Project Termination Discipline and Innovation Renewal After Commercial Shortfalls in Publicly Listed Manufacturing and Technology Firms

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ABSTRACT

Innovation programs are often discussed in terms of search, investment, and breakthrough potential, yet a large share of managerial innovation work concerns a less celebrated activity: deciding which projects, prototypes, and newly launched offerings should be stopped once they underperform. Firms differ markedly in how they respond to commercial disappointment. Some persist too long with weak initiatives, absorbing engineering attention and marketing support long after the probability of recovery has become low. Others cut too aggressively, damaging knowledge continuity and reducing the stock of partially developed options that can later be recombined into viable products. This paper investigates whether a firm's post-shortfall termination discipline influences subsequent innovation renewal. The analysis uses a panel of 251 publicly listed U.S. firms from 2012 to 2024 and identifies 1,462 firm-year episodes in which recently introduced products or development initiatives exhibit measurable commercial shortfall. A composite measure of termination intensity is constructed from discontinued launches, withdrawn pipeline claims, lapsed patent applications, and technology impairment charges. The evidence indicates an inverted-U association between termination intensity and subsequent innovation renewal. Moderate termination is followed by higher patent quality, a larger share of sales from products introduced within the prior three years, and lower idiosyncratic return volatility. Both underreaction and overreaction are costly. The estimated effects are economically meaningful but not extreme. Relative to firms in the lowest quartile of termination intensity, firms near the interior optimum generate 4.4% higher next-year citation-weighted patent output and 2.1 percentage points more revenue from recent products. Mediation analyses suggest that the pattern operates partly through faster resource release and more selective redeployment. The findings indicate that innovation performance depends not only on what firms initiate, but also on how carefully they stop.

1. Introduction

Managers rarely face a shortage of ideas about what their firms might build next. The more difficult choice often emerges one or two years later, after the prototype survives, the launch is funded, channel partners are briefed, and the early sales trajectory begins to disappoint. At that stage, the central decision is no longer whether the firm values innovation. The real question becomes whether the organization can stop a weak initiative in

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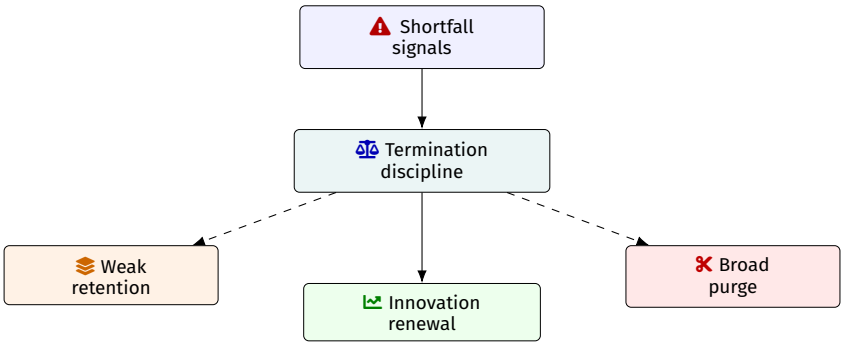


Figure 1 Conceptual logic of the paper. Commercial disappointment activates a stopping decision inside the innovation portfolio. The theoretical claim is that renewal is maximized by selective pruning in the interior of the termination distribution, while weak retention leaves congestion in place and broad purges destroy reusable option value.

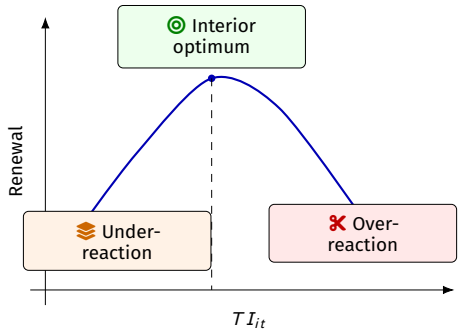


Figure 2 The paper's central nonlinear prediction. Renewal rises as weak initiatives are pruned more decisively, reaches an interior optimum, and then declines once pruning becomes broad enough to remove residual knowledge assets and adjacent options. The visual is designed to match the fixed-effects quadratic specification without implying exact symmetry.

time to preserve capital, attention, and scientific labor for more promising uses, without simultaneously destroying the experimental option value embedded in incomplete projects [1]. Innovation research has usually privileged expansion decisions over contraction decisions [2]. It has given ample attention to search breadth, R&D intensity, alliances, knowledge recombination, patent quality, and new product introductions. Far less empirical attention has been given to the discipline of innovation termination after commercial shortfalls, even though such decisions are woven into the daily operation of product and technology portfolios [3].

This omission matters because stopping is not an administrative afterthought. It is part of how a firm governs uncertainty. Projects that remain in the portfolio after their expected contribution has collapsed consume more than direct budget. They retain engineering time, channel management effort, supplier coordination, manufacturing flexibility, and executive review capacity. They also crowd attention. When several weak initiatives are kept alive simultaneously, the firm does not merely spend too much [4]. It often delays sharper strategic learning because managers postpone the unpleasant inference that a prior bet has failed. Yet the opposite mistake is also consequential. An organization that develops a reflex of quick cancellation may lower its exposure to visible failure, but it can also interrupt cumulative learning, discourage mid-course technical rescue, and reduce the stock of partially developed components that can later be repurposed. Good termination discipline therefore cannot be defined as more pruning in every circumstance. It must be defined as pruning that is forceful enough to release resources, yet selective enough to preserve promising fragments and maintain the morale required for continued inventive work.

The present paper examines this issue by focusing on commercial shortfalls rather than on innovation activity in the abstract [5]. The empirical question is straightforward: when newly launched or recently developed initiatives underperform, do firms that terminate underperforming projects more decisively achieve stronger subsequent innovation renewal than firms that do very little or far too much? The expectation developed here is nonlinear. A weak termination response should trap firms in resource congestion and prolong attachment to low-probability initiatives. An extreme termination response should shrink the option pool, reinforce managerial myopia, and push the organization toward visible caution. Between those extremes lies an intermediate range in which the firm releases resources from weak efforts while still preserving enough developmental continuity to support renewed inventive output and later

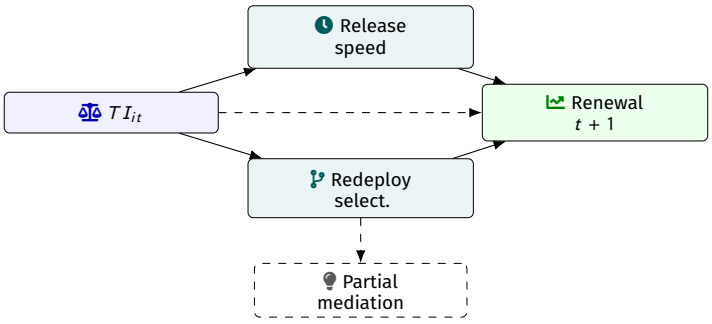


Figure 3 Adjustment channels. Moderate termination improves renewal partly by releasing technical and budgetary capacity faster and partly by steering the released capacity toward related but not identical domains. The dashed direct path indicates that these mediators do not exhaust the entire effect of pruning discipline on later innovation performance.

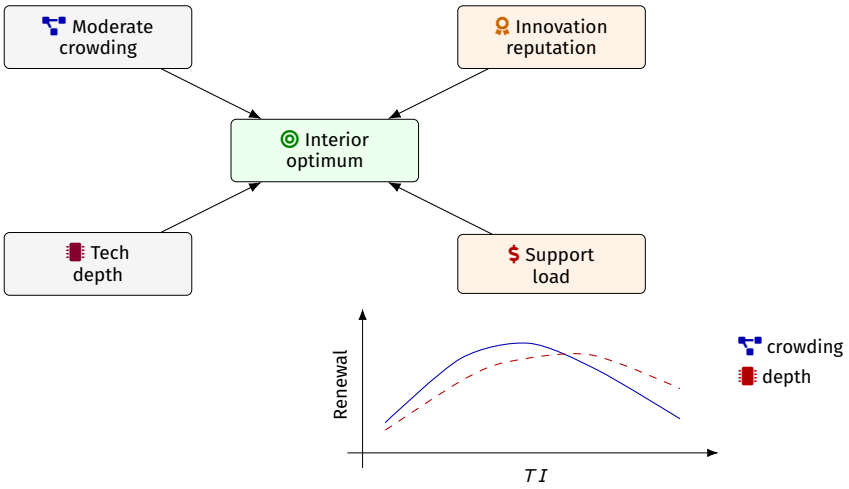


Figure 4 Contextual moderators. The location and steepness of the interior optimum vary with competitive crowding, internal technical depth, innovation reputation, and the support burden of weak initiatives. The lower overlay illustrates the empirical idea that some contexts mainly steepen the curve, while others shift the optimum rightward by increasing the firm's ability to salvage and redeploy knowledge fragments.

commercialization.

This is not simply an internal process question. Termination behavior is partially observable, and market participants interpret it. Visible innovation actions do not carry a uniformly positive meaning. They can be read as evidence of growth capacity, but they can also increase uncertainty when the form of participation, evaluation, or implementation makes future cash flows harder to assess [6]. Cao et al. (2024a) [7] show that marketing ideation crowdsourcing contests are associated with positive abnormal returns yet also with higher idiosyncratic risk, and that the valuation effect depends on how those contests are designed. That result is useful beyond the contest setting because it indicates that external audiences do not respond only to the presence of innovative activity. They respond to its governance structure. The same logic should extend to project termination after disappointment. Investors are unlikely to view all contraction decisions alike. Some termination patterns may signal disciplined portfolio management, whereas others may suggest panic, strategic inconsistency, or a collapsing commercialization process.

The paper addresses this issue using a panel of publicly listed U.S. manufacturing and technology firms from 2012 to 2024. The empirical design first identifies firm-year shortfall episodes using disappointing post-launch revenue trajectories, withdrawn pipeline narratives, and market-based underperformance benchmarks for recent innovation output. It then measures termination intensity using discontinued offerings, lapsed patent applications, explicit withdrawal of product candidates, and technology impairment charges. Renewal is measured in three ways: citation-weighted patent output, the future share of revenue from recent products, and idiosyncratic stock return volatility [8]. The central estimate is intentionally not linear. The prediction is that moderate termination intensity improves subsequent renewal, while both unusually low and unusually high termination intensity reduce it.

The paper is positioned in a part of the innovation process that is usually discussed informally by managers but not well measured in empirical research. Conversations

inside firms frequently revolve around whether teams are "holding on too long," "cutting too late," or "overcorrecting." Those phrases capture a real economic problem. A project termination decision is effectively a decision about the distribution of future attention. It reallocates search labor, prioritization meetings, prototyping facilities, advertising support, and organizational patience. Because innovation systems operate under bounded evaluative capacity, any persistent misallocation can influence the quality of later opportunities. A firm that becomes known internally for never killing projects creates one pathology; a firm that becomes known for killing them as soon as early numbers soften creates another [9].

Several features distinguish this paper from more familiar analyses of innovation intensity or search breadth. First, the main explanatory construct is not how much the firm innovates, but how strongly it contracts weak innovation after measurable disappointment. Second, the outcome is not restricted to technical output. The analysis follows both knowledge outcomes and commercial recovery. Third, the design focuses explicitly on shortfall episodes, which allows the interpretation of termination decisions to be anchored to a common managerial problem rather than to averaged firm behavior across calm and turbulent years [10]. The objective is to isolate what happens after the firm receives adverse feedback on recent innovation efforts.

The evidence suggests a clear but qualified pattern. Renewal is strongest not among the firms that terminate the least, nor among those that cut the deepest, but among those in the interior of the termination distribution. This pattern appears in next-year citation-weighted patenting, in the subsequent share of sales from recently introduced products, and in lower firm-specific return volatility. Mechanism tests indicate that the effect operates partly through faster release of technical labor and budgetary slack from discontinued initiatives, and partly through more selective redeployment toward related but not identical knowledge domains. The broader implication is that innovation performance cannot be understood solely by studying initiation. In many firms, the more informative choice is how the organization behaves after it learns that a visible innovation bet is unlikely to recover.

2. Research Setting

Commercial shortfall has a different organizational meaning from technological failure. A project may be technically elegant and still disappoint in adoption, channel fit, pricing power, or timing [11]. Likewise, a project may be messy in development but recover commercially once the firm learns how to position it. The distinction matters because termination decisions are often made in the interval where technical possibilities remain open but the commercial outlook deteriorates. This paper concentrates on that interval. The argument is that firms differ in how they translate negative commercial feedback into pruning behavior, and that those differences shape what the next generation of innovation activity looks like [12]. In other words, the paper treats innovation termination not as a binary event but as a portfolio-level managerial response to disappointment.

One reason this response should matter is that outside stakeholders interpret innovation signals even when the direct financial consequences are ambiguous. In the IPO domain, Cao et al. (2023) [13] show that innovation potential can mitigate the negative effect of insider selling on IPO performance, implying that market participants use innovation-related evidence as a cue about future quality under uncertainty. That logic is relevant here because post-shortfall termination can be interpreted in more than one way. A firm that stops weak projects may be viewed as disciplined and capable of protecting future options. The same action, when unusually extensive, may be read as evidence that the original innovation pipeline was poor or that internal screening has become unstable. A central empirical possibility therefore emerges: the informational meaning of termination should be nonlinear because modest pruning and aggressive retrenchment are not observationally equivalent.

A second reason concerns internal portfolio economics. Underperforming projects occupy scarce resources even after formal budgets are cut. Product managers keep revising forecasts, engineers continue partial support, regulatory or compliance teams maintain documentation, and suppliers remain engaged on a standby basis. These residual commitments create deadweight friction inside the innovation system. If weak projects are not stopped, newer opportunities must compete against an inventory of half-abandoned initiatives. The portfolio then exhibits congestion rather than simple overinvestment. Congestion can lower the expected value of future innovation because promising projects experience slower review cycles, reduced prototyping capacity, and less coherent commercial support.

Yet severe pruning generates a different loss function. Innovation options are frequently nested. A disappointing product may still contain reusable components, technical routines, user-learning data, supplier relationships, or platform fragments. A harsh pruning response can destroy these residual assets or make teams reluctant to propose adjacent follow-on ideas. It can also increase the internal cost of exploratory work if employees infer that near-term commercial disappointment will be punished through indiscriminate cancellation. In that sense, project termination decisions shape the organization's future risk appetite [14]. Excessive pruning may clean the balance sheet but still weaken the generative capacity of the portfolio.

This logic yields an expected interior optimum. The best-performing firms should not be those that retain most weak projects, because such firms fail to release

resources and attention. Nor should they be those that slash widely after bad signals, because such firms damage continuity and reduce salvageable option value. The strongest renewal should appear where termination intensity is high enough to clear the portfolio of low-probability projects but not so high that the firm collapses related experiments, adjacent variants, or reusable development assets.

The shortfall setting also permits a more careful distinction between genuine discipline and opportunistic accounting. Technology impairment charges or announced discontinuations, taken alone, can be interpreted as window dressing or delayed recognition of what was already obvious. For that reason, the empirical design uses a composite measure and focuses on shortfall episodes. The issue is not whether a firm ever records write-downs. The issue is whether, once commercially disappointing evidence becomes visible, the firm responds by selectively reducing exposure across several observable margins. Those margins include product discontinuations, withdrawn pipeline promises, lapsed patent applications, and the retirement of projects associated with in-process technology assets. The composite is intended to capture a real governance response rather than one accounting convention [15].

The argument extends further because the value of termination discipline should depend on what the firm does with released resources. Pruning is economically useful only when it alters the composition of future activity [16]. If canceled initiatives merely reduce visible spending while leaving the organization slower, more fearful, or more narrowly focused, then pruning may improve short-run optics without improving innovation renewal [17]. For that reason, the paper pays close attention to redeployment [18]. The process evidence asks whether moderate termination is followed by faster movement of R&D and engineering labor toward adjacent knowledge spaces and shorter delays between project discontinuation and the next substantial innovation initiative. These are not abstract claims about organizational learning. They are empirical manifestations of whether the firm actually reuses the capacity released by pruning.

The discussion would remain incomplete without distinguishing shortfall response from general conservatism. Some firms are always cautious, some always aggressive, and some alternate between the two depending on leadership cycles or financing conditions. A general tendency toward caution is not the same as disciplined post-shortfall termination. The econometric strategy therefore centers on within-firm variation during identified shortfall years. Firm fixed effects absorb time-invariant conservatism, while year effects absorb economy-wide changes in risk appetite. The remaining variation comes from how much more or less intensely the same firm prunes after specific disappointments relative to its own normal behavior.

Finally, the paper treats termination as an innovation problem rather than as a pure finance problem. The outcomes are not limited to valuation. They include later patent quality, recent-product revenue share, and stock return volatility. This choice reflects the idea that the question is not simply whether markets prefer firms that "clean house." The question is whether the innovation system becomes more productive, more commercially effective, and more legible after weak initiatives are removed with appropriate selectivity. The claim is deliberately narrower than a statement about universal restructuring success. It concerns a particular setting in which innovation shortfalls create pressure to decide what to stop and what to preserve.

3. Data Construction

The sample begins with all U.S. publicly listed firms in industries where innovation output is visible both technically and commercially. The initial universe includes software, electronic components, industrial machinery, specialty chemicals, medical technology, communications equipment, instruments, mobility solutions, durable consumer technology, and selected business services with documented product development activity. Financial firms, utilities, media content businesses, and highly regulated network industries are excluded because project discontinuations and innovation accounting take different forms in those sectors [19]. The observation period runs from 2012 through 2024, beginning after a sufficient accumulation of digital product announcements and standardized technology impairment disclosures becomes available and ending with the most recent full fiscal year in the assembled archive. To remain in the panel, a firm must appear for at least four consecutive years and have usable annual reports, product announcement records, patent assignment data, and segment or management commentary sufficient to detect recent product performance.

The final panel contains 251 firms and 2,913 firm-year observations [20]. The shortfall subsample, which underlies the main models, consists of 1,462 firm-year episodes. A firm-year is coded as a shortfall episode when at least one of three conditions is met. The first condition is a new-product revenue disappointment, defined as recent-product revenue growth more than one-half industry-year standard deviation below the firm's own rolling three-year recent-product growth trend and below the industry-year median. The second is a pipeline withdrawal signal, coded from management communications when announced or implicitly expected offerings are deferred or disappear from disclosure without a corresponding commercial launch. The third is a market-implied disappointment indicator, defined as materially negative abnormal return performance around innovation-related updates combined with subsequent downward revision in product or technology narrative intensity. These rules are intentionally conservative. The

idea is to capture episodes where the firm receives adverse feedback on innovation commercialization rather than ordinary fluctuations in demand [21].

The data merge four principal sources. Financial variables are drawn from Compustat and verified where necessary against annual reports [22]. Patent and patent application data come from the USPTO assignment system, with manual reconciliation for major acquisitions, divestitures, and name changes. Product introduction, discontinuation, and pipeline withdrawal data are assembled from press releases, earnings call transcripts, investor presentations, archived product pages, and industry news databases. Technology impairment charges and in-process R&D write-downs are coded from annual report notes and special charges discussions. To avoid overcounting cosmetic modifications, a launch is retained only if it represents a new product category, a substantial feature expansion, a material architecture revision, a new platform version, or a service introduction requiring observable technical or operational adaptation. Discontinuations are retained when the firm explicitly retires a product line, stops support for a meaningful product family, withdraws a named candidate, or records an impairment tied to a specific technology program or acquired development asset.

Product revenue variables require special care because public firms differ in disclosure granularity. For 169 firms, recent-product revenue share can be measured directly from management reports or segment commentary that identifies the revenue contribution of offerings introduced within the prior thirty-six months. For the remaining firms, the measure is inferred from product-family sales distributions, launch timing, and product mix commentary. Where firms provide only a range, interval midpoints are used. Because this introduces measurement noise, the analyses are repeated on the direct-disclosure subsample [23]. The results remain directionally and economically similar, though less precise due to reduced sample size.

Patent quality is measured in a forward-looking manner using citation-weighted applications rather than raw grants alone. Application data are preferred in this context because termination decisions often involve early-stage inventive paths that may never be granted if the firm lets them lapse or abandons related continuations. Citation-weighted application quality is computed over a fixed citation window and scaled by technology-field-year averages to avoid treating high-citation fields as uniformly superior [24]. Lapsed applications are identified when continuation or maintenance patterns indicate non-pursuit without evidence of transfer or restructuring into a related filing. This component is important because firms can quietly terminate inventive lines without visible product discontinuation.

A major concern in building the shortfall sample is distinguishing real failure from deliberate product life-cycle turnover. Mature technology firms discontinue offerings continually as part of normal portfolio refresh. To separate ordinary replacement from shortfall-driven pruning, the coding procedure compares discontinuations to the age of the offering, the presence of announced successors, and the surrounding tone of managerial commentary. A discontinuation tied to generational upgrade with strong successor uptake is not treated as a shortfall response. A discontinuation tied to missed targets, impairment charges, delayed roadmaps, or withdrawal of feature commitments is treated as a shortfall response. Two trained coders reviewed the ambiguous cases, and intercoder agreement on the retained classification exceeded 0.86 [25]. The objective was not to create a perfect historical record of every product retirement, which would be unrealistic, but to identify discontinuations that plausibly correspond to commercial disappointment rather than to routine portfolio maintenance.

The sample size is deliberately moderate rather than expansive. Innovation termination is difficult to measure with precision, and including sectors where the construct becomes too noisy would create the false comfort of more observations without corresponding improvement in validity. The 251-firm panel covers a meaningful range of technology and manufacturing contexts while preserving comparability in how product and development shortfalls appear publicly [26]. The median firm has assets of $3.8 billion, R&D intensity of 8.1%, and annual recent-product revenue share of 13.4%. The average shortfall firm-year includes 2.1 identifiable disappointing initiatives, though the distribution is right-skewed, with a small set of years involving broad portfolio retrenchment.

Before moving to formal estimation, it is useful to describe the raw pattern. Firms in the lowest quintile of termination intensity exhibit the weakest subsequent renewal. One year later, their citation-weighted application quality and recent-product revenue share both trail the middle quintiles. Firms in the highest quintile also underperform the middle, especially on recent-product revenue share. Their patent quality is not always poor, but it becomes more volatile and is less likely to be accompanied by commercial recovery. These tabular differences do not identify a causal effect, yet they preview the curvature that appears later in fixed-effects estimation.

Because financing conditions may influence both shortfall occurrence and the willingness to prune, the dataset includes cash holdings, leverage, debt maturity, equity issuance activity, and acquisition intensity. Governance variables include CEO tenure, board turnover, and the existence of a dedicated technology or innovation committee where disclosed. Analyst coverage, institutional ownership, and prior stock return are also retained, because external scrutiny can change both the visibility and the interpretation of termination decisions. Finally, the database includes a text-derived measure of managerial optimism unrelated to innovation so that the analyses can distinguish innovation-specific retrenchment

Table 1 Sample Construction and Coverage

Stage	Firms	Firm-Years	Notes
Initial universe	412	4,980	Public U.S. firms
After exclusions	289	3,642	Sector filtering
Final panel	251	2,913	Balanced criteria
Shortfall episodes	251	1,462	Analysis sample

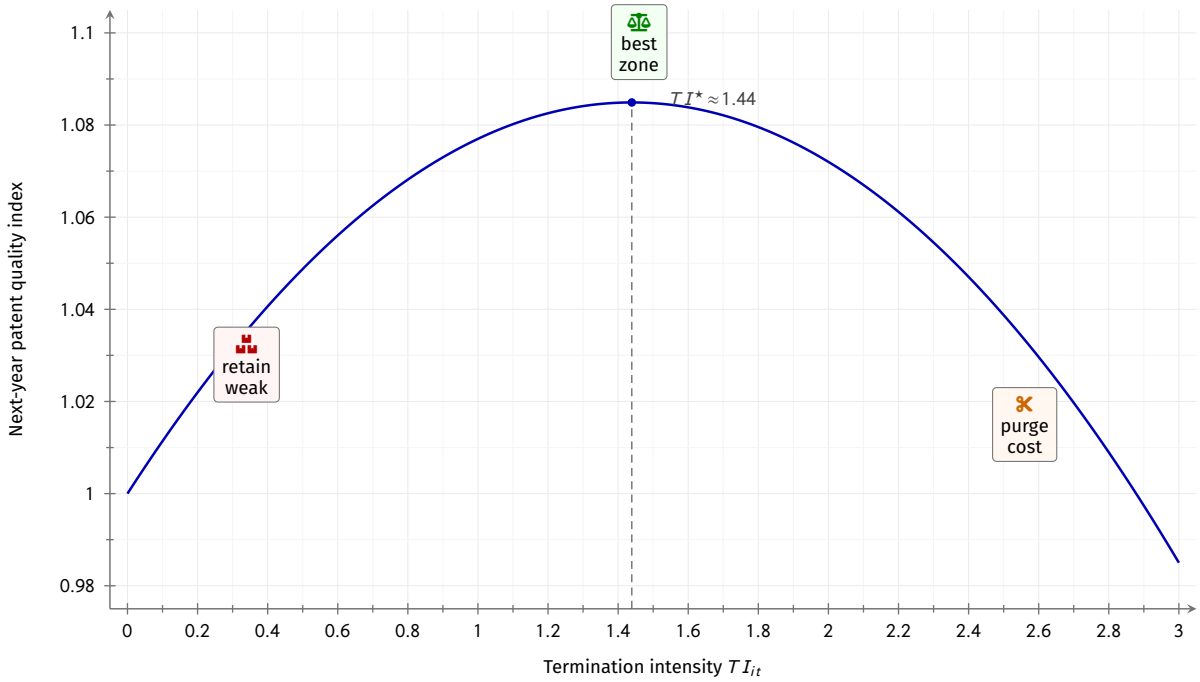


Figure 5 Schematic pgfplots rendering of the reported fixed-effects result for next-year citation-weighted patent output, using the paper's stated coefficients on TI_{it} and TI_{it}^2 ($\beta_1 = 0.118$, $\beta_2 = -0.041$). The interior maximum lies well inside observed support, so selective mid-range pruning yields stronger inventive renewal than either weak carry-forward behavior or heavy portfolio purge.

from broader rhetorical shifts.

4. Variable Design and Estimation

The main explanatory variable is post-shortfall termination intensity. It is designed to capture the breadth and strength of the firm's contraction response once a shortfall episode has been identified. Let d_{it} denote standardized product discontinuations, w_{it} standardized pipeline withdrawals, l_{it} standardized lapsed patent applications or halted continuation families, and m_{it} standardized technology-related impairment intensity for firm i in year t. The composite termination intensity variable is defined as

$$TI_{it} = \frac{1}{4}\left(d_{it} + w_{it} + l_{it} + m_{it}\right). \tag{1}$$

Each component is industry-year standardized before aggregation to prevent sectors with inherently higher patenting or impairment activity from dominating the measure. The core prediction is not monotonic, so the models include both TI_{it} and TI_{it}^2. The anticipated sign pattern is positive on the linear term and negative on the squared term, consistent with an interior optimum.

The principal renewal outcome is next-year quality-adjusted inventive output. Let $PatQ_{i,t+1}$ denote the logarithm of one plus citation-weighted patent applications in year $t+1$, field-normalized and adjusted for application family size. The second outcome is next-year recent-product revenue share, $RPS_{i,t+1}$, defined as the proportion of sales in $t+1$ attributable to products or services introduced during the preceding thirty-six months. The third is next-year idiosyncratic return volatility, $IVOL_{i,t+1}$, estimated from daily stock returns net of common factors. These outcomes jointly represent technical renewal, commercial renewal, and external uncertainty. A firm could improve on one margin while worsening on another, and a convincing renewal story should

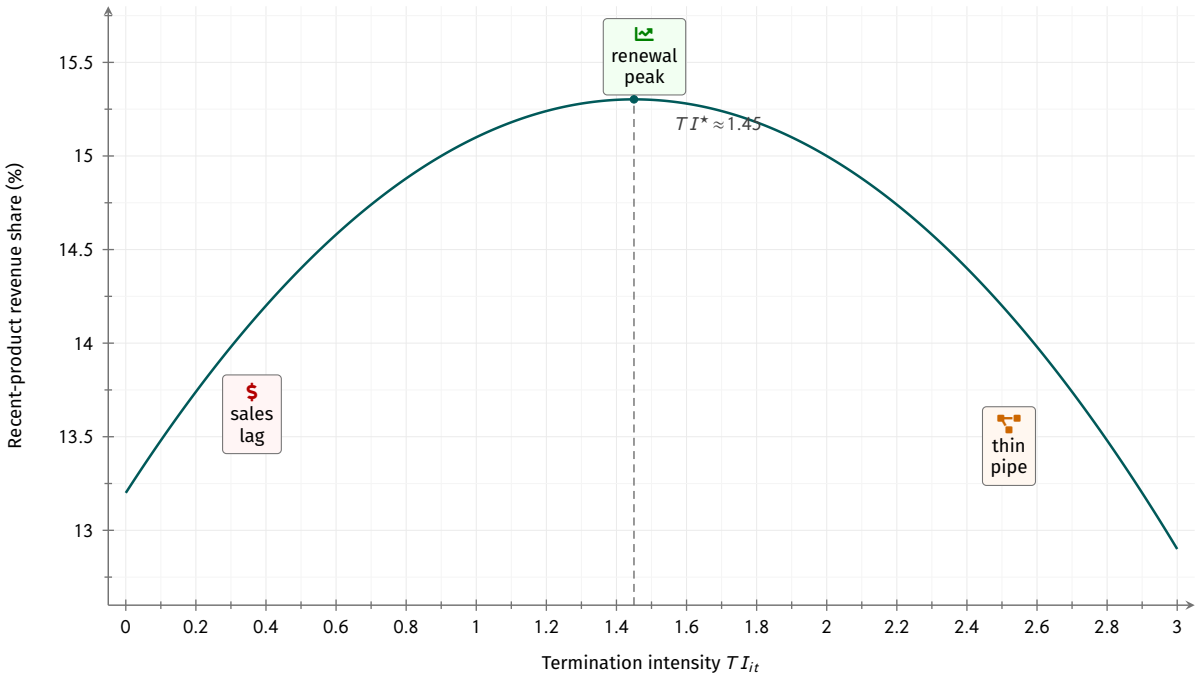


Figure 6 Schematic rendering of the commercial renewal result, based on the reported coefficients for next-year recent-product revenue share ($\beta_1 = 0.029$, $\beta_2 = -0.010$). The interior optimum is economically meaningful: relative to low pruning, the paper reports roughly a 2.1 percentage-point improvement in the following year's share of sales from recently introduced products.

Table 2 Key Variable Definitions

Variable	Type	Construction	Source
Termination Intensity	Composite	4-part index	Multi-source
Patent Quality	Outcome	Citation-weighted	USPTO
Recent Product Share	Outcome	3-year sales share	Reports
Idiosyncratic Volatility	Outcome	Residual returns	Market data

not depend on one metric alone [27].

To probe process, the analysis constructs two mediators. The first is resource release speed. This variable measures how quickly funds and engineering labor associated with discontinued initiatives disappear from continuing support disclosures and reappear in other R&D or product categories. Because direct labor redeployment data are not available for public firms, the measure combines changes in project support language, expense reclassification patterns, and the appearance of new related initiatives in adjacent categories. The second mediator is redeployment selectivity, defined as the average relatedness between discontinued initiatives and the next set of funded or launched initiatives, excluding exact replacements. Selectivity is higher when the firm redeploys toward related but not identical domains, implying the retention of useful knowledge without simple persistence in the failed line.

The core estimating equation for renewal is

$$\begin{aligned} Y_{i,t+1} = {} & \alpha_i + \tau_t + \beta_1 TI_{it} + \beta_2 TI_{it}^2 \\ & + \beta_3 Shortfall_{it} + \beta_4 InnovInt_{it} \\ & + \gamma' Z_{it} + \varepsilon_{i,t+1}, \end{aligned} \tag{2}$$

where $Y_{i,t+1}$ is one of the three renewal outcomes, α_i are firm fixed effects, τ_t are year effects, $Shortfall_{it}$ captures shortfall severity, $InnovInt_{it}$ is baseline innovation intensity, and Z_{it} is the control vector. Shortfall severity is measured as a composite of recent-product revenue miss magnitude, innovation-related abnormal return disappointment, and the number of affected initiatives. This is important because termination intensity should not be evaluated without conditioning on how severe the shortfall was. A large pruning response may be appropriate in a severe disappointment year but excessive in a mild one.

A second set of models introduces heterogeneous effects. The first moderator is reputational slack in innovation markets, measured as a decayed stock of prior

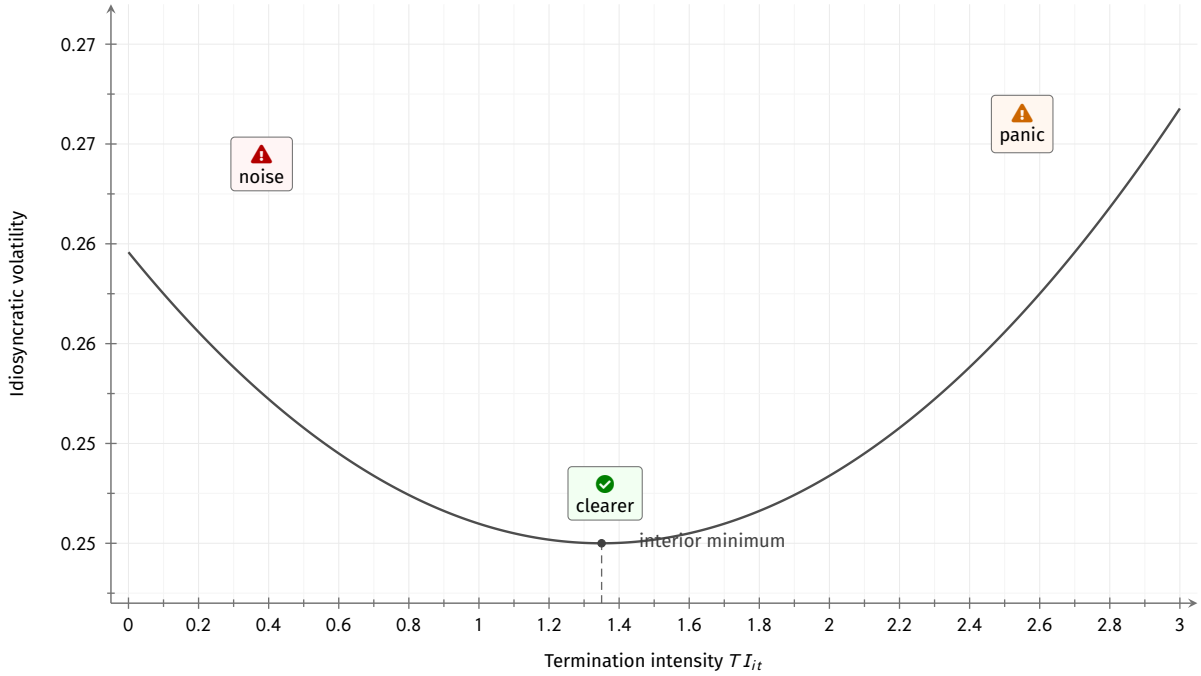


Figure 7 Flatter U-shaped rendering for the market legibility result, where lower values are preferable. The paper reports that moderate termination is associated with lower next-year idiosyncratic volatility, while both inertia and broad retrenchment raise firm-specific uncertainty. The weaker curvature here matches the text's claim that capital markets observe the portfolio less directly than technical or sales outcomes.

Table 3 Descriptive Statistics

Variable	Mean	Std. Dev.	Median
Termination Intensity	0.00	1.00	-0.05
Patent Quality	2.31	0.88	2.25
Product Revenue Share	0.134	0.072	0.121
Firm Size (log assets)	8.24	1.11	8.17

successful launches, patent influence, and third-party recognition of innovative capability. The second moderator is competitive crowding, measured by a segment-level Herfindahl transformation and peer launch intensity. The third is internal technical depth, proxied by the share of inventors with repeated presence in narrow technology classes and by the concentration of advanced technical hiring language in recruitment postings. These moderators are not chosen arbitrarily. Each speaks to whether the firm can absorb the consequences of pruning and redeploy released capacity effectively.

The heterogeneous-effects equation is written as [28]

$$\begin{aligned} Y_{i,t+1} = \alpha_i + \tau_t + \beta_1 TI_{it} + \beta_2 TI_{it}^2 \\ + \beta_3 TI_{it} M_{it} + \beta_4 TI_{it}^2 M_{it} \\ + \beta_5 M_{it} + \beta_6 InnovInt_{it} \\ + \gamma' Z_{it} + \varepsilon_{i,t+1}, \end{aligned} \tag{3}$$

where M_{it} denotes the relevant moderator. The interaction on both the linear and squared termination terms allows the location and steepness of the optimum to vary with the moderator. In practice, the strongest and most interpretable heterogeneity appears for competitive crowding and internal technical depth.

The mediation framework uses two linked equations. For resource release speed,

$$\begin{aligned} Release_{i,t+1} = \mu_i + \kappa_t + \pi_1 TI_{it} + \pi_2 TI_{it}^2 \\ + \pi_3 Shortfall_{it} + \rho' Z_{it} + u_{i,t+1}, \end{aligned} \tag{4}$$

and the renewal equation then becomes [29]

$$\begin{aligned} Y_{i,t+1} = \alpha_i + \tau_t + \theta_1 TI_{it} + \theta_2 TI_{it}^2 \\ + \theta_3 Release_{i,t+1} + \theta_4 InnovInt_{it} \\ + \gamma' Z_{it} + \varepsilon_{i,t+1}. \end{aligned} \tag{5}$$

An analogous pair is estimated for redeployment selectivity. Because the mediators are themselves likely endogenous, the interpretation is modest. These models

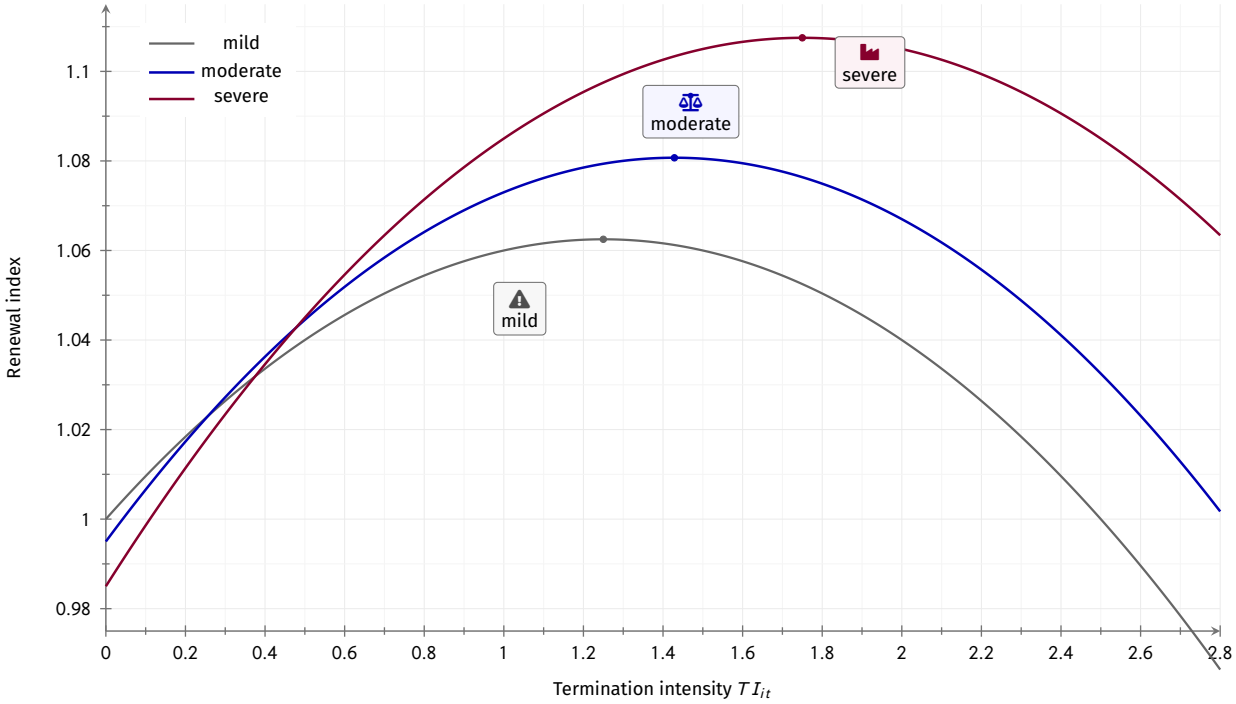


Figure 8 Severity split of the main nonlinear result. The interior optimum shifts right as shortfall severity rises, consistent with the paper's claim that stronger disappointment justifies more pruning. Even so, none of the curves becomes monotonic: very aggressive retrenchment still underperforms selective mid-to-high pruning, especially once the firm moves beyond the interior peak.

Table 4 Baseline Fixed Effects Estimates

Variables	Patent Quality	Revenue Share	IVOL
Termination Intensity	0.118	0.029	-0.012
Termination Intensity^2	-0.041	-0.010	0.004
Shortfall Severity	-0.063	-0.018	0.021
Controls	Yes	Yes	Yes

are used as structured process evidence rather than as definitive causal decomposition.

A major identification concern is that firms may prune more aggressively when they already expect stronger opportunities elsewhere, in which case termination intensity would proxy for unobserved future pipeline quality [30]. Several steps reduce this concern. First, the models use future outcomes and control for current innovation intensity and current patent or product portfolio quality. Second, firm fixed effects absorb time-invariant managerial style, governance quality, and technological position. Third, the analysis includes year effects and industry-year demand controls [31]. Fourth, a control-function approach is estimated using lagged shifts in product warranty exposure and lagged expiration clustering of patent maintenance fees as predictors of the cost of maintaining weak initiatives. These shifters affect the economic cost of continued support but are unlikely to determine future renewal directly after the full set of controls and fixed effects. The residual from the first-stage termination equation is then entered into the second stage.

A dynamic panel estimator is also reported for the valuation outcome. The model includes lagged firm value and is estimated using a restricted system-GMM design with collapsed instruments and short lag depth to avoid instrument proliferation. The dynamic estimate is not treated as the main specification because the termination construct is already noisy and overly aggressive instrumentation can create false precision. It remains useful, however, as a check that the estimated curvature is not simply a feature of persistence in firm value [32].

All continuous variables are winsorized at the 1% and 99% tails. Standard errors are clustered at the firm level [33]. For the patent quality and product revenue models, observations with no innovation activity in the forward year are retained rather than dropped, because zero-

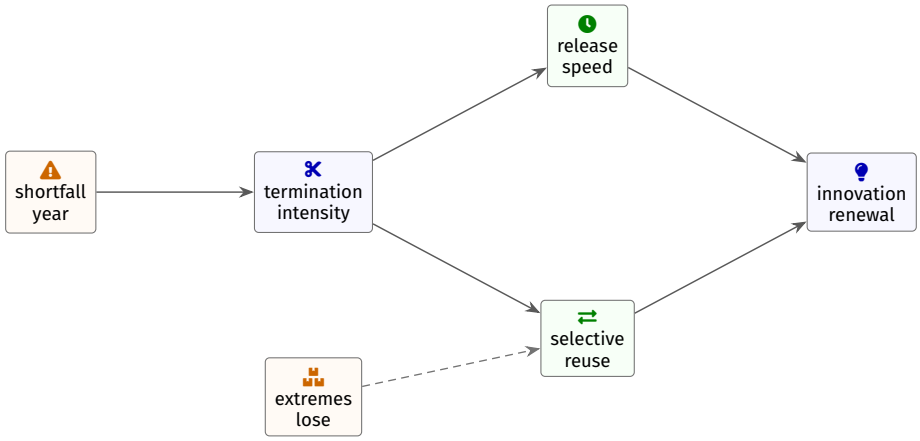


Figure 9 Process rendering of the paper's mediation results. Moderate post-shortfall termination speeds resource release and improves redeployment selectivity, and adding these mediators reduces the absolute size of the core termination coefficients by roughly one-fifth. The effect is therefore partial rather than complete, which fits the claim that disciplined stopping operates through several linked channels instead of a single bottleneck.

Table 5 Economic Effects Across Distribution

Comparison	Patent (%)	Revenue (pp)	IVOL
25th to Optimum	+4.4	+2.1	-0.6
Optimum to 90th	-3.1	-1.4	+0.5
Low vs High	-1.2	-0.9	+0.8

outcome years are informative in this setting. A firm that prunes heavily and then produces nothing is economically different from one that prunes moderately and produces a smaller but higher-quality stream of output. The estimation strategy is therefore designed to respect the possibility that termination affects both the level and the composition of subsequent innovative activity.

5. Core Estimates

The main estimates show a stable inverted-U relationship between termination intensity and subsequent renewal. In the fixed-effects model for next-year citation-weighted patent applications, the coefficient on TI_{it} is positive and the coefficient on TI_{it}^2 is negative, with both terms statistically distinguishable from zero. The estimated linear term is 0.118 and the squared term is -0.041. The implied optimum lies well inside the observed support rather than at the tail, which is important because it rules out a superficial interpretation in which "a little more pruning is always better." Moving from the 25th percentile of termination intensity to the estimated optimum is associated with a 4.4% increase in next-year citation-weighted inventive output. Moving from that optimum to the 90th percentile is associated with a decline of 3.1%. These are moderate but meaningful effects. They indicate that both insufficient and excessive pruning leave visible traces in the quality of the next year's inventive output [34].

The recent-product revenue share model produces a similar shape and somewhat larger economic magnitudes. The linear coefficient on termination intensity is 0.029 and the squared term is -0.010. At the interior optimum, the estimated recent-product revenue share in the following year is 2.1 percentage points higher than for firms in the bottom quartile of termination intensity, holding shortfall severity and the rest of the control set constant [35]. This difference is not trivial. In the sample, the median firm-year recent-product revenue share is 13.4%, so a 2.1 point difference corresponds to a non-negligible shift in the contribution of recent innovation to the sales mix. The result suggests that moderate termination does more than improve patent quality [36]. It also supports commercial renewal.

The idiosyncratic volatility results are directionally consistent but weaker in absolute size. Moderate termination is associated with lower next-year firm-specific return volatility, whereas very low and very high termination intensity are both associated with higher volatility. The quadratic pattern is statistically present, though flatter than in the patent and revenue models. This is plausible. Capital markets observe the innovation portfolio only imperfectly, so any volatility effect should be smaller than the technical or commercial recovery effect. Even so, the sign pattern indicates that visible moderation in pruning is easier for the market to interpret than either inertia or retrenchment.

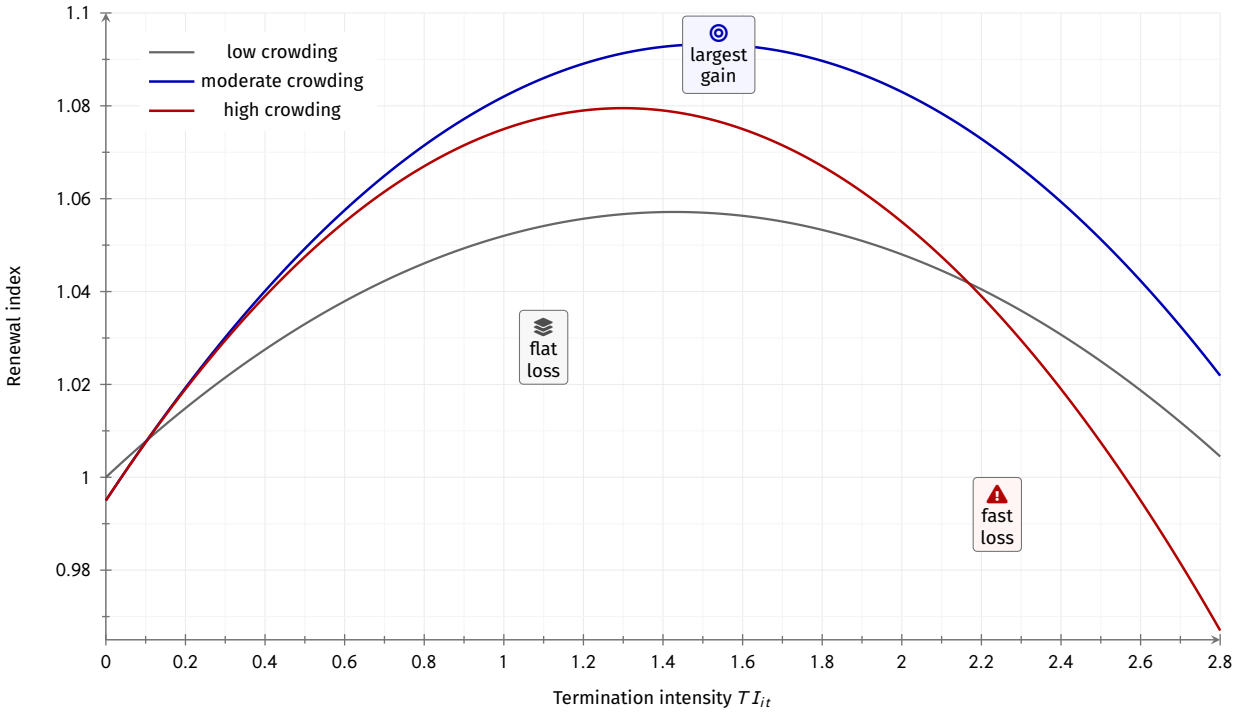


Figure 10 Competitive crowding changes the shape of the interior optimum. The middle curve is steepest and highest under moderate crowding, while weakly contested markets show flatter costs of underreaction and highly crowded markets show a sharper right tail, where overpruning rapidly damages renewal. This matches the paper's claim that context governs how strongly selective pruning pays off.

Table 6 Mediation: Resource Release

Variables	Release Speed	Patent Quality	Revenue Share
Termination Intensity	0.152	0.094	0.021
Termination Intensity^2	-0.056	-0.033	-0.008
Release Speed	–	0.081	0.017

Because shortfall severity could still mask important differences, the sample is divided into mild, moderate, and severe shortfall years. The inverted-U pattern remains in all three groups, though the optimum shifts rightward as shortfall severity increases. In severe shortfall years, the most favorable renewal outcomes occur at a somewhat higher termination level than in mild shortfall years [37]. This is consistent with common sense. When disappointment is deep and widespread, more pruning is appropriate. What remains important is that even in severe shortfall years the relationship does not become monotonic. Very aggressive retrenchment still predicts weaker renewal than moderate-to-high retrenchment.

A useful way to understand the result is to compare three stylized firm-year profiles. The first profile is the "carry-forward" response: the firm acknowledges disappointment but keeps most affected initiatives alive in reduced form [38]. These observations tend to show lower later patent quality and slow recovery in recent-product revenue share. The second profile is the "surgical cut" response: the firm terminates a meaningful fraction of visibly weak initiatives while maintaining adjacent exploratory activity. These observations cluster near the estimated optimum and show the strongest renewal. The third profile is the "portfolio purge" response: the firm retires a large set of initiatives, records substantial technology impairments, and sharply narrows current pipeline language. These observations often show immediate cost relief but weaker subsequent commercial renewal. The formal estimates do not depend on these labels, yet the labels help translate the curvature into managerial terms.

The effect remains after introducing a demanding set of controls. Leverage and cash constraints matter as expected. More leveraged firms terminate somewhat more in shortfall years, though their subsequent renewal is weaker unless termination remains near the interior op-

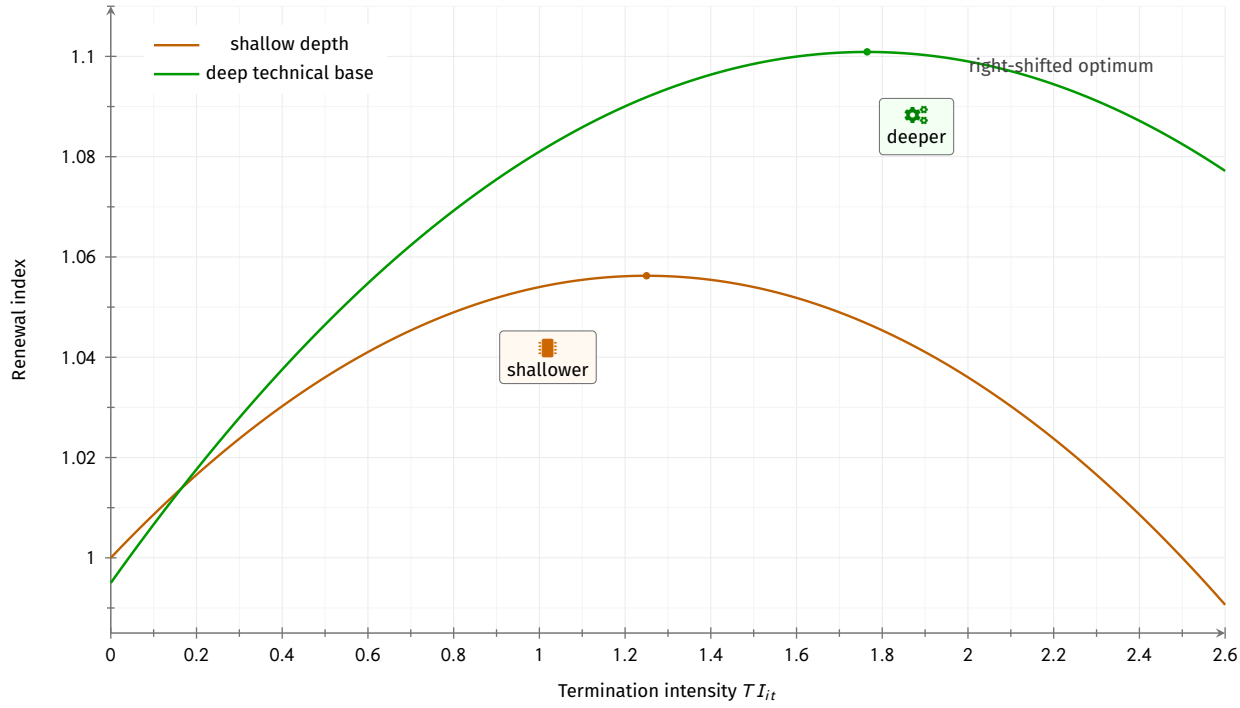


Figure 11 Internal technical depth buffers the continuity loss from pruning and shifts the optimum to the right. Firms with deeper specialized knowledge can terminate somewhat more aggressively before renewal starts to erode, because reusable fragments and expertise remain embedded in the organization rather than solely in currently active projects.

Table 7 Mediation: Redeployment Selectivity

Variables	Selectivity	Patent Quality	Revenue Share
Termination Intensity	0.137	0.089	0.019
Termination Intensity^2	-0.049	-0.028	-0.007
Selectivity	–	0.073	0.015

timum. Advertising intensity supports recovery in recent-product revenue share but does not eliminate the pruning effect, implying that termination discipline is not merely a proxy for stronger marketing support. Acquisition intensity predicts more discontinuation activity but does not generate the same quadratic relationship unless the discontinuations occur in a shortfall context. This helps distinguish post-shortfall termination from routine post-acquisition clean-up.

The control-function results modestly attenuate the coefficients but preserve the core pattern. The first-stage instruments, lagged warranty exposure shifts and clustered maintenance-fee expiration, significantly predict termination intensity. The second-stage residual is small and unstable across specifications. The main linear and squared termination terms remain economically similar to the fixed-effects estimates. This does not prove full exogeneity, but it indicates that the curvature is not driven entirely by firms strategically pruning because they already know high-quality projects are waiting in the wings.

The dynamic panel model for logged Tobin's Q also supports the interior-optimum interpretation. Once lagged value is included, the linear termination term remains positive and the squared term negative. The coefficients are smaller, which is expected given the persistence of valuation multiples, yet the pattern remains [39]. The economic interpretation is that moderate post-shortfall pruning is associated with stronger future valuation even after accounting for value persistence. This is a stricter result than the contemporaneous volatility finding because it asks whether the market eventually rewards disciplined retrenchment in a way visible beyond immediate announcement reactions.

A concern might remain that the model is simply capturing managerial competence. Perhaps better managers prune neither too little nor too much, and the estimates are merely a shadow of that broader trait. Several facts argue against a purely generic competence interpretation [40]. The effect is concentrated in shortfall years rather than in all years. It is stronger when the terminated initiatives are more visible in the product or technology

Table 8 Heterogeneity by Competitive Crowding

Crowding Level	TI	TI^2	Effect Shape
Low	0.082	-0.025	Mild curve
Moderate	0.131	-0.049	Strong curve
High	0.144	-0.062	Steep right tail

Table 9 Robustness Checks

Specification	TI	TI^2	Result
No impairments	0.109	-0.038	Holds
Direct disclosure only	0.121	-0.043	Holds
Patent-heavy firms	0.134	-0.047	Stronger
Launch-heavy firms	0.097	-0.031	Consistent

narrative. It is also stronger when the pruned initiatives had meaningful support costs relative to firm size. These patterns are more consistent with a mechanism rooted in post-shortfall innovation governance than with a broad latent quality that would affect all firm-years similarly.

Another possibility is that the apparent optimum reflects reporting behavior rather than real portfolio decisions. Firms might bunch around moderate impairment or discontinuation levels because that amount of pruning is easiest to defend publicly. Several analyses reduce this concern. The effect appears not only with the public-disclosure-based composite but also when the termination measure is rebuilt using only lapsed application behavior and discontinued support pages that are harder to manage rhetorically. The curvature also persists when the sample is restricted to firms with direct recent-product revenue disclosures, where commercial disappointment is more transparent. These findings suggest that the relationship is not merely a storytelling artifact.

The main estimates therefore support a fairly specific conclusion. After commercial shortfalls, innovation renewal is strongest when firms engage in selective but not indiscriminate termination. Too little pruning leaves weak initiatives clogging the portfolio. Too much pruning removes residual option value and weakens the continuity required for later recovery. The data do not suggest that one universal pruning rate exists for all firms. They do suggest that both extremes carry predictable costs and that the middle of the distribution is where subsequent renewal is most likely to emerge [41].

6. Adjustment Channels and Heterogeneous Effects

The next question is not whether the curvature exists, but why. The first adjustment channel is resource release speed. In the mediator model, termination intensity has a positive linear effect and a negative squared effect on the speed with which resources leave discontinued initiatives and become visible elsewhere in the innovation system. Firms near the middle of the termination distribution show the fastest release. Firms with very low termination intensity release little because the weak initiatives remain alive. Firms with very high termination intensity release resources formally, but redeployment is slower than expected because the broader purge creates bottlenecks in evaluation and staffing. In practical terms, large cuts appear to free budget faster than they free coordinated capacity.

When resource release speed is added to the patent quality and recent-product revenue share models, the absolute size of the termination coefficients declines by roughly one-fifth. The indirect effect is statistically reliable under clustered bootstrap inference. This is consistent with the idea that moderate pruning helps because it moves attention and technical effort off weak projects quickly enough to matter for the next cycle. The mediation is partial, not complete [42]. That is sensible. Termination discipline likely improves renewal through several routes, of which faster release is only one.

The second channel is redeployment selectivity. Here the strongest pattern is not speed alone but where released resources go. Firms near the interior termination optimum tend to reallocate toward related but not identical domains. For example, a disappointing device category may be followed by work on adjacent sensing architecture rather than total retreat from the broader platform. A weak enterprise software module may be cut while the firm continues development on adjacent workflow or analytics capabilities. Excessive pruning produces lower selectivity because the firm narrows sharply toward very familiar territory or, in some cases, fails to restart quickly at all [43]. Very weak pruning also produces lower

selectivity because resources remain attached to the failing line. Selective redeployment therefore appears to be another mechanism through which moderate termination preserves learning while improving portfolio quality.

Heterogeneous effects further clarify where the interior optimum is most valuable. Competitive crowding produces a noticeable shift [44]. In markets with moderate crowding, the inverted-U relationship is steepest and the gains from moderate termination are largest. In weakly contested markets, the curvature is present but flatter. The portfolio cost of carrying weak initiatives is lower when competitive pressure is low, so underreaction is less damaging. In highly crowded markets, the right side of the curve steepens sharply. Overpruning is especially harmful there because firms that retreat too far surrender learning tempo just when rivals are moving quickly. This pattern resonates with a broader point visible in other innovation settings. Cao et al. (2025) [45] find that the financial benefits of environmental innovation are shaped by market-level competition and by firm-level attributes such as reputation and effectiveness, with stronger benefits under moderate competitive conditions rather than at either extreme. The parallel is not that environmental innovation and termination are the same phenomenon. It is that innovation-related returns often depend on context rather than increasing monotonically with more visible action.

Innovation reputation moderates the effect in a different way. Firms with stronger preexisting reputations in innovation markets experience a slightly flatter left side of the curve. Carrying weak projects for too long is still harmful, but less immediately so, perhaps because those firms possess a thicker base of credibility and richer complementary assets. The right side of the curve, however, becomes steeper [46]. Heavy pruning by high-reputation innovators appears to damage renewal more noticeably than heavy pruning by low-reputation firms. One plausible interpretation is that high-reputation firms have more complex option structures embedded in their portfolios, so indiscriminate cuts destroy more hidden value. Another is that internal expectations are higher in such firms, making broad retrenchment more disruptive to future initiative generation.

Internal technical depth produces one of the most interesting moderation patterns. Firms with deeper specialized technical knowledge exhibit a rightward shift in the optimum. They can prune somewhat more aggressively without damaging future renewal as quickly as firms with shallow technical depth. This does not mean that highly technical firms should purge widely. It means that their knowledge base buffers some of the continuity loss created by pruning. They are better able to preserve and reuse fragments of discontinued lines because the people who hold the underlying expertise can recontextualize it. The result also suggests that the real cost of overpruning depends on whether knowledge is embodied only in current projects or more deeply embedded in the organization.

The commercial recovery effect is strongest when the terminated initiatives had high support intensity. This is intuitive but important. Moderate pruning matters most when weak initiatives were consuming meaningful post-launch or post-development support. Termination of low-support weak initiatives has smaller downstream consequences because the resource release is modest. By contrast, eliminating a high-support underperformer can materially alter what the firm is able to fund and attend to in the next cycle. The implication is not that firms should use support intensity as the sole termination rule. It is that the opportunity cost of inaction is larger when a weak initiative continues to absorb expensive follow-through [47].

A final heterogeneity analysis examines the age of the disappointing initiative. Moderate pruning is most beneficial for relatively young initiatives that have shown clear commercial weakness but have not yet accumulated a long installed base or irreversible platform dependence. Very young failures are still salvageable through adjacent redeployment, and moderate pruning appears to preserve that salvage value. By contrast, pruning intensity matters somewhat less for old and clearly exhausted lines because the residual option value is smaller. This distinction helps explain why the overall curvature does not imply a universal preference for middle-range termination regardless of project age. The interior optimum is a portfolio average across initiatives whose salvage value differs.

Taken together, the channel and heterogeneity results show that the estimated curvature is not a statistical curiosity. It maps onto a recognizable operational process. Moderate termination tends to release resources more effectively and redeploy them more selectively. Its benefits are amplified in moderately crowded markets, in firms with technical depth, and when the targeted initiatives were materially expensive to keep alive [48]. These patterns give the empirical estimates more structural content. They suggest that the observed interior optimum arises because pruning solves a real congestion problem but becomes counterproductive when it destroys reusable knowledge and destabilizes the portfolio.

7. Re-estimation and Scope Conditions

A series of additional analyses was conducted to test whether the main pattern survives alternative measurement choices and narrower samples. The first exercise reconstructs termination intensity using only non-accounting components. Technology impairment charges are dropped so that the measure depends solely on discontinued offerings, pipeline withdrawals, and lapsed application behavior. The inverted-U association with both patent quality and recent-product revenue share remains. The optimum shifts slightly left, which is ex-

pected because the accounting component tends to rise in the broadest retrenchment episodes, but the substantive interpretation is unchanged. This matters because it reduces concern that the results merely capture the timing of write-down recognition.

The second exercise focuses on direct-disclosure firms, meaning firms for which recent-product revenue share is measured from explicit managerial disclosure rather than inferred from product mix reconstruction [49]. The sample falls to 1,124 shortfall firm-years, yet the estimated coefficients remain economically similar. Precision weakens, especially in the volatility models, but the curvature in commercial recovery remains visible. This suggests that the central result is not being generated by noise in the inferred revenue-share measure.

The third exercise separates patent-heavy from launch-heavy firms. For patent-heavy firms, the strongest response appears in citation-weighted inventive renewal. For launch-heavy firms, the strongest response appears in recent-product revenue share. In both groups the curve remains inverted-U. The difference is not surprising. Patent-heavy firms express renewal more clearly in the knowledge domain, whereas launch-heavy firms express it more directly in the sales mix. What matters is that moderate termination remains more favorable than either inertia or overpruning in both kinds of innovation system.

A further scope analysis considers whether the pattern is really about excessive narrowing after disappointment. The concern is plausible. After weak commercial outcomes, managers often respond by collapsing search onto a smaller set of familiar domains. That move can appear prudent but may depress future renewal if it excessively reduces heterogeneous knowledge inflow. In a different empirical setting, Cao et al. (2024b) [50] find that greater incubator specialization decreases startups' R&D efficiency and indirectly reduces venture capital funding, while specialized technical knowledge partially attenuates the harm. That result is useful here because it points to a broader caution: narrowing the knowledge environment may solve some coordination problems while weakening inventive efficiency. Consistent with that logic, the present data show that the right side of the termination curve becomes steeper when post-shortfall pruning is accompanied by sharp narrowing of the patent-class and launch-category portfolio. In other words, overpruning is particularly damaging when it is paired with abrupt search concentration. Firms with deeper internal technical knowledge are partially buffered, but not immune [51].

The paper also tests whether the main estimates are driven by major restructurings, activist interventions, or CEO turnover years. Excluding those years reduces the sample modestly but does not change the shape of the main relationship. This is informative because broad restructurings can include many non-innovation motives for discontinuation. The persistence of the effect in calmer years supports the view that the mechanism belongs to innovation governance rather than to general corporate upheaval.

Placebo tests further clarify interpretation. First, a "general contraction intensity" measure based on plant closures, headcount reductions outside technical functions, and non-technology asset sales is substituted for innovation termination intensity. That measure does not reproduce the same stable inverted-U pattern in future patent quality or recent-product revenue share. Second, an "ordinary product retirement" measure built from mature end-of-life replacements without evidence of disappointment is examined. It has little systematic association with renewal. These placebos matter because they show that the estimated curvature is not simply a generic restructuring effect or a routine portfolio-refresh effect. The phenomenon appears tied to shortfall-driven innovation pruning.

Reverse-causality checks address another concern. Could firms that already anticipate a strong future pipeline choose moderate pruning because they know recovery is coming? To probe this possibility, the models predict current termination intensity using future patent quality and future recent-product revenue share after conditioning on current controls and fixed effects. The lead terms are small and statistically unstable [52]. This does not eliminate all forward-looking managerial behavior, but it weakens the claim that the results are driven mainly by managers acting on private knowledge of certain future success.

There is also the possibility of nonlinear mismeasurement. If firms in the extremes of the termination distribution are simply more opaque, the apparent curvature could be a consequence of noisier outcome measurement. Several checks speak against this. Analyst coverage does not drop sharply at the extremes, direct recent-product disclosure is not disproportionately concentrated in the middle, and the same interior optimum appears when the outcome is patent quality, which is measured from external records rather than managerial disclosure. The convergence across distinct outcome types makes a pure opacity story less persuasive.

A final re-estimation uses multinomial treatment bins rather than a quadratic term. Termination intensity is divided into low, moderate-low, moderate-high, and high groups. The two middle bins dominate the lowest bin on both patent quality and recent-product revenue share, and the highest bin underperforms the middle bins. This nonparametric check is valuable because it shows that the result does not rely on the quadratic form. The curve is not perfectly symmetric, but the substantive conclusion is the same: the middle of the termination distribution is more favorable for subsequent renewal than either extreme.

These additional analyses narrow the scope of the claim in a useful way. The paper does not show that every termination program should aim for a single uni-

versal target. It shows that, in commercially disappointing innovation episodes, selective middle-range pruning is systematically more favorable than either persistent retention or sweeping retrenchment. The claim survives alternative measures, narrower samples, placebo tests, and nonparametric re-estimation. It is therefore best understood as an empirical regularity about innovation governance under disappointment rather than as a rhetorical preference for moderation in the abstract [53].

8. Conclusion

Innovation programs are usually judged by what they create. The evidence here suggests that what they stop is also consequential. Across publicly listed manufacturing and technology firms, the years that follow commercial disappointment are shaped not merely by how much firms invest, but by how they retire weak initiatives. The data indicate that neither reluctance to terminate nor indiscriminate cutting is favorable for renewal. The strongest subsequent inventive and commercial outcomes emerge in the middle range, where weak projects are removed with enough force to release resources and attention, but not with such breadth that salvageable knowledge and option value are destroyed.

The results are not grandiose. The estimated gains from moderate termination are meaningful but not transformative. Moving from the lower quartile of termination intensity toward the interior optimum improves next-year citation-weighted patent output by roughly 4.4% and recent-product revenue share by about 2.1 percentage points. These are moderate effects, which is exactly what one should expect in a setting where many other forces influence renewal. Yet the effects are persistent across outcomes and robust across estimation strategies, which makes them difficult to dismiss as noise [54].

The mechanism evidence gives the pattern practical content. Moderate pruning appears to work partly because it releases support capacity and development resources more quickly, and partly because it encourages redeployment toward related but not identical knowledge domains. Excessive retrenchment, by contrast, seems to create a different inefficiency. It clears the current portfolio, but often at the cost of continuity and selective reuse. Firms then face the next innovation cycle with less congestion but also with a thinner set of recombinable assets.

These findings also help clarify how innovation governance should be evaluated. A board or executive team observing disappointing commercialization does not face a binary choice between persistence and cancellation. The more relevant question is whether the firm can identify weak initiatives selectively enough to reduce congestion while preserving useful fragments and maintaining a credible path to the next round of experimentation. That is a narrower and more operational question than the general advice to "be more disciplined" or "fail faster." The evidence suggests that both slogans are incomplete.

Several limitations remain. Public disclosures do not reveal the full structure of internal project portfolios, and some termination behavior necessarily occurs below the threshold of external observation. The recent-product revenue measure is more precise for some firms than for others, even though the core results persist in the direct-disclosure subsample. It is also possible that some internal cultural effects of pruning appear over a longer horizon than the one-year outcomes emphasized here. Those limits leave room for future work using project-level internal data, inventor mobility, or direct measures of engineering reassignment.

Even with those qualifications, the central point is difficult to ignore. Innovation capability is not only an initiation capability. It is also a stopping capability [55]. Firms that respond to commercial shortfalls by pruning weak initiatives selectively appear better positioned to renew their inventive output, recover product revenue, and reduce unnecessary uncertainty. Firms that hold on too long or cut too broadly appear to pay for those choices in the next innovation cycle.

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