999), the concept of failure has received limited attention in the law and economics literature, probably due to the shared wisdom that firms tend to privilege learning from success and are incapable of finding insights from failures (Denrell 2003; Baumard and Starbuck 2005). In focusing primarily on successes, scholars overlook the important fact that failing companies do many of the same things as companies that succeed.

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Drawing on these principles, the literature on research and learning is vast and methodologically diverse. Several contributions have pointed out that research organizations can learn by vicariously observing other players in the same field, including their failures (Levitt and March 1988; Chuang and Baum 2003; Baum and Dahlin 2007; Terlaak and Gong 2008; Francis and Zheng 2010). More recent papers have refined these insights (Haunschild and Sullivan 2002; Lapré and Tsikriktsis 2006; Baum and Dahlin 2007).

From a broader perspective, the outcome of research cannot be predicted. Indeed, one key function of the patent system is to encourage the pursuit of highly uncertain research (Merges 1992). Moreover, most research might be classified as a failure in the sense that the immediate results are not useful or exploitable. A problem arises in that organizations' and researchers' failures are not always highly visible. The knowledge and publication of failures might help organizations to indirectly gain learning benefits without directly experiencing the reputational and operational costs related to failure. Thus, Parchomovsky and Mattioli (2011) propose a "semi-patent" and Seymore (2012) proposes a "null patent" to facilitate dissemination of failures through the Patent Office. Krieger (2021) examines how negative information affects competitors' research, focusing on the biomedical industry, where clinical trial failures are publicly disclosed through FDA filings and industry reports. Same-market, same-technology failures send strong signals that often prompt competitors to terminate their own projects. Krieger finds that firms frequently overreact to such signals, terminating at rates disproportionate to the actual risk.

Our project closely aligns with Levmore (2013), who argues that the growing significance of knowledge in the modern economy necessitates a reevaluation of the traditional emphasis in patent law on new inventions and technological innovations. Several other papers have studied the optimal scope and efficiency of patents and trade secrets when research generates knowledge with potential positive spillovers on other researchers (Denicolo and Franzoni 2003, 2012; Franzoni 2016; Franzoni and Kaushik 2016).

The strand of literature on open innovation is also relevant to our research. Over the past three decades, open-access models have emerged as stable models for provisioning critical segments of information. The success of these practices has led prominent scholars to question the need for intellectual property instruments to foster optimal investments in research—these scholars point to the expanding frontiers of open source innovation as the emerging example of knowledge flow using a mix of pecuniary and non-pecuniary incentives (see, e.g., Benkler 2002, 2012, 2017). Open innovation scholarship criticizes the widespread reliance on intellectual property instruments for rewarding innovation, and their criticism would, to some extent, apply to our focus on instruments that reward research failures. We do not plan to engage in this debate. We hope, however, that our analysis may lead open innovation scholars to investigate the extent to which the incentives for open innovation considered in their models also account for the benefits of research failures and incentives to openly disclose negative information.[2]

## A simple sequential-stage model

Consider a sequential-move game involving $N$ firms engaged in an innovation race, such as the development of a new vaccine. The first firm to develop the vaccine gains patent rights and FDA exclusivity, securing the potential for significant financial returns from its

[2] For a recent review of this literature, see Bertello, De Bernardi, and Ricciardi (2024). For a methodological presentation of this research field, see Chesbrough and Bogers (2014), Holgersson and Granstrand (2021), and The Economist Group (2022).

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discovery. A firm enters the race as a first mover. Those engaging in research in later periods can observe the outcomes of earlier research.

Each Firm $i \in [1, N]$ invests $e_i$ in research. Not all research is successful in the sense of producing an exploitable invention; research may also reveal that a given invention will not be viable. We can categorize the two possible conclusive research outcomes as either "positive" or "negative."

1) *Positive result.* A positive research result allows the firm to capture the applicative value of its discovery (e.g., a pharmaceutical firm obtains FDA approval after its clinical trials demonstrate that a vaccine candidate is safe and effective). We shall broadly refer to the applicative value of positive results as the "value of success," $V$.
2) *Negative result.* A negative research outcome indicates that a chosen path is unviable (e.g., a vaccine candidate is toxic or ineffective). This has informational value, allowing other firms to avoid duplicating efforts and reallocating resources. We term this benefit the "value of failure," $F$. For the purpose of our analytical presentation, $F$ excludes the broader value of information that may aid other research or contribute to general industry knowledge (i.e., the "value of learning" generated by the firm's research).

In addition, research may be inconclusive in the sense that the results leave unclear whether a research path can produce an exploitable invention (e.g., a pharmaceutical firm conducts clinical trials, but the sample size turns out to be too small to produce statistically significant results). The probability of reaching a conclusive result, $p(e_i)$, is an increasing function of a firm's own research investment—i.e., $p' > 0$; with probability $1 - p(e_i)$, Firm $i$'s research is inconclusive. For our analysis, we assume that when a firm is unable to reach any positive or negative result, no applicative or informational value is generated, and the expenditure $e$ is largely a sunk waste of resources.

For ease of presentation and tractability of our results, let us consider a case where (1) a successful result can be reached following $M \geq N > 1$ possible lines of research; (2) only one of the $M$ lines of research can lead to a successful discovery[3]; and (3) firms do not reenter the patent race after failure.[4] A real-world example of this scenario is a field where start-up firms with specialized expertise attempt to introduce a novel product to market. If a start-up's effort reaches a dead end, it exhausts its funding and exits the market.

The first mover's research investment can lead to either a positive result (hereinafter, "success") with probability $p(e_1)\frac{1}{M}$ or a negative result (hereinafter, "failure") with probability $p(e_1)\frac{M-1}{M}$. In the former case, the first mover captures the value of his success, $V$. In the latter case, the negative result simply shows that the research path already pursued led to a dead end and it is not worth exploring again in the future.

When considering a firm's decision to invest in research, it is important to consider two countervailing effects of a firm's timing: (i) a "lost opportunity effect"—delaying increases the risk that others will make the discovery first; and (ii) an "informational benefit effect"—delaying allows the firm to learn from past research failures. In the following, we will proceed to illustrate these two effects analytically.

[3] The same qualitative results can be reached assuming that a larger subset, $m$, of the $M$ lines of research can lead to success, where $M > m > 1$.

[4] Our qualitative results still apply in the more general case where firms have a positive probability of reentering the race, though the gap between private and social optima would be narrower in such a scenario.

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(i) Lost opportunity effect

As a first mover, Firm 1 engages in research before all other firms, and will thus always have the full opportunity to pursue research, $\theta_1 = 1$. Subsequent firms' opportunity to engage in research hinges upon the probability that no other firm reached a successful result before them. Hence, for a generic Firm $i \in [1, N]$:

$$\theta_i = \frac{M - i + 1}{M} \tag{2.5}$$

Opportunities to engage in research thus decrease as the race progresses[5]:

$$\theta_1 > \theta_2 > \ldots > \theta_{N-1} > \theta_N \tag{2.6}$$

**Lemma 2.1: Lost Opportunity Effect.** *Delaying investment creates the risk that earlier movers will make the discovery first. The "lost opportunity effect" drives firms to accelerate their research investments.*
*This effect may induce firms to expedite their investment.*

(ii) Informational benefit effect

If publicly known, the failures of the early entrants in a patent race create an informational benefit to later researchers. Firms that delay research can increase their odds of success. Formally, Firm $i+1$ can benefit from the failure of Firm $i$ as it has one fewer path to consider.[6] Let $f_i$ represent the informational benefit generated by Firm $i$'s failure, which is received by all subsequent firms. In our case, this benefit can be quantified as follows:[7]

$$f_1 = \frac{1}{M-1} - \frac{1}{M} \tag{2.8}$$

$$f_2 = \frac{1}{M-2} - \frac{1}{M-1} \tag{2.9}$$

$$\cdots$$

$$f_{N-1} = \frac{1}{M-N+1} - \frac{1}{M-N+2} \tag{2.10}$$

$$f_N = 0 \tag{2.11}$$

The informational benefits from the failures of early movers flow down to all subsequent firms, while the failures of later movers do not impact those who entered earlier. For example, the informational benefit $f_1$ carries over to all remaining $N-1$ firms, whereas the informational benefit $f_{N-1}$ only benefits the last entrant, Firm $N$. A firm's expectations regarding the outcome of its research should therefore depend on both (1) the probability of reaching a conclusive result as a function of its own effort and (2) the information received from the failures of prior firms.

[5] Also note that, as the race progresses, waiting imposes incrementally larger losses of opportunity: $(\theta_1 - \theta_2) < (\theta_2 - \theta_3) < \ldots < \theta_{N-2} > \theta_{N-1}$.

[6] The reader might note that we are treating the situation as one of Knightian uncertainty. Future work may consider the more complex case in which firms' estimate of the probability of success of any given path are "updated" with the information generated by prior failures. Through this extension, the value of failure would increase and enhance the benefits of delaying research.

[7] The failure of the $N$th firm creates no informational benefit for other firms because, in the future, no other firms will invest in that line of research.

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$$V_2^f(e_2) = p(e_2)\left[\frac{1}{M} + f_1\right]V = p(e_2)\left[\frac{1}{M-1}\right]V \tag{2.12}$$

$$\dots$$

$$V_{N-1}^f(e_{N-1}) = p(e_{N-1})\left[\frac{1}{M} + f_1 + f_2 + f_3 \dots + f_{N-2}\right]V = p(e_{N-1})\left[\frac{1}{M-N+2}\right]V \tag{2.13}$$

$$V_N^f(e_N) = p(e_N)\left[\frac{1}{M} + f_1 + f_2 + f_3 \dots + f_{N-1}\right]V = p(e_N)\left[\frac{1}{M-N+1}\right]V \tag{2.14}$$

As shown in equations (2.12)–(2.14), a generic Firm $i \in [1,N]$ receives an informational benefit from the failures of previous firms, i.e., $\sum_1^{i-1} f_i$, and at the same time creates a flow of informational benefit for all subsequent firms, from $i+1$ to $N$. To capture this latter effect, let us define $F_i$ as the *cumulative* informational benefit generated by Firm $i$ to all subsequent firms:

$$F_i = (N-i)f_i, \forall i \in [1,N] \tag{2.15}$$

It is evident from the above that the marginal informational benefits, and the corresponding increases in success probabilities, grow as the patent race progresses, i.e.,

$$f_1 < f_2 < \dots < f_{N-1} \tag{2.16}$$

Since early failures benefit all subsequent firms in the race, the *cumulative* informational benefit created by early movers is higher than that of late movers:

$$1 > F_1 > F_2 > \dots > F_{N-1} > 0 \tag{2.17}$$

In our setting with sequential entries, the nature of the race suggests that firms receiving the most information generate the least informational benefit for others, and vice-versa. At the beginning of the race, early-movers receive little information (Firm 1 receives no information; indeed, $V_1^f(e_1)$ is omitted from equations (2.12)–(2.14) because $f_0$ does not exist); but generate a large flow of informational benefit for others (Firm 1's negative results benefit all subsequent firms in the race, as shown in equation (2.17)). At the end-tail of the race, late-movers receive large amounts of information (Firm $N$ receives information from all prior firms, as shown in equation (2.14)) but generate a small flow of informational benefit on others (indeed, at the very end of the race, Firm $N$ does not benefit any subsequent firm in the race, as shown in equation (2.17)).

**Lemma 2.2. Informational Benefit Effect.** *Delaying research allows firms to learn from past research failures, increasing their chances of success by avoiding known dead-ends. The "informational benefit effect" drives firms to delay their research investments.*

## Socially optimal incentives

Socially optimal research investments are those that promote research progress and maximize the total expected returns for all participating firms. In such an ideal scenario, firms would consider not only the expected value of their success, $V$, but also the informational value of their failures, $F$, after accounting for research costs:

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$$R_1^S(e_1) = p(e_1)\left[\frac{1}{M} + \frac{M-1}{M}F_1\right]V - e_1 \tag{2.18}$$

$$R_2^S(e_2) = p(e_2)\theta_2\left[\frac{1}{M} + f_1 + \frac{M-2}{M-1}F_2\right]V - e_2 \tag{2.19}$$

$$\cdots$$

$$R_{N-1}^S(e_{N-1}) = p(e_{N-1})\theta_{N-1}\left[\frac{1}{M} + \sum_{i=1}^{N-2} f_i + \frac{M-N+1}{M-N+2}F_{N-1}\right]V - e_{N-1} \tag{2.20}$$

$$R_N^S(e_N) = p(e_N)\theta_N\left[\frac{1}{M} + \sum_{i=1}^{N-1} f_i\right]V - e_N = p(e_N)\frac{1}{M}V - e_i \tag{2.21}$$

By comparing the firms' respective payoffs, we get the following lemma:

**Lemma 2.3. Socially Optimal Timing.** *The social return of the first-moving firm is higher than that of the second-moving firm, and so on for all subsequent firms, i.e.,* $R_1^{**} > R_2^{**} > \ldots > R_N^{**}$.

The first-moving firms generate larger social value because (i) they have the first opportunity to reach a successful result (i.e., no lost opportunity effect) and (ii), in case of a negative result, they generate the greatest flow of informational benefit onto the industry, which percolates down to all the subsequent firms (i.e., greatest informational benefit effect).

Let us derive the socially optimal investments. In our sequential race, a generic Firm $i \in [2,N]$ gets to enter the race and invests in research only if no other firm previously reached a successful result. That is, Firm $i \in [2,N]$ enters the race only if it has not lost the opportunity to make successful research; formally, given $\theta_i = 1$. At that time, firms choose their investment knowing that past firms failed. Formally, Firm $i$'s social maximization problem becomes:

$$\max_{e_i} R_i^S(e_i) | (\theta_i = 1) i \in [1,N] \tag{2.22}$$

Given that knowledge and conditional on that probability $\theta_i = 1$, when firms enter the research race, social optimality requires them to invest in research knowing that past firms have failed. Additionally, entering firms must include the value of their possible failure for subsequent firms in their optimization problem.

The firms' socially optimal levels of effort would thus be given by the following equations:

$$e_1^{**} : p'(e_1)\left[\frac{1}{M} + \frac{M-1}{M}F_1\right]V = 1 \tag{2.23}$$

$$e_2^{**} : p'(e_2)\left[\frac{1}{M} + f_1 + \frac{M-2}{M-1}F_2\right]V = 1 \tag{2.24}$$

$$\cdots$$

$$e_{N-1}^{**} = p'(e_{N-1})\left[\frac{1}{M} + \sum_{i=1}^{N-2} f_i + \frac{M-N+1}{M-N+2}F_{N-1}\right]V = 1 \tag{2.25}$$

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$$e_N^{**} = p'(e_N)\left[\frac{1}{M} + \sum_{i=1}^{N-1} f_i\right] V = 1 \tag{2.26}$$

Later firms have a reduced opportunity to enter the race, but, when those opportunities arise, they have increased probabilities of success. As a result, we get the following lemma.

**Lemma 2.4. Socially Optimal Investment.** *The socially optimal investments increase as the patent race progresses,* $e_N^{**} > \ldots > e_2^{**} > e_1^{**}$.

## Incentivizing success and failure: protection vs. rewards

In this section, we examine the interdependent roles of "protection" and "reward" mechanisms on firms' research incentives. We analyze the impact of these instruments on firms' (i) timing and (ii) investment decisions, comparing them to the benchmark scenario where negative information is neither protected nor rewarded.

Negative research results often pave the way for others' successes, advancing the overall progress of research. However, without legal or institutional mechanisms, firms tend to overlook the informational benefits their failures provide to others. This is most evident in the case of failing firms with no plans to reenter the patent race, as the only way to benefit from their own negative information is by reengaging. Lessons from past failures only help firms that intend to stay active in that field. Even then, firms' cost-benefit calculations typically ignore the value their failed research provides to others. Their investment decisions are driven solely by the potential to capture value $V$, without considering the informational value of $F$ to the industry. From an economic perspective, this creates a public good problem: third parties benefit from negative information without bearing the cost of generating it, leading to free-riding and *suboptimal timing* and *investment* in research.

Intellectual property law addresses this issue for positive results by granting property rights to the party that invested in successful research. Patents and copyrights both "protect" and "reward" successful discoveries. They "protect" by allowing firms to exclude third parties from using their research, and they "reward" by enabling owners to profit through supra-competitive pricing, licensing, or selling their invention. This system allows firms to internalize the positive externalities generated by their findings.

However, these mechanisms do not address the public good problem related to research failures. In this case, the "public good" is the information that improves future research success. When "negative" information is not protected, firms' incentives deviate from the social optimum, as they are less likely to move first, leading to a "suboptimal *timing* problem." Similarly, when the information from failed research efforts is not rewarded, firms do not fully internalize the benefits their research creates, leading to a "suboptimal *investment* problem."

To address these misalignments between private and social incentives, we explore alternative mechanisms for protecting and rewarding research failures. The following sections examine four categories of instruments, as outlined in Table 1, that offer protection or rewards to firms with unsuccessful discoveries.

This section is structured as follows: "The benchmark case: failures without protection or rewards" section outlines the benchmark case of failures without protection or rewards. "Protecting failure: trade secrets," "Rewarding failure: research subsidies," and "Protecting and rewarding failure: negative patents" sections, respectively, explore the impact of

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**Table 1** Protecting and rewarding failures.

| | | **Reward** | |
|---|---|---|---|
| | | **No ($\phi = 0$)** | **Yes ($\phi = 1$)** |
| **Protection** | **No ($\omega = 0$)** | 1. None (Benchmark) | 3. Research Subsidies |
| | **Yes ($\omega = 1$)** | 2. Trade Secrets | 4. Negative Patents |

protection (trade secrets), rewards (research subsidies), and a combination of both (negative patents) on addressing research failures.

## The benchmark case: failures without protection or rewards

Consider again the sequential-move game from "The value of failure" section, where $N$ competitors engage in research, making investment decisions after observing the outcomes of earlier efforts. A firm enters a patent race as a first mover. Its research investment can lead to either a positive result (i.e., "success") with probability $p(e_1)\frac{1}{M}$, a negative result (i.e., "failure") with probability $p(e_1)\frac{M-1}{M}$, or no results with probability $1-p(e_1)$.

Without legal or institutional mechanisms to protect or reward the informational value of failure, the first mover's expected return is based solely on the value of its success, minus research costs. As a first mover, Firm 1 faces no lost opportunity effect from prior attempts and gains no informational benefit from predecessors' failures. Its expected return from the research is therefore given by:

$$R_1(e_1) = p(e_1)\frac{1}{M}V - e_1 \tag{3.01}$$

If later entrants base their investment decisions on earlier research outcomes, Firm 1's failure generates valuable information. If Firm 1 produces no results, no information is gained, and Firm 2 faces the same expected returns and incentives as Firm 1. However, if Firm 1 achieves any results, Firm 2 enters the race with the benefit of that information. With probability $\frac{M-1}{M}$, Firm 2 will consider Firm 1's negative results and capture the informational benefit of Firm 1's failure. However, with probability $\frac{1}{M}$, Firm 1 could achieve a successful result, causing Firm 2 to face a loss of opportunity. Firm 2's expected return would thus become:

$$R_2(e_2) = p(e_2)\theta_2\left[\frac{1}{M} + f_1\right]V - e_2 = p(e_2)\frac{1}{M}V - e_2 \tag{3.02}$$

As can be seen from equation (3.02), the two effects—informational benefit and loss of opportunity—offset one another, giving Firm 2 the same expected returns as Firm 1. The $N$th firm' expected return would be:[8]

[8] The full offsetting of informational benefits and lost opportunities in our model is due to the assumption that all paths have an equal likelihood of success. If we relax this and assume firms can reasonably estimate a path's likelihood of success, the lost opportunity effect would outweigh the informational benefit. However, the ability to produce accurate estimates likely increases over time as firms can benefit from the information generated by prior failures, potentially shifting the balance in favor of informational benefits. We leave the analysis of these extensions to future work.

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$$R_N(e_N) = p(e_N)\theta_N\left[\frac{1}{M} + \sum_{i=1}^{N-1} f_i\right]V - e_N = p(e_N)\frac{1}{M}V - e_N \tag{3.03}$$

Late movers can capture the informational benefit created by earlier firms, but their delayed entry will cause a loss of opportunities. As firms delay, both benefits and losses increase, and in this benchmark case, the two effects fully offset each other. The next lemma follows straightforwardly:

**Lemma 3.1. Timing Incentives in the Benchmark Case.** *The private returns are identical for all firms, i.e., $R_1 = R_2 = \cdots = R_N$, with the last mover's expected returns coinciding with the socially optimal ones ($R_N^S = R_N$). This will yield a pace of research that falls below the socially optimal level.*

These results show that in a regime where negative information from failures is neither protected nor rewarded, firms have no incentive to start research early, leading to a slower pace of research compared to the socially optimal level.[9]

Let us now discuss investment incentives. When deciding on timing, firms weigh the expected returns of early versus late entry, aiming to maximize their payoff. This choice is based on success and failure probabilities, without knowing how they will unfold. In contrast, a firm makes its investment decision only if it still has the opportunity to enter, knowing that no prior firm has succeeded. Similarly to equation (2.22), a generic Firm $i$ will maximize its expected private return, given that it still has the opportunity to make a successful discovery (i.e., no prior firm has succeeded); formally:

$$\max_{e_i} R_i(e_i) | (\theta_i = 1) i \in [1, N] \tag{3.04}$$

Hence, the privately optimal investments in research are given by the following equations:

$$e_1^* : p^{'}(e_1)\frac{1}{M}V = 1 \tag{3.05}$$

$$e_2^* : p^{'}(e_2)\frac{1}{M-1}V = 1 \tag{3.06}$$

$$\cdots$$

$$e_{N-1}^* : p^{'}(e_{N-1})\frac{1}{M-N+2}V = 1 \tag{3.07}$$

$$e_N^* : p^{'}(e_N)\frac{1}{M-N+1}V = 1 \tag{3.08}$$

As in the case of socially optimal efforts, the information externalities created by early movers in the research race increase the success probability for later entrants by narrowing

[9] Due to the positive information externalities that arise from failures in research, as the number of research paths and competing firms grows larger, it is possible that no firm would choose to be the first to enter a new field of research. If the number of research avenues and the number of competitors tends toward infinity, the expected profit for the 1st competitor would tend toward zero and the expected profit for the $N$th competitor would tend toward the value of innovation: $\lim_{M,N\to\infty} R_1 = \lim_{M,N\to\infty} \frac{1}{M}V - e_N = 0$ and $\lim_{M,N\to\infty} R_N = \lim_{M,N\to\infty} \frac{1}{M-N+1}V - e_N = V$. This would lead to a stall in the research process, even in the hypothetical case where the total expected benefits of research exceed the total expected costs.

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the available research paths. As a result, unlike what we have seen when considering expected payoffs, we get the following lemma:

**Lemma 3.2. Investment Incentives in the Benchmark Case.** *The investment incentives of firms that enter the race grow stronger as the patent race progresses,* $e_N^* > \ldots > e_2^* > e_1^*$. *Firm research efforts fall below the socially optimal levels,* $e_i^{**} > e_i^*$ *for all Firms* $i \in [1, N)$, *with only the last-mover converging toward optimality,* $e_N^{**} = e_N^*$.

The discrepancy between the privately and socially optimal incentives to invest in research stems from the fact that firms' socially optimal efforts are determined by the sum of the expected *marginal and cumulative* values of success, *V*, and failure, *F*, while privately optimal efforts are only driven by the corresponding expected *marginal* values.

## Protecting failure: trade secrets

Now consider a state of the world, $\omega = 1$, corresponding to Case (2) in Table 1, where a firm's negative results are fully protected. Instruments like trade secrets prevent firms in a patent race from benefiting from the negative information of earlier firms. Granting protection to the information generated by their failures does not change the earlier firms' research outlook. Firms' returns remain tied to successful results, net of costs, as in the benchmark case in "The benchmark case: failures without protection or rewards" section. Though firms can block others from using their negative information, they cannot capture the informational value for themselves. Follower firms, unable to use this information, face similar returns to the first mover. Firms' expected returns under this protective regime are:

$$R_1^{\omega}(e_1) = p(e_1)\frac{1}{M}V - e_1 \tag{3.09}$$

$$R_2^{\omega}(e_2) = p(e_2)\theta_2\frac{1}{M}V - e_2 \tag{3.10}$$

$$\ldots$$

$$R_N^{\omega}(e_N) = p(e_N)\theta_N\frac{1}{M}V - e_N \tag{3.11}$$

By nullifying informational benefits for later entrants, the protection regime removes the advantage of waiting, eliminating the last-mover benefit seen in the previous regime. As the race progresses, the likelihood of a firm achieving success increases, reducing opportunities to enter for late movers.[10] The next lemma follows straightforwardly:

**Lemma 3.3. Timing Incentives under Trade Secrets.** *In a protective regime, waiting only creates a lost opportunity effect for late movers, leading to a first-mover advantage,* $R_1^{\omega} > R_2^{\omega} > \ldots > R_N^{\omega}$.

Similarly to equation (3.05), a generic Firm *i* will maximize the expected private return given that it has not yet lost the opportunity to make a successful discovery, formally:

[10] This result may explain the empirical finding showing that patents are less important in industries where firms can effectively rely on a combination of first-mover effects and trade secrecy. See Graham et al. (2009).

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$$\max_{e_i} R_i^{\omega} \ (e_i) \mid (\theta_i = 1) \ i \ \in [1, N] \tag{3.12}$$

In a protective regime, every firm carries out research without access to the information acquired by prior firms' research and failed investments. As a result, we arrive at the following lemma:

**Lemma 3.4. Investment Incentives under Trade Secrets.** *In a protective regime, all competitors exert the same research efforts,* $e_N^{\omega*} = \cdots = e_2^{\omega*} = e_1^{\omega*} = e_1^*$. *Every firm's effort level falls short of socially optimal levels,* $0 < (e_1^{**} - e_1^{\omega*}) < (e_2^{**} - e_2^{\omega*}) < \ldots < (e_{N-1}^{**} - e_{N-1}^{\omega*}) < (e_N^{**} - e_N^{\omega*})$.

In a protective regime, the effort levels of all firms, including the first mover, are below socially optimal levels. Unlike in the benchmark case (Lemma 3.2), the last-mover's effort does not converge toward optimality, $e_N^{**} < e_N^{\omega*}$.

## Rewarding failure: research subsidies

Information externalities, like other externalities, can be addressed through tax or subsidy systems. In the following, we consider the state of the world $\phi = 1$ corresponding to Case (3) in Table 1, where firms are rewarded with subsidies for disclosing negative research results. For example, a firm could voluntarily publish its failed research in exchange for a subsidy, funded by the pool of likely beneficiaries. The subsidy would need to reflect the external benefit of the firm's information, though determining this value may be challenging for a central agency.[11]

Subsequent firms can then benefit from the publicly available information.[12] When engaging in research, each firm's expected return consists of the expected value of its positive result (i.e., "success") plus the expected reward, $S_i > 0, \forall i \in [1, N-1]$, obtainable from the publication of its negative result (i.e., "failure"), net of research costs.

$$R_1^{\phi}(e_1) = p(e_1)\left[\frac{1}{M}V + \frac{M-1}{M}S_1\right] - e_1 \tag{3.13}$$

$$R_2^{\phi}(e_2) = p(e_2)\theta_2\left[\left(\frac{1}{M} + f_1\right)V + \frac{M-2}{M-1}S_2\right] - e_2 \tag{3.14}$$

$$\ldots$$

$$R_{N-1}^{\phi}(e_{N-1}) = p(e_{N-1})\theta_{N-1}\left[\left(\frac{1}{M} + \sum_{i=1}^{N-2} f_i\right)V + \frac{M-N+1}{M-N+2}S_{N-1}\right] - e_{N-1} \tag{3.15}$$

[11] In most situations, the value of a firm's failure only reaches other firms that are active in the same industry or line of research. In these cases, an industrial subsidy paid through revenue raised within the specific industry would be the appropriate instrument, to avoid inter-industrial effects. Conversely, when the benefits of the information extend to broader networks and to society at large (such as for the more general case of learning), governmental subsidies may be a viable instrument.

[12] In our scenario, failing firms are assumed not to reenter the patent race, making them more likely to disclose their negative results to receive the subsidy. Qualitatively similar results obtain when firms have an opportunity to re-enter the race.

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$$R_N^{\phi}(e_N) = \ p(e_N)\ \theta_N\left[\frac{1}{M} + \ \sum_{i=1}^{N-1} f_i\right]V - \ e_N = p(e_N)\frac{1}{M}V - \ e_N \tag{3.16}$$

Firms will pursue research as soon as an opportunity arises. As the first mover, the initial firm can either succeed and capture the value $V$, or fail and receive the largest available subsidy, $S_i$, and so on for all subsequent firms.[13]

**Lemma 3.5. Timing Incentives under Research Subsidies.** *The subsidy regime generates a first-mover advantage: The private return of the first mover is higher than that of the second mover, with each subsequent firm receiving progressively lower returns,* $R_1^{\phi}(e_1) > R_2^{\phi}(e_2) > \ldots > R_N^{\phi}(e_N)$. *Under a properly gauged subsidy regime* $(S_i = F_i V < V, \ \forall i \in [1, N-1])$*, private and social timing incentives will be aligned for all N firms:* $\left(R_1^S - R_1^{\phi}\right) = \left(R_2^S - R_2^{\phi}\right) = \cdots = \left(R_{N-1}^S - R_{N-1}^{\phi}\right) = \left(R_N^S - R_N^{\phi}\right) = 0$.

When firms make their investment decisions, they have complete information about the outcomes of previous firms' research efforts. Their opportunity to invest arises only if all earlier firms have failed to achieve success. In this context, the firms' private optimization function becomes:

$$\max_{e_i} R_i^{\phi}(e_i) | (\theta_i = 1) i \in [1, N] \tag{3.17}$$

The firms' privately optimal efforts in research under a research subsidy regime will thus be based on the knowledge of those past events, and their respective effort levels are given by the following equations:

$$e_1^{\phi *} : p^{'}(e_1)\left[\frac{1}{M}V + \frac{M-1}{M}S_1\right] = 1 \tag{3.18}$$

$$e_2^{\phi *} : \ p^{'}(e_2)\left[\left(\frac{1}{M} + f_1\right)V + \frac{M-2}{M-1}S_2\right] = 1 \tag{3.19}$$

$$\ldots$$

$$e_{N-1}^{\phi *} : p^{'}(e_{N-1})\left[\left(\frac{1}{M} + \sum_{i=1}^{N-2} f_i\right)V + \frac{M-N+1}{M-N+2}S_{N-1}\right] = 1 \tag{3.20}$$

[13] One might worry that rewarding failure could encourage firms to pursue low-effort "cheap failures." However, our model rules out this possibility by construction, because the cost of research is fixed and identical for both success ($V$) and failure ($F$), with $V > F$. A firm thus always prefers to succeed. Failure is the undesired byproduct of the firm's search for success, and the reward for failure serves only as fallback compensation. If one were to extend the model to allow for heterogeneous costs—so that failures could be generated more easily or at lower cost than successes—"cheap failures" would correspondingly generate less valuable information, leading to smaller rewards. The risk of "gaming the system" would then be self-correcting. Needless to say, as with many centrally administered tax and subsidy systems, determining the appropriate subsidy amount can be challenging, and firms may distort information. If negative results are not verified, firms could claim failure, attempting to collect subsidies without genuinely engaging in research. If the central authority makes errors in distinguish between a true dead end and an abandoned or uninformative project firms may put minimal effort into research while falsely claiming subsidies, a problem more pronounced in the early stages of the race, when the subsidies are larger.

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$$e_N^{\phi^*} : p^{'}(e_N)\left[\frac{1}{M}+\sum_{i=1}^{N-1} f_i\right]V=1 \tag{3.21}$$

The value of negative information to other firms changes as the patent race progresses. To align incentives optimally, the subsidy amount must be carefully calibrated and linked to the expected cumulative value of the negative information, in the amount of $S_i = F_i V < V,\ \forall i \in [1, N-1]$,[14] with $F_i$ as expressed as in equation (2.15), i.e., $F_i = (N-i)f_i,\ \forall i \in [1, N]$.[15] Given the decreasing cumulative marginal value of firms' failures observed in equation (2.17), i.e., $1 > F_1 > F_2 > \ldots > F_{N-1} > 0$, this would require reducing the amount of the subsidy as the patent race progresses, with higher subsidies given to the firms that pioneered newer research.

In an ideal world with efficiently determined subsidies, firms' incentives would align with the social optimum. Public access to earlier movers' research would increase the probability of success for later entrants. Consequently, under this regime:

**Lemma 3.6. Investment Incentives under Research Subsidies.** *In a subsidies regime, each firm's privately optimal effort levels coincides with the socially optimal levels:* $(e_1^{**} = e_1^{\phi^*}) < (e_2^{**} = e_2^{\phi^*}) < \ldots < (e_{N-1}^{**} = e_{N-1}^{\phi^*}) < (e_N^{**} = e_N^{\phi^*})$*, with research efforts growing stronger as the patent race progresses,* $e_N^{\phi^*} > \ldots > e_2^{\phi^*} > e_1^{\phi^*}$.

In sum, the use of research subsidies can solve the suboptimal timing problem observed in the benchmark case ("The benchmark case: failures without protection or rewards" section) and the suboptimal investment problem observed in the protection regime ("Protecting failure: trade secrets" section).

## Protecting and rewarding failure: negative patents

Consider a state of the world corresponding to Case (4) in Table 1, where negative research results are fully protected by an enforceable right to exclude ($\omega = 1$), and this right is transferable ($\phi = 1$). In this scenario, the right to exclude "protects" the information, while the right to transfer "rewards" the firm. This regime, akin to the patent system for positive information, would grant property-type protection to negative information, allowing firms to sell or resell these rights. We refer to this as the "negative patents" regime. Under this regime, negative information is not publicly available—only the firm that owns it has access.

The failing firm's reservation price for selling the information is zero, as it cannot otherwise benefit from it. However, an entering firm values the information positively and is willing to pay for it. The immediate benefit that a firm would obtain from Firm $i$'s information is $f_i V$. The buying firm knows that, if it also fails, it can resell the information, raising its valuation to $F_i V$. As both firms benefit from trading, the negative patent will transfer at a price between 0 and $F_i V$.

[14] The informational benefit gained by a failing firm increases the likelihood of future discoveries but is, by definition, less than the actual value of the discovery. This undermines the objections raised by Feldman (2023: 286), who argued that compensating for failure incentivizes inefficient invention and creates a paradoxical scenario where greater failure yields higher rewards. Our findings demonstrate that, contrary to Feldman's assertion, no rational firm would allocate resources toward pursuing failures over success.

[15] As a policy measure, the subsidy should be capped at the actual level of investment undertaken. This limitation prevents firms from pursuing research solely to produce negative results and claim subsidy payments, ensuring that no profit accrues to failing firms. Additionally, it discourages research investments that exceed socially optimal levels.

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Under the negative patent regime, firms' expected returns would factor in the costs of acquiring information from earlier firms and the revenue from selling negative information (both acquired and produced) to later firms. In a symmetric information trading environment, we assume the gains from trade will be shared based on the parties' relative bargaining power.[16] Let $\alpha$ and $1-\alpha$ respectively denote the bargaining power of the seller (i.e., the failing firm, selling the negative patent) and the buyer (i.e., the following firm, purchasing the negative patent), with $\alpha \in [0,1]$.[17] In an asymmetric valuation setting, $\alpha$ can similarly be used to capture asymmetries in the firms' valuation of the negative information.[18]

Consider Firm 2 acquiring a negative patent that grants access and exclusive ownership to the negative information from Firm 1's research failure. This patent will provide Firm 2 with a direct informational benefit of $f_1$. In case of its own failure, Firm 2 will also be able to resell the negative patent to the subsequent firm, capturing the downstream informational value $(N-2)f_1$.[19] In case of failure, Firm 2 will additionally have the negative information generated by its own failure, $F_2$. The total information owned by Firm 2 after its own failure will thus be $(F_1 - f_1) + F_2$.

The same logic applies to the value of negative patents for later entrants. After its failure, Firm 3 will own the combined information from Firms 1 and 2, with a total value of $(F_1 - 2f_1) + (F_2 - f_2) + F_3$. The information acquired by Firm $N$ has no resale value, as no further firms will enter the race to purchase it.

Let us denote the value of the negative patent that a generic Firm $i$ can transfer to Firm $i+1$ as:

$$\pi_i = \left\{ F_i + \sum_{j=1}^{i-1} [F_j - (i-j)f_j] \right\} \mathrm{V} \tag{3.22}$$

Recall that with probability $1-p(e_i)$, Firm $i$ will reach no result. In this case, Firm $i$'s research adds no new information, $F_i = 0$. Firm $i$ will exit the race, reselling the

[16] Our analysis shows that failing firms can capture more or less of the informational value of their negative patents depending on their bargaining power relative to prospective buyers. For simplicity, we assume $\alpha$ represents the sellers' (failing firms') bargaining power as an exogenous parameter. This assumption can be relaxed to account for firm-specific differences in $\alpha$, without changing our qualitative results. Following Dunlop and Higgins (1942), patience and competition are key determinants of bargaining power. In our case, failing firms are the sole sellers, while multiple firms may compete under time pressure to buy the negative patent, giving sellers an advantage. However, if only one buyer approaches, both firms have zero outside options. In this case, a Nash bargaining split of the patent's value is likely. For more, see Aghion and Holden (2011), Holden and Malani (2014), and Choi and Triantis (2012) on competition as a restraint on bargaining power.

[17] Under the alternative bargaining protocol used in the literature, the seller and buyer make a demand/offer with certain probability, exogenously given. Under this alternative protocol, the probabilities $\alpha$ and $1-\alpha$ can be understood as proxies for the bargaining power of the seller and buyer, respectively. Assume the failing firm (seller) makes a take-it-or-leave-it (TIOLI) demand with probability $\alpha \in (0,1)$ ; the new entrant firm (buyer) makes a TIOLI offer with the remaining probability, $(1-\alpha)$. When the failing firm gets to make a TIOLI offer, its demand will approach $F_i V$. On the other hand, if the buying firm gets to make the TIOLI offer, the offering price will approach the reservation value of the failing firm, 0.

[18] This framework allows for asymmetries in how firms value negative information. The division of surplus via the bargaining parameter $\alpha$ could in this case be used to reflects the fact that failed knowledge may be worth more (or less) to the firm that holds it than to potential recipients. This structure would preserve our results, while ensuring that transactions occur only when mutual gains exist, and that the private value of failure need not match its social value in order for exchange to take place.

[19] The sum of the direct and patent resale values of the information will thus equal $(N-1)f_1$. For a generic Firm $i$, the sum of the direct and resale patent values of the information will thus be equal to $F_i = (N-i)f_i, \quad \forall i \in [1,N]$, as defined in equation (2.15).

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previously acquired information at price $\alpha\ \pi_i$, in this case equal to $\alpha\ \pi_{i-1}$ for $\forall i \in [1, N-1]$.

Additionally, for Firm 1,$\pi_1 = F_1 V$, because the patent $\pi_1$ conveys only the information derived from Firm 1's failure (no prior failures occurred before Firm 1). Under our trading environment, Firm $i$ will thus be able to capture a share of the value of its negative patent, obtaining a price $\alpha\ \pi_i$, for $\forall i \in [1, N-1]$.

Under a negative patent regime, the firms' expected returns will thus be:[20]

$$R_1^{\rho}(e_1) = p(e_1)\left[\frac{1}{M} + \frac{M-1}{M}\alpha F_1\right]V - e_1 \tag{3.23}$$

$$R_2^{\rho}(e_2) = \theta_2\left\{p(e_2)\left[\left(\frac{1}{M} + f_1\right) + \alpha f_1\right]V - e_2\right\} \tag{3.24}$$

$$\dots$$

$$R_{N-1}^{\rho}(e_{N-1}) = \theta_{N-1}\left\{p(e_{N-1})\left[\left(\frac{1}{M} + \sum_{i=1}^{N-2} f_i\right) + \alpha f_{N-2}\right]V - e_{N-1}\right\} \tag{3.25}$$

$$R_N^{\rho}(e_N) = \theta_N\left\{p(e_N)\left(\frac{1}{M} + \sum_{i=1}^{N-1} f_i\right)V - \alpha\pi_{N-1} - e_N\right\} \tag{3.26}$$

where $\pi_{N-1}$ in equation (3.27) is defined as in equation (3.23).

**Lemma 3.7: Timing Incentives under Negative Patents.** *When sellers have no bargaining power,* $(\alpha = 0)$*, early movers have lower private returns than later movers,* $R_1^{\rho}(e_1) < R_2^{\rho}(e_2) < \dots < R_N^{\rho}(e_N)$*, as they generate information for followers without receiving revenue or benefiting from prior firms' information. In contrast, when sellers have full bargaining power* $(\alpha = 1)$*, early movers have higher private returns,* $R_1^{\rho}(e_1) > R_2^{\rho}(e_2) \lesseqgtr \dots \lesseqgtr R_{N-1}^{\rho}(e_{N-1}) > R_N^{\rho}(e_N)$*. This is because early movers benefit most from cumulative informational gains,* $\frac{M-1}{M}F_1$*, without incurring costs for acquiring past information.*

As for what occurs between the two extremes, the ranking between the other competitors' expected returns cannot be clearly stated. Indeed, as the race progresses, two countervailing factors affect the expected revenues: the *decreasing* opportunity to reach successful research vs. the *increasing* informational benefits from previous competitors' failures. For example, by comparing Firm $N-1$'s vs Firm 2's expected returns, we have that $\theta_{N-1} < \theta_2$, but $\sum_{i=1}^{N-2} f_i > 2f_1$. This results in $R_2^{\rho}(e_2) \lesseqgtr \dots \lesseqgtr R_{N-1}^{\rho}(e_{N-1})$.

Similarly to equation (2.22), a generic Firm $i$ will maximize its expected private return, when it still has the opportunity to make a successful discovery, formally:

[20] Firm 2's expected returns in equation (3.24) directly derives from these steps: $R_2^{\rho} = \theta_2\left\{p(e_2)\left[\left(\frac{1}{M}+f_1\right)V + \frac{M-2}{M-1}\alpha\pi_2\right] + (1-p(e_2))[\alpha\pi_1] - \alpha\pi_1 - e_2\right\} =$
$\theta_2\left\{p(e_2)\left[\left(\frac{1}{M}+f_1\right)V + \frac{M-2}{M-1}\alpha\pi_2\right] - p(e_2)\alpha\pi_1 - e_2\right\} = \theta_2\{p(e_2)[\left(\frac{1}{M}+f_1\right)V + \alpha\left(\frac{M-2}{M-1}\pi_1 - \pi_2\right)] - e_2\}$. By substituting $\pi_i$ as expressed in equation (3.22), $R_2^{\rho} = \theta_2\left\{p(e_2)\left[\left(\frac{1}{M}+f_1\right)V + \alpha\left(\frac{V}{M(M-1)}\right)\right] - e_2\right\}$, where $\frac{V}{M(M-1)} = f_1 V$, hence equation (3.24). Similar steps apply to compute the expected returns of the remaining $N-1$ firms.

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$$\max_{e_i} R_i^{\rho}(e_i) \mid (\theta_i = 1)\, i \in [1, N] \tag{3.27}$$

The firms' privately optimal research efforts under a negative patent regime are described by the following equations:

$$e_1^{\rho*} : p'(e_1)\left[\frac{1}{M} + \frac{M-1}{M}\alpha F_1\right]V = 1 \tag{3.28}$$

$$e_2^{\rho*} : p'(e_2)\left[\left(\frac{1}{M} + f_1\right) + \alpha f_1\right]V = 1 \tag{3.29}$$

$$\cdots$$

$$e_{N-1}^{\rho*} : p'(e_{N-1})\left[\left(\frac{1}{M} + \sum_{i=1}^{N-2} f_i\right) + \alpha f_{N-2}\right]V = 1 \tag{3.30}$$

$$e_N^{\rho*} : p'(e_N)\left(\frac{1}{M} + \sum_{i=1}^{N-1} f_i\right)V = 1 \tag{3.31}$$

**Lemma 3.8: Investment Incentives under Negative Patents.** *When sellers have full bargaining power* $(\alpha = 1)$*, the research investments of the first and last movers approach the socially optimal level, with* $e_i^{\rho*} \to e_i^{**}$*, with,* $e_N^{\rho*} > e_1^{\rho*}$*, while the other firms invest below the optimal level. If sellers have no bargaining power* $(\alpha = 0)$*, and buyers capture the full value of the information, firms' incentives revert to those in the absence of protection or rewards,* $e_i^{\rho*} \to e_i^{*}$*. Hence* $e_N^{\rho*} > \ldots > e_2^{\rho*} > e_1^{\rho*}$*, and only the last mover invests at the socially optimal level,* $e_N^{\rho*} = e_N^{**} = e_N^{*}$*.*

## Main results: effects of protective vs. rewarding remedies on research

We are now in a position to compare the impact of protective and rewarding remedies on fostering optimal research. The first mover's returns under the four regimes are key to predicting which regimes yield timely participation. Aggregate investment levels reveal which regime supports socially optimal research investments.

Our analysis shows that socially optimal returns from research investments are more easily achieved through rewarding instruments, such as research subsidies and negative patents, than through protective instruments like trade secrets. The key feature of rewarding instruments is the financial incentive for firms to disclose negative information. Research subsidies rely on regulatory mechanisms, offering rewards for industry-wide disclosure, while negative patents rely on markets, allowing firms to sell their negative information to others. Rewarding instruments have two important effects: (i) they incentivize firms to disclose negative information, making it available to others and (ii) they allow firms to benefit not only from successes but also from the knowledge gained through failures. The expected returns differ between regimes: under negative patents, subsequent firms must pay for the information, which lowers their returns compared to the subsidy regime.

Protective instruments, like trade secrets, prevent others from using a firm's negative information, but they also limit industry access to valuable knowledge. This creates a risk of duplicative research and prevents firms from internalizing the value of their failures.

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**Proposition 1: Returns from New Research.** *Research subsidies and negative patents when the sellers have full bargaining power provide first movers with expected returns close to the social optimum, promoting optimal timing for new research.*

$$\left(\underbrace{R_1^S}_{\text{Social}} = \underbrace{R_1^\phi}_{\text{Subsidy}} = \underbrace{R_1^\rho(\alpha=1)}_{\substack{\text{Negative}\\ \text{Patent}\\ (\alpha=1)}}\right) > \underbrace{R_1^\rho(\alpha\in(0,1))}_{\substack{\text{Negative}\\ \text{Patent}\\ (\alpha\in(0,1))}} > \left(\underbrace{R_1}_{\text{Benchmark}} = \underbrace{R_1^\omega}_{\substack{\text{Trade}\\ \text{Secret}}} = \underbrace{R_1^\rho(\alpha=0)}_{\substack{\text{Negative}\\ \text{Patent}\\ (\alpha=0)}}\right) \quad (3.32)$$

**Corollary 1.**

i) *A research subsidy regime, with $S_i = F_i V$, brings both first mover and aggregate expected returns to the socially optimal level.*

ii) *A negative patent regime can achieve the same result for the first mover when sellers have full bargaining power $(\alpha = 1)$. In this case, the first failing firm can price the negative patent at $\pi_1 = F_1 V$ capturing the full informational value of its failure, thereby approaching social optimality and encouraging optimal research investments. However, aggregate returns under this regime will be lower due to the costs imposed on subsequent firms for purchasing information.*

iii) *In the other cases (i.e., benchmark case, and negative patents with $\alpha = 0$ or $\alpha \in (0,1)$), firms, including the first mover, do not capture the full benefit of their failures. As a result, both first mover and aggregate returns fall below the social optimum.*

The difference in expected revenues between the subsidy and negative patent regimes stems from the source of rewards for failing firms. Subsidies are paid by the industry or government, but they are not cost-free. If funded by general government revenues, the cost is spread across society (this spreading of the cost might be sensible for research that has widely-dispersed benefits). If funded by the industry, the burden falls on a smaller group of firms (this concentration of the cost might be sensible for research that has more narrowly-felt benefits). If the subsidies are funded from an industry-specific tax (or similar mechanism), then their impact on the expected revenues from research would be similar to that of the negative patent regime.

Our analysis indicates that rewarding instruments, such as research subsidies and negative patents, are more effective than protective instruments, like trade secrets, in creating socially optimal research incentives.

**Proposition 2: Aggregate Investments in Research.** *The aggregate investments ($Ae = \sum_{i=1}^{N} e_i$) that firms make under the alternative regimes can be ranked as follows vis-à-vis the social optimum:*

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$$\left(\underbrace{Ae^{S}}_{\text{Social}} = \underbrace{Ae^{\phi}}_{\text{Subsidy}}\right) > \underbrace{Ae^{\rho}(\alpha=1)}_{\substack{\text{Negative}\\ \text{Patent}\\ (\alpha=1)}} > \underbrace{Ae^{\rho}(\alpha\in(0,1))}_{\substack{\text{Negative}\\ \text{Patent}\\ (\alpha\in(0,1))}} > \left(\underbrace{Ae}_{\text{Benchmark}} = \underbrace{Ae^{\rho}(\alpha=0)}_{\substack{\text{Negative}\\ \text{Patent}\\ (\alpha=0)}}\right) > \underbrace{Ae^{\omega}}_{\substack{\text{Trade}\\ \text{Secret}}} \tag{3.33}$$

**Corollary 2.**

i) *A research subsidy regime, $S_i = F_i V$, results in aggregate research investments that match the social optimum, fostering a socially optimal investment in research.*

ii) *Negative patents with $\alpha = 1$ yield the second highest level of investment. In this case, failing firms capture the informational value of their failures, but entering firms face higher costs due to patent fees compared to the research subsidy regime, where information is freely available.*

iii) *Other regimes lead to lower aggregate investments. Trade secrets produce the lowest investment, followed by the benchmark case and negative patents with $\alpha = 0$. Negative patents regime with $\alpha \in (0,1)$, leads to a comparatively higher but still suboptimal level of investment, as failing firms capture only a portion of the informational benefits from their failed research.*

In sum, rewarding instruments can more effectively promote socially optimal outcomes for both research timing and investment. In contrast, the current intellectual property system, which primarily protects negative information through trade secrets, is far from achieving the social optimum. Protective instruments like trade secrets prevent failing firms from capturing the value of their failures, and additionally restrict the dissemination of valuable knowledge, preventing the industry from benefiting from negative information generated through failed research. This lack of information sharing leads to inefficiencies, such as redundant research efforts and delayed innovation, compared to alternative solutions.

## Market and legal solutions

In "Incentivizing success and failure: protection vs. rewards" section, we explored the problem of negative information in four stylized scenarios. In this section, we map those stylized scenarios to the real world. We first explore how actual exit mechanisms enable failed firms to obtain some modest compensation for their negative information. Although reality is less worrisome than the benchmark scenario, it still appears to fall well short of the ideal. Second, we explain how the patent system could provide legal scaffolding for transactions over negative information. We also propose reforms to the patent system that would better account for the value of failure. Finally, our model indicates that subsidies can best align social and private incentives with respect to negative information. We identify prizes as the preferred form for those subsidies and describe novel ways to use prize systems to serve this goal.

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## Exit mechanisms

In our benchmark scenario, a firm that discovers negative information simply exits; it obtains no reward at all. But in the real world, a firm that discovers negative information can choose one of several exit mechanisms. And while some exits will match the benchmark scenario of no reward, others might enable the firm's owners to obtain some compensation. To be clear, such compensation will still fall well below the social value of the negative information that the failed firm discovered. Nevertheless, compared to the benchmark scenario of no reward, these exit mechanisms can soften the blow of failure.

One exit mechanism is formal bankruptcy. A firm that becomes insolvent upon discovering negative information could file for bankruptcy. In a Chapter 7 proceeding, a court-appointed trustee liquidates the firm's assets to pay the firm's creditors some fraction of what it owes; investors and employees ordinarily receive nothing.[21] This is the closest scenario to our benchmark. In a Chapter 11 proceeding, a court oversees a reorganization of the firm's debts in an effort to preserve its going-concern value; in this scenario, investors and employees may recover some value. But because that value depends principally on the positive information that the firm eventually produces, it would not mitigate the problems we identify.[22]

Two other exit mechanisms may, however, partially compensate failed firms for the value of negative information. The first is an assignment for the benefit of creditors ("ABC"); the second is an acqui-hire. High-tech firms often opt for one of these alternatives to formal bankruptcy (Mann 2004; Pollman 2023).

Begin with the ABC. Angel and venture capital investors in high-tech firms typically do not own common stock. Instead, they own convertible notes, convertible preferred stock, and other instruments that give them priority over at least some claimants upon exit (Bratton 2002; Smith 2005; Ibrahim 2008). They can accordingly participate to some extent in the proceeds obtained for a failed firm's assets. And in these settings, an ABC will give these investors more than a formal bankruptcy. Failed high-tech firms have unique, hard-to-value, intangible assets. A court-appointed trustee will not often have the expertise to accurately appraise those assets; such a trustee will also be unable to identify the buyers who would pay the most for them. In an ABC, however, the failed firm's board and shareholders agree on an assignee to liquidate the firm's assets. This handpicked assignee will typically have the expertise to properly evaluate the failed firms and the relationships required to identify prospective buyers.

The ABC procedure itself, however, is insufficient for investors and key employees of high-tech firms to recover meaningful value for their failures. The key is that these ABCs take place within Silicon Valley's famously tight-knit network of repeat players (Saxenian 1996). As detailed by Mann (2004) and Pollman (2023), several Silicon Valley firms specialize in managing ABCs. Their role in providing quick, low-cost, and value-maximizing alternatives to formal bankruptcy proceedings is now well-known.

[21] Although we refer simply to the "firm" for most of our analysis, at exit, it is important to distinguish the investors and employees who make the decisions to invest in research from creditors and others who may have claims upon an insolvent firm. This distinction matters because those investors and employees may be more willing to make the initial investments if they anticipate recovering something in the event of failure.

[22] Chapter 11 proceedings sometimes result in a sale of the firm. When those sales are driven by the value of the firm's negative information, they could resemble the assignment for the benefit of creditors or the acqui-hire. In some instances, then, a Chapter 11 proceeding could be viewed through the lens that we provide for those two alternatives to formal bankruptcy. We thank Anthony Casey for this point.

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Less well-appreciated, however, is that these ABC specialists might effectively function as the intermediaries required to facilitate a market for negative information. In the "negative patent" regime we model, failed firms could use the formal legal system to (1) prevent rivals from using negative information and (2) transfer the right to control negative information. Firms could then capture some of the value of failure, as a function of their bargaining power. Our hypothesis is that, in some settings, failed firms can rely on ABC specialists to achieve a similar result.

Because of their position in Silicon Valley's innovation ecosystem, high-tech ABC specialists can apply reputational penalties that keep the risk of opportunism to a tolerable level; this facilitates at least partial disclosure of negative information to potential buyers. We do not argue that ABC specialists can punish all instances of buyer opportunism—ABC specialists would still face the ordinary problems associated with proving unauthorized use of negative information. But they might have privileged access to insiders that could alert them to the most egregious instances of opportunism; like Shasta County's ranchers, they might then be able to keep a rough tally of who owes what to whom that gives sellers enough protection to enter into these transactions (Ellickson 1991). Negative information might also serve as a "gift" bestowed by the ABC specialist on the buyer, which will be paid back to the seller in some later deal. In any event, the repeated nature of the interactions among the various players would be critical to giving sellers the assurance they need to engage in at least some disclosures.

On the other side of the transaction, buyers might rely in part on ABC specialists to appraise the negative information. Here, the reputation of the ABC specialist is of paramount importance. That reputation appears to suffice for buyers to purchase assets in an ABC even though they are sold without ordinary bankruptcy protections (Pollman 2023). Indeed, this is a core part of the value proposition offered by Silicon Valley's most well-known ABC specialist, Sherwood Partners, which has a rich database of potential buyers and a track record of monetizing the intellectual property of failed Silicon Valley firms.[23] Buyers might similarly rely on ABC specialists' reputation to gain confidence that the prices they are asked to pay are not unreasonable. Silicon Valley's informal rules and reputation-based innovation ecosystem might thereby enable failed firms to obtain some compensation for the value of the negative information they discovered.

To the extent that buyers are still only willing to pay significantly less than the value of failure, ABC firms could reward investors and key employees of failed firms indirectly through mechanisms that would not be subject to the prioritization of claims that determines payouts in a bankruptcy. For example, an investor in a failed firm who chooses Sherwood to conduct an ABC might then be given a privileged opportunity to purchase the assets of another failed firm. Or Sherwood might recommend the investor as a trustworthy partner for a new venture. Or it could help the key employees of a failed firm find funding for their next project. In these ways, the investors and key employees of a failed firm that discovered negative information might receive some indirect compensation for the value of that information, even if it still falls short of the information's social value.

Another common exit mechanism for high-tech firms is an acqui-hire (Coyle and Polsky 2013). In an acqui-hire, an established tech firm buys a startup, jettisons most of its assets,

[23] Sherwood touts its ability to do so as part of its pitch to its clients. "Furthermore, if IP is involved, we have the expertise and deep relationships with the IP buying community to work towards the best outcome. We have the experience and relationships to undertake sales and licensing opportunities, lending against, or purchasing patents, trademarks, copyrights, trade secrets, and know-how." https://www.sherwoodpartners.com/debtor-and-creditor-representation

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and retains only a group of skilled employees. Because the buyer shuts down or abandons the acqui-hired firm's projects, those projects can be understood as failures. Acqui-hires serve several purposes, including giving the startup's founders a graceful exit, allowing the buyer to obtain enforceable noncompete agreements binding the startup's skilled employees, keeping founders together with IP assets they created, and ensuring those IP assets cannot be used against the buyer (Coyle and Polsky 2013; Sawicki 2015; Lemley 2016; Pollman 2023). We hypothesize that they might also be mechanisms for (1) compensating a failed firm's investors and key employees; and (2) granting the buyer access to and some control over the failed firm's negative information.

Buyers who are interested in hiring a failed startup's employees could simply poach them, in which case those employees would receive one hundred percent of the deal price. When buyers instead pursue an acqui-hire, they divert some of the deal price to the startup's investors and employee shareholders (Coyle and Polsky 2013). Those investors and key employees thus receive some compensation they would not receive in a formal bankruptcy exit.

Meanwhile, the buyer typically obtains three things that facilitate its access to and control over negative information. First, the failed startup grants the buyer a covenant not to sue for hiring the startup's employees (Coyle and Polsky 2013). As a practical matter, this covenant makes it easier for the buyer to access the negative information possessed by the failed firm's employees because it prevents the failed firm from pursuing the most effective means of preventing such access (i.e., suing for breach of a non-solicitation or noncompete covenant).[24] Second, the buyer obtains noncompete agreements from the failed startup's key employees (Coyle and Polsky 2013). This gives the buyer some control over the failed startup's negative information insofar as the key employees will join the buyer and will not be able to use it at other firms. Finally, the buyer often also obtains any patents and trade secrets owned by the failed firm or possessed by its key employees (Sawicki 2015; Pollman 2023). These further limit rivals' use of negative information.

To the extent that the price paid for the failed startup reflects in part the value of its negative information, acqui-hires resemble the "negative patent" markets we describe in our model.[25] Thus, as is the case for ABCs, acqui-hires leverage the social norms of high-tech ecosystems (Coyle and Polsky 2013; Pollman 2023) to support transactions involving negative information.

Nevertheless, the picture is not entirely rosy. In all of these scenarios, the failed firm is almost surely not being fully compensated for the social value of the negative information it discovered. Informal mechanisms like trust and reputation cannot provide the sorts of control over negative information that patents and contracts can provide over positive information. Sellers will be reluctant to completely disclose their negative information for fear that buyers will use it without detection; buyers will be reluctant to pay for the full social value of negative information in the absence of such disclosure and because of concerns that they will lack adequate control over whatever information they pay for. So while ABCs and acqui-hires in tight-knit innovation ecosystems might mitigate the problems in our benchmark scenario, they do not offer a complete solution. We accordingly turn our attention to patents.

[24] Massachusetts (and other states with robust high-tech startup ecosystems) have been willing to enforce noncompetes, and California has been less hostile to them than is conventionally understood (Barnett and Sichelman 2020).

[25] We acknowledge that only a portion of the price paid will reflect the value of failure. For example, key employees may have valuable talent and skills that the buyer is paying to obtain.

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## Patents

In line with traditional assumptions, our model treats a patent as a winner-takes-all reward that issues at the end of a race to the first firm that uncovers positive information (Loury 1979). But real-world patents are more complex. They arise at various points in the development of a technology, including well before the inventor can produce a commercially viable product (Kitch 1977; Sichelman 2010). In addition, they can encompass negative information, including predictions that turn out to be incorrect and embodiments that do not work as described (Seymore 2018; Freilich 2019; Mar and Pardini 2022). Making matters worse, patents ordinarily do not reveal that their predictions are wrong or that certain embodiments in fact do not work; instead, such negative information is usually kept secret even though it relates to technology that falls within the scope of the patent's claims (Seymore 2018).

While these features of the patent system have been much criticized (Kapczynski and Syed 2013), our analysis suggests that they might have an unexpected upside: ordinary patents on (early) positive information could provide formal legal scaffolding to support a "negative patent" market in (later) negative information. Furthermore, our model points the way to reforms that could help such markets work better.[26]

To see how, suppose a firm is researching electrolytes suitable for solid-state batteries. It achieves promising preliminary results on one material. The firm then obtains a patent claiming it as part of a class of related materials that it has not yet tested.[27] Subsequent experiments, however, demonstrate that the initial material will not work. The firm, meanwhile, has run out of capital to continue its research.

The firm might now try to sell the patent on the class of materials. While the initial material failed, one of the related materials in the claimed class may work, and another firm might want to investigate them. Note that while the patent itself will not disclose the newly-uncovered negative information, the buyer would want to acquire it in order to enjoy the informational benefit effect.[28]

The challenge here is the fundamental problem in trading information highlighted by Arrow's (1962) information paradox: before disclosure, a buyer will refuse to pay because it does not know what it is paying for; after disclosure, the information loses its value since the buyer will not pay for something it now possesses. This paradox is especially pronounced for negative information because of the difficulty in detecting whether a potential buyer used negative information. Even if firms could obtain patents on pure negative information (i.e., patents that conferred exclusivity in negative information standing alone), it would be nearly impossible to demonstrate that others avoided pursuing a specific

[26] There are, of course, considerations that counsel against the issuance of early patents (Merges and Nelson 1990; Lemley 1997; Lemley 2004). We focus here on this previously unnoticed benefit.

[27] The enablement requirement demands that the inventor explain in the patent how to make and use the invention (*Amgen v. Sanofi*, 598 U.S. 594, 2023). That explanation, however, can include "made-up experiments and fictional data" (Freilich 2019: 666). In addition, the inoperative embodiments doctrine and the flexible *Wands* factors make it possible for applicants to meet the enablement requirement even when they have not actually tested a large number of the claimed embodiments (Seymore 2018). Preliminary data on one material therefore often satisfies the enablement doctrine across a range of related materials. Similarly, the utility requirement prevents a patent from issuing when the applicant cannot articulate a plausible use for an invention (*Brenner v. Manson*, 383 U.S. 519, 1966). But courts have not been particularly demanding. An applicant need only provide evidence that reasonably supports her assertions regarding potential uses (*In re Brana*, 51 F.3d 1560, Fed. Cir. 1995).

[28] The initial patent would not include the negative information at the outset because the first firm discovered that negative information after the patent issued.

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approach precisely because they had knowledge of the negative information disclosed in the "negative patent." Consequently, sellers in these scenarios would face severe challenges in capturing the market value of negative information, leading to systematic underinvestment and underdisclosure.[29]

These problems are known by IP practitioners, and courts have been tackling them, though in a piecemeal fashion. Negative trade secrets—know-how about what does not work—are legally protectable. In cases like *Genentech v. JHL Biotech*, successful plaintiffs pair detailed evidence of misappropriated failed formulas or protocols with proof that the thief could avoid costly dead ends thanks to that information, justifying injunctions despite the use being "virtually untraceable".[30] Other decisions show the line blurring between negative and positive secrets, leading some courts to re-label negative know-how as its positive mirror image.[31] Alternatively, when positive information is also available, firms can bundle negative know-how with related positive trade secrets to survive judicial scrutiny (Mar and Pardini 2022). Still, in the mine run of cases, a prospective buyer's use of negative information will be difficult to observe, making recourse to the judicial process ineffective in overcoming Arrow's challenges to information exchange.

We explained one way to meet these challenges in "Exit mechanisms" section. In close-knit innovation ecosystems, trusted intermediaries can connect potential buyers and sellers, reduce the risk to sellers of buyer opportunism, and help buyers properly price negative information. Nevertheless, even in these ecosystems, failed firms are unlikely to be fully compensated for their investments in research—social norms can only go so far to mitigate the risk of opportunism by buyers, so under-compensation persists.

However, if those norms are backed by a patent obtained early in the innovation process, the seller might be able to extract a price closer to the social value of the negative information. Social norms buttressed by early patents can facilitate negotiations over the failed firm's broader portfolio of information assets. These negotiations would resemble the staged disclosures that Burstein (2012) describes in the context of positive information. At the start, the failed firm would simply present the buyer two options: (1) it could buy the patent standing alone, or (2) it could buy the patent along with the failed firm's trade secrets and know-how. We expect that a seller would first refer generally to trade secrets and know-how; it would not disclose detailed negative information about a specific embodiment.[32] If the buyer expressed interest, the failed firm could provide some partial

[29] Beyond legal or market settings, negative information is also valued in high-stakes sectors such as aerospace and military strategy. For example, space startups like Astra, or competitors in national defense, routinely monitor failed launches or failed prototypes of their rivals to avoid repeating errors. Historical rivalries in tech—such as between Microsoft and Apple—also illustrate how awareness of others' failed development paths can shape product strategy.

[30] *Genentech, Inc. v. JHL Biotech, Inc.*, No. C 1806582 WHA, 2019 WL (N.D. Cal. June 13, 2019).

[31] In *Maharis v. Omaha Vaccine Co.*, 967 F.2d 588 (9th Cir. 1992), for example, the court reasoned that the value of a list of customers who have expressed an interest in a product is greater than a list of all customers precisely because "exclud[ing] people not interested in the product [has] value from a negative viewpoint." In a very similar case, in *Courtesy Temporary Service, Inc. v. Camacho*, 222 Cal. App. 3d 1278 (1990), the California Court of Appeal explicitly recognized that knowing that a customer is not interested constitutes a trade secret under the Uniform Trade Secrets Act, effectively re-labeling the negative know-how of "whom not to target" as equivalent to knowing the positive—a mirror image of what does work—information that has commercial value and is protectable.

[32] Although in our example the inventor discovered that the initial material did not work, in reality the inventor might have discovered that any of the materials within the claimed class did not work. The buyer accordingly would not be able to infer from the fact of the offer (or of the firm's failure) which of the materials in the class does not work.

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disclosure about the nature of its trade secrets and know-how, including negative information, while stopping short of full disclosure (Burstein 2012).

Crucially, even upon partial disclosure, the buyer would not be able to fully exploit negative information regarding the tested embodiment. Because the early patent's claims will encompass both tested and untested embodiments, the failed firm could prevent the buyer from making, using, or selling not only the embodiment that does not work, but also the ones that may turn out to work. Thus, while the buyer could use the negative information by avoiding the failed embodiment, it could do so only at the cost of being unable to pursue the untested embodiments. Moreover, the patent's disclosure of the class of materials ought to provide a reasonable basis for valuing the negative information. Finally, because the patent confers at least some bargaining power on the seller, our model suggests that this scenario would be an improvement over the benchmark. Arrow's impediments to information exchange thus do not seem to present insurmountable obstacles in these scenarios.

To be sure, such an approach is not guaranteed to work. Although a claim is not invalid merely because a few inoperative embodiments fall within its scope, "if the number of inoperative combinations becomes significant," the claim "might indeed be invalid" (*Atlas Powder Co. v. E.I. du Pont De Nemours & Co.*, 750 F.2d 1569, 1576-77, Fed. Cir. 1984). Upon partial disclosure, then, a buyer may pursue the untested embodiments without paying, relying instead on the ability to raise an invalidity argument if the seller subsequently sues for infringement. This approach would therefore work better earlier in a race, when the number of known inoperative embodiments is relatively small, than later in a race, when the number of known inoperative embodiments becomes significant.

That said, this still may be inadequate to support broad markets for negative information. In many instances, especially outside close-knit innovation ecosystems, search costs would prevent buyers and sellers from finding each other. Prospective buyers of positive information can search patent registries to find potential sellers; meanwhile, there is no registry of negative information, which must be concealed in order to be protected as a trade secret (Graves 2007; Hrdy and Seaman 2024). Although some subset of patentees will in fact possess negative information, prospective buyers have no way of knowing which ones.[33] In Silicon Valley and similar ecosystems, trusted intermediaries can introduce potential buyers to potential sellers of negative information. But outside those contexts, more is needed.

The literature includes interesting proposals for making the patent system a more effective mechanism for disseminating negative information. For example, Parchomovsky and Mattioli (2011) propose a "semi-patent," which would require "disclosure of all research results—both positive and negative—that led to the claimed invention." The semi-patent would offer the same set of rights as an ordinary patent; in exchange for the more robust disclosure it demands, Parchomovosky and Mattioli suggest that the semi-patent feature faster examinations, reduced fees, and longer duration. Seymore (2012), meanwhile, proposes a "null patent," which would provide a structured format for the disclosure of negative information. The null patent, however, would not offer any exclusionary rights; instead, because firms acquire substantial amounts of negative information as part of their

[33] A patentee approached by an arm's-length prospective buyer will not readily disclose the existence of negative information; after all, a patent claiming an embodiment that works is more valuable than a patent claiming one embodiment that is known to fail and several other embodiments that may or may not work. The seller in these scenarios would not be eager to disabuse the buyer of the illusion that the embodiments in the patent work as described.

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ordinary research processes, Seymore argues that modest inducements, like expedited review or fee reductions on other patent applications, may elicit considerable disclosures.

We agree with the spirit of these proposals: optimal aggregate investment can only be achieved with widespread dissemination of negative information. We are less optimistic, however, that the inducements for disclosure in the "semi-patent" and "null patent" proposals will be adequate to encourage firms to participate. In particular, there is no obvious way to calibrate the value of the inducements in their proposals to the value of the information disclosed. In our view, it is worth considering ways to support markets that might better calibrate the value a failed firm can appropriate to the value of its negative information.

We propose that patentees be able to "flag" their own patents when they discover negative information that pertains to the subject matter of the claimed invention. The flag would appear in electronic searches of the Patent Office's database, akin to the "negative treatment" flags that appear in legal databases like Westlaw and Lexis. The substantive negative information would be disclosed to the Patent Office, which would keep it confidential (as it typically does with pending applications) until the patent expires, at which point it would become public.[34] This flagging system would reduce the search costs that a potential buyer of negative information would otherwise incur. Any entity interested in buying negative information could search the patent registry for flags. They could then attempt to purchase the patent along with the negative information through a staged disclosure as described above.

The improved prospects of selling information on those markets may prove sufficient to motivate some use of this flagging mechanism. That said, we agree with existing proposals that additional inducements may be required. To that end, we note that over 50% of patents are ultimately abandoned for failure to pay maintenance fees (U.S. Patent and Trademark Office 2024).[35] These patents likely encompass negative information—after all, the patentee paid roughly $20,000 in attorneys' fees and PTO fees to initially obtain the patent, but refused to pay roughly $15,000 over 11.5 years to keep it in force. Although that may be due to changes in general market conditions, the inventor's idiosyncratic circumstances, or unusual scenarios in which the patent's value was expected to be more than $20,000 but less than $35,000, it seems likely that a significant fraction of patents are not renewed because subsequent research revealed negative information.

As a result, one inducement to encourage disclosure through flags is to reduce or waive renewal fees for applicants who submit negative information to the Patent Office.[36] To be

[34] This could resemble the existing Information Disclosure Statement ("IDS"). (37 C.F.R. § 1.97-1.98.) Applicants have a duty of candor that can be satisfied by submitting an IDS to the Patent Office if information material to patentability becomes known while the application is pending. (37 C.F.R. § 1.56(a); MPEP § 2001.04.). That duty, however, can also be satisfied simply by cancelling or amending claims, rather than submitting an IDS. In addition, the duty of candor does not extend after patent issuance; any negative information discovered in the years after issuance, then, would not be captured by the existing IDS mechanism.

[35] Maintenance fees are due at 3.5, 7.5, and 11.5 years from issuance. In the current fee schedule, the PTO charges $2,150 at 3.5 years; $4,040 at 7.5 years; and $8,280 at 11.5 years. Reduced fees are available for smaller entities. A summary of the current fee schedule is available at https://www.uspto.gov/learning-and-resources/fees-and-payment/uspto-fee-schedule#Patent%20Fees.

[36] We acknowledge that it may still be better for a firm to keep negative information secret. Supposing that a firm does not exit upon discovering negative information, the waived or reduced maintenance fees combined with the prospect of selling a patent that would otherwise expire may be a relatively modest sum compared to the value of allowing the firm's rivals to waste money pursuing a dead-end. Still, the

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sure, this inducement would have to be carefully calibrated. If the inducement works as intended, then some patents that would otherwise have been abandoned will instead remain in force and impose corresponding social costs. Ideally, those social costs would be outweighed by the social benefits associated with increasing dissemination of negative information that would otherwise have been kept secret. But there is no guarantee that this would be the case.

Moreover, optimal policy, may entail a system that allows firms to choose between intellectual property rights and rewards (Shavell and van Ypersele 2001). Our proposed flagging system might therefore be fruitfully combined with a buyout scheme along the lines of that proposed by Kremer (1998). When a patentee flags its patent, it could also opt-in to an auction for that patent along with its negative information, at least as codified in the firm's laboratory notebooks, codebases, and similar artifacts. To be sure, such an approach would capture the value only of codified negative information; tacit negative information could not easily be auctioned. We might also worry that the patentee could coordinate with bidders to manipulate the auction (Chari, Golosov, and Tsyvinski 2012). Still, given the lack of mechanisms to compensate firms for negative information, we think that further research on possible combinations of "negative patents" and reward systems is warranted.

## Prizes

Our model indicates that optimal outcomes can only be achieved with subsidies that disseminate negative information to all participants in the race. Even the best theoretical market-oriented mechanism will not result in optimal aggregate research investments because each firm (except the first-mover) would incur private costs to acquire negative information produced by its predecessors. Our model does not, however, directly address what form those subsidies should take.

We think that prizes are the most promising. Because effort is difficult to verify but essential for producing definitive outcomes, ex post subsidies should be preferred over ex ante subsidies (Hemel and Ouellette 2019). We are also skeptical that government can identify ex ante who would be the most efficient producer of negative information (Hemel and Ouellette 2019). For those reasons, prizes seem preferable to grants and direct spending. Meanwhile, tax credits do not seem especially helpful in settings where failed firms exit because these entities likely will not have much taxable income to offset.[37] Still, tax policy could be a more useful instrument when considering joint ventures or large firms with multiple ongoing research projects. In this setting, a more modest suggestion would be to allow firms to deduct a larger share of experimentation costs when they publish negative or null results to a shared repository. This less information-demanding solution could help close the gap between the expected returns of positive and negative outcomes.

The chief obstacle to the use of prizes for negative information is that it may be difficult to specify criteria for awarding the prize. With that difficulty in mind, we describe here three ways in which prizes might be deployed to improve policy with respect to negative information.

First, prizes might be directly offered for the production and disclosure of negative information. We are not aware of any prizes explicitly designed to elicit negative information

mechanism may improve the situation compared to the status quo in which such patents simply expire and the negative information is kept secret.

[37] Although tax credits won't do much to incentivize the firms considered in our model (we assume that failing firms exit the race and this will not have any future taxable revenue), expanding our lens to include larger firms with ongoing operations would make tax policy a more effective tool.

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about potential but not yet realized technological advances. The most well-known innovation prizes—like the Longitude Prize, the Ansari X PRIZEs, and DARPA's Grand Challenges—all provide(d) rewards for positive information.

The closest analogue to a prize for negative information at a technological frontier is a vulnerability rewards program ("VRP"), commonly known as a "bug bounty." VRP sponsors, like Google and Mozilla, pay when someone discloses that a designated software product is vulnerable to malicious actors (Finifter, Akhawe, and Wagner 2013). Because the software is intended to prevent this possibility, the software vulnerability can be conceptualized as negative information—the software does not work as desired. And empirical studies indicate that VRPs can be efficient from the perspective of the program sponsor (Finifter, Akhawe, and Wagner 2013; Walshe and Simpson 2020; Sridhar and Ng 2021).

The analogy is admittedly imperfect. As a general matter, it seems easier to validate a software vulnerability report than it would be to validate negative information in other settings. In addition, unlike the firms we focus on, the researchers who discover software vulnerabilities appear to be significantly motivated by non-pecuniary factors (Sridhar and Ng 2021). For those who wish to monetize the discovery of software vulnerabilities, moreover, there are few legal alternatives to VRPs. Prizes for negative information at a technological frontier may be more difficult to implement than VRPs. Still, VRPs serve as proof-of-concept for our proposal.

As noted, specifying criteria for awarding negative information prizes is no small task. The problems generally associated with proving a negative seem particularly pronounced in this context because the point is to advance the technological frontier; any technological goal that would plausibly be the subject of such a prize would be impossible to achieve given the existing state of the art. The "negative information" offered to claim a prize could thus comprise little more than a declaration that the technology does not exist.

Nevertheless, prizes "in practice fall along a spectrum of generality," ranging from those that "permit submission of any innovation or startup under the sun" to those "that describe the problem to be solved in painstaking detail" (Reinicke 2018: 129). Prize administrators have significant flexibility to determine what kinds of demonstrations merit rewards. And they may indeed be able to distinguish (1) an observation that a technology does not exist, from (2) a demonstration that it would be impossible to achieve it.[38]

Consider, for example, the field of optics in the late 1800 s. At that time, it was unclear just how powerful a light microscope could be invented. A prize might have been offered for either a light microscope that could be used to visualize atoms or for a demonstration that such a technology could not be achieved. A prize administrator would not have accepted a mere statement that then-existing microscopes could not visualize atoms. But the administrator would justifiably have awarded Ernst Abbe the prize for his discovery of the eponymous Abbe diffraction limit, which proved that light microscopes could not visualize things as small as atoms. An analogous scenario today might involve potential designs for fusion reactors—a prize might be offered either for a sustainable fusion reactor or for a demonstration that a particular approach to fusion reactors (e.g., a stellarator-based reactor) is unworkable.

[38] Just how "impossible" a technological path must be in order to merit a prize is one of the challenges that prize administrators would have to overcome. As an example, it may have been reasonable to say that it would have been impossible, during the Roman Empire, to produce a technology that would enable Roman soldiers to travel to the farthest reaches of the empire in under a day, even though it is possible to do so today. The many advances required were so far beyond the reach of that civilization that it was, for all practical purposes, impossible, even if the laws of physics permit it.

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Ordinary prizes for positive information might also be reformed so that they too can ameliorate the problems of negative information. Prizes are not straightforward compensation instantly paid to an inventor for disclosing her invention; in practice, prizes are typically structured competitions involving repeated interactions between organizers and competitors. They constitute "a particular institutional arrangement for governing the uncertainty and asymmetric information that plagues most technological innovation" (Burstein and Murray 2016: 406).

One possibility, then, is for internal prize governance to require participants to disclose negative information they discover during the competition. As Burstein and Murray (2016) describe the Auto X Prize, each participating team entered into a Master Team Agreement with the organizers. The competition proceeded in multiple stages, with teams required to achieve milestones in order to proceed to the next stage. The Master Team Agreement, which included provisions regarding ownership of intellectual property generated during the competition, could have required disclosure of technical information by teams that failed to achieve a given milestone. It could also have compensated teams that disclosed valuable negative information over the course of the competition.

Another possibility is to invite "red teams" to compete against participants attempting to achieve some positive goal. Continuing with the Auto X Prize, the competition sought to reward the winner of a long-distance race in a production-capable vehicle that exceeded 100 miles-per-gallon energy equivalent. Participants attempted a variety of fuel sources and vehicle designs. The organizers could have invited red teams that sought to demonstrate that a given participant's proposal would fail. If a red team succeeded (for example, by producing evidence that persuaded a participant to drop out), it could earn a portion of the prize purse. Of course, the red team concept also presents challenges, especially in calibrating the compensation due to a red team and in avoiding collusion between ordinary participants and red teams.

In sum, there seem to be several unexplored opportunities to use prizes to address the problems of negative information. We do not wish to overstate the case—prizes for negative information may only be feasible in limited circumstances given the challenges we have identified. Still, given the paucity of existing solutions to the problem of negative information, as well as the sophisticated governance of prize competitions and access to expertise that prize organizations have, we think further research into those challenges is warranted.

## Conclusions

Negative information short-cuts expensive experimentation. In R&D-intensive sectors (pharma, advanced materials, complex software), each failed pathway represents months or years of lab work and regulatory filings. Acquiring a competitor's "don't bother" data can therefore yield substantial savings in development budgets, costly regulatory filings, and research redirected toward more promising venues. Negative results mark a failure in the research path—one that, to paraphrase Paul Romer, is "a terrible thing to waste."[39]

In this paper, we examined the distortions created by the lack of rewards obtainable for negative research results. Whereas academic researchers may be encouraged to share negative information by the opportunity to publish research in dedicated journals, private firms

[39] Paul Romer first used the line "A crisis is a terrible thing to waste" at a venture-capital meeting in California in November 2004, in remarks about rising foreign education levels, as reported by Rosenthal (2009).

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have stronger incentives to withhold negative information to prevent giving competitors an advantage. To foster a socially optimal level of research, markets and legal mechanisms should provide incentives to pull firms out of the trade secret regime, encouraging disclosure of information that firms might otherwise keep secret. The inability to capture the full social value of negative information weakens firms' incentives to invest in high-expected-return projects that also entail multiple likely dead ends in research. The asymmetric treatment of successes and failures generates suboptimal levels of research investments in several common situations.

Our analysis demonstrates that socially optimal research incentives can be achieved by implementing mechanisms that reward both a firm's successes and failures. We explored two such mechanisms: research subsidies and negative patents. Both approaches create financial incentives for firms to disclose negative information from unsuccessful research. Research subsidies encourage industry-wide disclosure, while negative patents restrict the information to specific firms. These mechanisms have significant effects: they incentivize firms to share negative findings with others in the industry and allow firms to benefit from both successful and unsuccessful research. In contrast, trade secrets, while protecting negative information, do not optimize research downstream incentives as they lead to duplicative efforts and suboptimal returns.

Our findings suggest that research subsidies offer the best potential to align private and social research incentives, despite practical challenges such as funding and accurately valuing negative information. Negative patents also present a viable alternative by protecting and monetizing failures, though they may result in lower overall industry returns compared to subsidies. The choice between these instruments could influence research investment flows across industries, depending on the regime adopted.

Extensions of our model should explore the robustness of our findings by relaxing some of its simplifying assumptions. One key area for further investigation is the assumption that all unexplored research paths are equally likely to succeed, and that researchers have no ability to reduce uncertainty regarding the success probability of any given path. This assumption overlooks the fact that acquiring information about others' failures could enhance a firm's ability to estimate the likelihood of success for remaining research paths. For instance, knowing that a particular compound does not bind to a target should enable firms to update their beliefs about the likelihood that structurally similar compounds will bind to that target.

Another area worthy of exploration is the model's focus on the value of failure while setting aside the interconnected value of learning. As a result, our function $p(e)$ does not account for the potential learning that can occur from prior research failures. This assumption could be relaxed to consider situations where failures also contribute to learning, such as the development of skills or techniques that enhance a firm's ability to conduct its own research. A firm's ability to reach a conclusive result (positive or negative) would require less effort as the stock of learning increases: in nascent fields, it might be relatively more difficult to achieve successful outcomes than in mature ones. This extension would require a recalibration of our policy implications to account for the fact that failures can reveal information that improves firms' chances of eventual success.

Moreover, further analysis is necessary before drawing definitive normative conclusions about the desirability of specific policy instruments. To mention a few points worthy of exploration, our model assumes a sequential research process, where each new firm can acquire information from prior failures. However, this sequential process breaks down when firms engage in parallel research. In such cases, a subsidy regime would make negative

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information available to all competitors, whereas negative patents would only share the information with one or a few firms, excluding others. Under a patent system, equilibrium is likely to yield exclusive patent rights granted to a single firm, rather than licenses shared among multiple firms, as exclusive patents mitigate the duplicative costs of parallel research. Further research should therefore explore the comparative advantages of patent and subsidy mechanisms under these conditions.

A similar extension of our model should investigate the robustness of our findings by relaxing the assumption that failing firms exit the race after a single failure, such as for larger firms engaged in multiple lines of research. When a firm holds a significant market share and internalizes the value derived from its failures, the subsidy can be reduced. A dominant firm benefits from the knowledge gained through its failures, allowing it to refocus its research and maintain a competitive edge. By internalizing this value, the firm requires fewer incentives, allowing for a reduction in the subsidy. Relatedly, when firms undertake parallel rather than sequential research, joint ventures could be important for internalizing the value of negative information. Joint ventures have a dual effect: while they can promote optimal research investment in contexts where negative results are probable, they may also reduce prospective competition. An interesting extension would examine how antitrust law should approach joint ventures given this tension.

Lastly, our analysis concentrated on the effects of information externalities from failed research on the timing and level of investment in productive research. Future work should explore how these effects interact with other strategic incentives that may counterbalance them. Specifically, our findings should be considered alongside recent literature on patent races, which suggests that the current patent system may lead to an excessive rate of research and innovation. The delayed research we identify could potentially mitigate or offset the excessive research rates highlighted in the patent race literature. Further theoretical and empirical research is needed to determine whether the "race effect" or the "procrastination effect" will dominate in real-world scenarios.

## Acknowledgments

The authors gratefully acknowledge valuable comments and suggestions from Luigi Franzoni, Keith Hylton, Louis Kaplow, Saul Levmore, and participants at the 2024 Annual Meeting of the American Law & Economics Association and the 2024 Annual Meeting of the Italian Society of Law and Economics; participants at the May 2024 M3 Workshop; Bernard Chao, Joseph Fishman, Lisa Ouellette, and participants at the 2024 Intellectual Property Scholars Conference; Michael Burstein, Jacob Noti-Victor, Saurabh Vishnubhakat, Felix Wu, and participants at the 2024 Cardozo IPIL Colloquium; Holger Spamann, Alexander Stremitzer, Gianmarco Torchetti, and attendees of the May 2025 presentation at the University of Zurich; and Anthony Casey, Andrew Dawson, and Jonathan Masur. We are also grateful to Erik Birkeneder, Gen. Vincenzo Camporini, and Arturo Parisi for suggestions and examples drawn from their respective areas of expertise. Samuel Makikalli at the University of Minnesota Law School provided valuable research assistance.

## Funding

No external funding was received for this research.

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## Conflicts of interest

The authors declare no conflicts of interest.

## Data availability statement

No data were generated or analysed in support of this research.

## References

Aghion, Philippe, and Richard Holden. 2011. "Incomplete Contracts and the Theory of the Firm: What Have We Learned over the Past 25 Years?" *Journal of Economic Perspectives* 25: 181–97.

Arrow, Kenneth. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, edited by R.R., 219–236 Nelson. Princeton: Princeton University Press.

Barnett, J.M. and T. Sichelman. 2020. "The Case for Noncompetes." *The University of Chicago Law Review*, 87: 953–1050.

Baum, Joel A. C., and Kristina B. Dahlin. 2007. "Aspiration Performance and Railroads' Patterns of Learning from Train Wrecks and Crashes." *Organization Science* 18: 368–85.

Baumard, Philippe, and William H. Starbuck. 2005. "Learning from Failures: Why It May Not Happen." *Long Range Planning* 38: 281–98.

Benkler, Yochai. 2002. "Coase's Penguin, or Linux and the Nature of the Firm." *Yale Law Journal* 112: 369–446.

Benkler, Yochai. 2012. "Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption." *Harvard Journal of Law and Technology* 26: 69–163.

Benkler, Yochai. 2017. "Open Access and Information Commons." In *Oxford Handbook of Law & Economics*, edited by F., 256–279 Parisi. Oxford: Oxford University Press.

Bertello, Alberto, Paola De Bernardi, and Francesca Ricciardi. 2024. "Open Innovation: Status Quo and Quo Vadis—An Analysis of a Research Field." *Review of Management Science* 18: 633–683. https://doi.org/10.1007/s11846-023-00655-8

Bratton, William W. 2002. "Venture Capital on the Downside: Preferred Stock and Corporate Control." *Michigan Law Review* 100: 891–945.

Burstein, Michael J. 2012. "Exchanging Information Without Intellectual Property." *Texas Law Review* 91: 227–82.

Burstein, Michael J., and Fiona E. Murray. 2016. "Innovation Prizes in Practice and Theory," *Harvard Journal of Law & Technology* 29: 401–53

Chari, V. V., Mikhail Golosov, and Aleh Tsyvinski. 2012. "Prizes and Patents: Using Market Signals to Provide Incentives for Innovations," *Journal of Economic Theory 147:* 781–801.

Chesbrough, Henry, and Marcel Bogers. 2014. "Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation." In *New Frontiers in Open Innovation*, edited by H. Chesbrough, W. Vanhaverbeke, and J. West, 3–28. Oxford: Oxford University Press.

Choi, Albert, and George Triantis. 2012. "The Effect of Bargaining Power on Contract Design." *Virginia Law Review* 98: 1665–1743.

Chuang, You-Ta, and Joel A.C. Baum. 2003. "It's All in the Name: Failure-Induced Learning by Multiunit Chains." *Administrative Science Quarterly* 48: 33–59.

Coyle, John F., and Gregg D. Polsky. 2013. "Acqui-Hiring." *Duke Law Journal* 63: 280–346.

Downloaded from academic.oup.com/jleo/advance-article/doi/10.1093/jleo/ewag025/8825349 by guest on 03 October 2026

Denicolo, Vincenzo, and Luigi A. Franzoni. 2003. "The Contract Theory of Patents." *International Review of Law & Economics* 23: 365–80

Denicolò, Vincenzo, and Luigi A. Franzoni. 2012. "Weak Intellectual Property Rights, Research Spillovers, and the Incentive to Innovate." *American Law and Economics Review* 14: 111–40.

Denrell, Jerker. 2003. "Vicarious Learning, Undersampling of Failure, and the Myths of Management." *Organization Science* 14: 227–43.

Dunlop, John T., and Benjamin Higgins. 1942. "'Bargaining Power' and Market Structures." *Journal of Political Economy* 50: 1–26.

Ellickson, Robert. 1991. *Order Without Law: How Neighbors Settle Disputes*. Cambridge: Harvard University Press.

Feldman, Robin. 2023. "Rewarding Failure with Patents." *Yale Journal of Health Policy, Law, and Ethics* 21: 286–334.

Finifter, Matthew, Devdatta Akhawe, and David Wagner. 2013. "An Empirical Study of Vulnerability Rewards Programs." In: *Proceedings of the 22nd USENIX Security Symposium*, 273–88.

Francis, John, and CongCong Zheng. 2010. "Learning Vicariously from Failure: The Case of Major League Soccer and the Collapse of the North American Soccer League." *Group & Organization Management* 35: 542–71.

Freilich, Janet. 2019. "Prophetic Patents." *U.C. Davis Law Review* 53: 663–731.

Franzoni, Luigi A. 2016. "Trade Secrets Law." In: *Encyclopedia of Law and Economics*. New York: Springer.

Franzoni, Luigi A., and Arun K. Kaushik. 2016. "The Optimal Scope of Trade Secrets Law." *International Review of Law and Economics* 45: 45–53.

Graves, Charles T. 2007. "The Law of Negative Knowledge: A Critique." *Texas Intellectual Property Law Journal* 15: 387–416.

Graham, Stuart J. H., Robert P. Merges, Pamela Samuelson, and Ted M. Sichelman. 2009. "High Technology Entrepreneurs and the Patent System: Results of the 2008 Berkeley Patent Survey." *Berkeley Technology Law Journal* 24: 255–327.

Haunschild, Pamela R., and Bilian Ni Sullivan. 2002. "Learning from Complexity: Effects of Prior Accidents and Incidents on Airlines' Learning." *Administrative Science Quarterly* 47: 609–43.

Hemel, Daniel J., and Lisa L. Ouellette. 2019. "Innovation Policy Pluralism." *Yale Law Journal* 128: 544–614.

Holden, Richard T., and Anup Malani. 2014. "Renegotiation Design by Contract." *University of Chicago Law Review* 81: 151–78.

Holgersson, Marcus, and Ove Granstrand. 2021. "Value Capture in Open Innovation Markets: The Role of Patent Rights for Innovation Appropriation," *European Journal of Innovation Management* 25: 320–39.

Hrdy, Camilla A., and Christopher B. Seaman. 2024. "Beyond Trade Secrecy: Confidentiality Agreements That Act Like Noncompetes." *Yale Law Journal* 133: 669–754.

Ibrahim, Darian M. 2008. "The (Not So) Puzzling Behavior of Angel Investors." *Vanderbilt Law Review* 61: 1405–52.

Kapczynski, Amy, and Talha Syed. 2013. "The Continuum of Excludability and the Limits of Patents." *Yale Law Journal* 122: 1900–63.

Kitch, Edmund W. 1977. "The Nature and Function of the Patent System." *Journal of Law and Economics* 20: 265–90.

Downloaded from academic.oup.com/jleo/advance-article/doi/10.1093/jleo/ewag025/8825349 by guest on 03 October 2026

Kremer, Michael. 1998. "Patent Buyouts: A Mechanism for Encouraging Innovation." *Quarterly Journal of Economics 113:* 1137–67.
Krieger, Joshua. 2021. "Trials and Terminations: Learning from Competitors' R&D Failures." *Management Science* 67: 5525–5545.
Lant, Theresa K., and David B. Montgomery. 1987. "Learning From Strategic Success and Failure." *Journal of Business Research* 15: 503–18.
Lapré, Michael A., and Nikos Tsikriktsis. 2006. "Organizational Learning Curves for Customer Dissatisfaction: Heterogeneity Across Airlines." *Management Science* 52: 352–66.
Lemley, Mark A. 1997. "The Economics of Improvement in Intellectual Property Law." *Texas Law Review* 75: 989–1084.
Lemley, Mark. 2004. "Ex Ante and Ex Post Justifications for Intellectual Property Law." *University of Chicago Law Review* 71: 129–49.
Lemley, Mark. 2016. "Rethinking Assignor Estoppel." *Houston Law Review* 54: 513–44.
Levitt, Barbara, and James G. March. 1988. "Organizational Learning." *Annual Review of Sociology* 14: 319–38.
Levmore, Saul. 2013. "The Impending iPrize Revolution in Intellectual Property Law." *Boston University Law Review* 93: 139–62.
Loury, Glenn C. 1979. "Market Structure and Innovation." *Quarterly Journal of Economics* 93: 395–410.
Mann, Ronald J. 2004. "An Empirical Investigation of Liquidation Choices of Failed High Tech Firms." *Washington University Law Quarterly* 82: 1376–444.
Mar, E. Y., and T., Pardini (2022, October 5). "Protecting 'What Not to Do' as a Negative Trade Secret." Daily Journal.
Marcus, Alfred A., and Mary L. Nichols. 1999. "On the Edge: Heeding the Warnings of Unusual Events." *Organization Science* 10: 482–99.
Merges, Robert P., and Richard C. Nelson. 1990. "On the Complex Economics of Patent Scope." *Columbia Law Review* 90: 839–917.
Merges, Robert P. 1992. "Uncertainty and the Standard of Patentability." *(Berkeley) High Technology Law Journal* 7: 1–70.
Parchomovsky, Gideon, and Michael Mattioli. 2011. "Partial Patents." *Columbia Law Review* 111: 207–54.
Pollman, Elizabeth. 2023. "Startup Failure." *Duke Law Journal* 73: 327–86.
Reinicke, Jason. 2018. "General Innovation Competitions." *Stanford Technology Law Review* 21: 128–66.
Rosenthal, J. (2009, July 31). *A terrible thing to waste. The New York Times*. https://www.nytimes.com/2009/08/02/magazine/02FOB-onlanguage-t.html. Date accessed 9 August 2025.
Sawicki, Andres. 2015. "Buying Teams." *Seattle University Law Review* 38: 651–85.
Saxenian, AnnaLee. 1996. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge: Harvard University Press.
Seymore, Sean B. 2012. "The Null Patent." *William & Mary Law Review* 53: 2041–105.
Seymore, Sean B. 2018. "Patenting Around Failure." *University of Pennsylvania Law Review* 166: 1139–87.
Shavell, Stephen, and Tanguy van Ypersele. 2001. "Rewards versus Intellectual Property Rights." *Journal of Law & Economics* 44: 525–47.
Sichelman, Ted. 2010. "Commercializing Patents." *Stanford Law Review* 62: 341–411.

Downloaded from academic.oup.com/jleo/advance-article/doi/10.1093/jleo/ewag025/8825349 by guest on 03 October 2026

Sitkin, Sim B. 1992. "Learning Through Failure: The Strategy of Small Losses." *Research in Organizational Behavior* 14: 231–66.

Smith, D. Gordon. 2005. "The Exit Structure of Venture Capital." *UCLA Law Review* 53: 315–56.

Sridhar, Kiran, and Ming Ng. 2021. "Hacking for Good: Leveraging HackerOne Data to Develop an Economic Model of Bug Bounties." *Journal of Cybersecurity* 7: 1–9.

Tarde, Gabriel. (1903). *The Laws of Imitation*, E.C. Parsons, trans. New York: Henry Holt. (Original work published 1880).

Terlaak, Ann, and Yan Gong. 2008. "Vicarious Learning and Inferential Accuracy in Adoption Processes." *Academy of Management Review* 33: 846–68.

The Economist Group. 2022. "The Open Innovation barometer. Assessing the Collaborative Spirit of a World in Flux." https://impact-economist-com.ezproxy.unibo.it/projects/open-innovation/Open%20Innovation%20Briefing%20Paper.pdf. Date accessed 8 February 2023.

U.S. Patent and Trademark Office. 2024. *Agency Final Report FY 2024*. Alexandria, Virginia: U.S. Patent and Trademark Office.

Walshe, Thomas, and Andrew Simpson. 2020. "An Empirical Study of Bug Bounty Programs." In: *2020 IEEE 2nd International Workshop on Intelligent Bug Fixing*, 35–44.

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The Journal of Law, Economics, and Organization, 2026, 00, 1–36
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