Creation, destruction and the social value of innovations: Evidence from financial markets

Abhijit Tagade*
London School of Economics

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Abstract

How much value do innovations create, and for whom? I provide a new measure of the economic value innovations create and destroy in the market, and show how it reaches consumers. Using stock market responses to news about patents granted between 1981 and 2024 to companies listed in the United States, I estimate that one dollar of private value created for innovators produces an additional $1.05 on net for other producers. This external value produced by innovations has grown over time as a share of the US economy and varies substantially across industries that differ in their technological connectedness, competitiveness and market size. These forward-looking estimates derived from financial data predict real growth, market power and productivity of firms, and greater creative destruction within sectors accounts for the subsequent rise in productivity and fall in prices. To interpret these results, I develop an endogenous growth model featuring multi-product firms, embedded in a production network, that compete for leadership over products through innovation. Innovations provide fresh ideas that spur research in other firms, so sectors that receive more ideas do more research and their products change hands faster. Technology gains and rivalry losses are two stages of one process that benefits consumers: spillovers speed up creative destruction, whose gains to consumers grow with the centrality of the innovating sector in the production network.

JEL codes: O33, O34, D57, G14, L13, E22
Keywords: innovation, competition, spillovers, stock returns, growth, productivity

*Department of Economics, London School of Economics, CEP and POID. Email: a.tagade@lse.ac.uk. I am grateful to Philippe Aghion, Xavier Jaravel and John Van Reenen for their advice and support. I thank Bijan Aghdasi, Maria Cecilia Bustamante, John Campbell, Arnaud Dyevre, Benjamin Friedman, Xavier Gabaix, Ben Golub, Michael Gmeiner, Basile Grassi, Allison Green, Matthew O. Jackson, Bill Janeway, Dirk Jenter, Christian Julliard, Leonid Kogan, Danial Lashkari, Hongting Leng, Isabela Manelici, Ben Moll, Ramana Nanda, Steve Pischke, Sergio Rebelo, Ricardo Reis, and participants at Network Science and Economics, Harvard Macro and HBS Finance lunches, and Econometric Society European Meeting for valuable suggestions that have improved the paper, and to Refine.ink for help with reviews.

1 Introduction

How much economic value does an innovation create, and for whom? When firms innovate in the pursuit of monopoly rents, they produce economic growth and benefits to society that exceed what they privately accrue. (Schumpeter, 1942; Aghion and Howitt, 1992) However, investment in innovation depends on incentives and these incentives differ substantially by firms. Since Arrow (1962), economists have recognized that if firms may underinvest in innovation if the value they capture only a small portion of the value they create for others; by contrast, when firms face prospect of large private gains, they may overinvest even when their creative contribution is low. (Arrow, 1962; Jones and Williams, 2000) Therefore, who gains from innovation, who loses, and by how much, is an important metric that captures the incentives of an investor who decides *where* to invest in R&D to maximize the economic value that innovations can generate. An ideal measure of such a metric should provide a common unit of the economic value that accrues to innovators, relative to value creation and destruction for others in the economy.

I provide a new measure of such a metric using stock market responses to patent announcements. The virtues of asset prices are that they are measurable, market based, and provide the best publicly available forward-looking estimate of prospects of firms based on current information. When an innovator earns a patent, its increase in asset price provides an ex ante dollar measure of its future gains. In this paper, I shift the focus from measuring the gains implied by change in asset prices for the innovator, as pioneered by Kogan et al. (2017), to measuring changes in the dollar value of firms connected to the innovator. The ratio of the change in dollar values of assets of connected firms relative to those of innovator then provides a forward-looking measure of each innovator's economic footprint of the external versus private value for the same underlying patent. Such a ratio that relies on the network location of each firm can be useful to forecast incentives for direction of innovation, to decompose firm and sector wise hetrogeneity in social returns to R&D investment, and to identify sources of business dynamism and value creation in the economy. Because such a multiple is unit free, it also provides a comparable metric across sectors, firms, and time periods.

Constructing this measure requires knowing both how firms are connected, and estimating how their stock prices respond to patent announcements based on their individual exposures. To do so, I build a panel of companies listed in United States matched to over 3 million patents granted by the US Patents and Trademark Office between 1976 and 2024, and construct linkages between them by three economically distinct channels. The first is rivalry, which captures the degree of reallocation between firms, which I measure using similarity in their business operations. The second is propagation through demand and supply channels along supply chains. And the third is technological opportunities that new innovations create for firms that share similar technologies to build their products and services. Since firms that do not patent also face competitive pressures from their innovating rivals or a market expansion or contraction from supply chains, I include

them in my main estimation panel. Using these firm to firm exposures, I estimate movements in stock returns within a few days of the news of patent announcements using granular variation in patents announcements to each firm by each date. I then convert these estimated stock market responses into ratios of external to private dollars using pre-announcement market capitalizations.

The identifying assumption in estimating effects of patent announcements on stock returns is that the variation in announcements across firms on a given day is conditionally orthogonal to other unrelated news. To provide a comparison between firms that differ by their systematic risk, I use cumulative abnormal returns, measured by Fama and French (1993) factors, over a three day window from each announcement date as my outcome for the headline estimation. The US patent office announces patents on each Tuesday in their *Official Gazette*, so the three day window balances time to absorb patent news while avoiding noise or run ups to the next week. As firms with many connected peers are systematically more prone to be exposed to news, I recenter them by allowing the return to a firm's overall technology and rivalry connectedness to vary freely on every grant date. (Borusyak et al., 2022, 2025) This complements the standard recentering by date that neutralizes common news affecting the market. Since mean reversion and run ups from past events may coincide with patent news, I control for prior returns of both the focal firm and its peers, each of which reflect past equilibrium outcomes. The empirical design therefore compares two equally connected firms whose specific connected peers receive different patent batches of patents on each date.[1] My estimates survive a battery of robustness checks, including alternative measurements of patenting activity, return windows, risk factor adjustments, connectedness and contemporaneous controls. Moreover, my estimates of the private value of patents line up ordinally against Kogan et al. (2017) method implementation on my sample with a rank correlation of .96.[2]

The central finding of this paper is that innovators capture half the total value they create for all firms in the market. In my headline estimates, one dollar in private value creates over $1.7 dollars in technology spillovers and destroys about $0.67 for rivals. My estimates find near zero supply chain transmission in all specifications, which inherit possibly severe attenuation due to data limitations of sparsely disclosed ties by listed firms, or a delayed stock market reponse that I am unable to measure within the short window. A positive external balance means that measured gains to other producers exceed their competitive losses. Whether these revaluations accompany greater productive capacity is a separate question, which I examine using subsequent firm and industry outcomes. Comparing rivals alone shows a surplus of a third of total private gains. The market value omitted in innovators' gains is large even within the universe of listed companies,

[1] This differs qualitatively from Aghdasi and Tagade (2025), who use alternative constructions of outcome, shocks and controls, over different sample and period. However, their evidence provides useful motivation for this analysis and a starting point for the main results on measuring the social value of innovations and clarifying the economic content underlying them.

[2] For dollar on dollar in logs, the R^2 is .91 and slope against their values is .78: my estimates are systematically lower for small firms but line up closely for large firms. By total volume, the two differ by less than 10 percent.

before accounting for gains consumers earn from innovations. By dollar volume, external value has grown over time as a share of the US economy (9 percent of the nominal GDP, 4 percent of total stock market capitalization) as firms have grown more interconnected by technology.

Underlying this aggregate measure is wide heteroegeneity of gains and losses both within and across industries. By volume, firms in software and IT services generated the highest private dollar value, but it is computer hardware, chips, and business equipment firms that have generated the most net external value. Others, such as pharmaceuticals and drug manufacturers, show a saturated composition of all forces: while producing large private gains and technological spillovers, steep rivalry among firms erodes almost all external gains. As a consequence, pharma's external-to-private ratio is among the lowest at 0.17. A second source of heterogeneity is the gap between market value created by inventing (out-degree) versus market received (in-degree) because others innovate. Hardware, chips, and equipment generate a third of all external dollar value but receive only a fifth. Finance and wholesale and retail trade receive nearly a quarter of all external value but generate half as much. Since an innovator's incentives omit the former, this paper provides a measurable market-value counterpart to Liu and Ma (2024)'s optimal R&D allocation problem that prioritizes the out degree centrality.

To demonstrate the usefulness of my measure derived from financial data, I examine their economic content relevant to three questions in growth literature. First, growth theory distinguishes spillovers, which raise the productivity of other firms' research and production, from creative destruction, which moves products and profits from incumbents to innovators (Aghion et al., 2015; Klette and Kortum, 2004). An influential approach in this literature has been to use patent citations to trace sources of knowledge or use investments in R&D for sources of shocks. (Bloom et al., 2013). My measure provides a receiver specific metric: I create an index per company that aggregates economic value it gains or loses from the micro shocks of patents announced to connected firms as a share of its size. I find that that my index measured from financial data predicts subsequent firm scale, market power and productivity. A firm whose own patents add one percent to its size grows its sales, earnings, and expands its capital and employment. By contrast, a percent loss in value from rival innovations precedes its subsequent contraction by scale and productivity. Using news that ends before the baseline fiscal close, technology spillovers predict growth in R&D spending over three years. The research association is consistent with later innovations building on earlier ones (Scotchmer, 1991), while firms that lose value to rivals subsequently contract, as in models of creative destruction.

These findings also connect to the information financial analysts use to forecast firm performance and growth. Price-to-earnings (PE) ratios have long been used in practice as parsimonious indicators of firm's future earnings. Recent work by Boppart et al. (2026) suggests that these ratios also provide an interpretation of contributions to economic growth as earnings reflect past innovations, but prices reflect information about the future. But since current price of firms combines both prior valuation and its change into innovation and unrelated news, I decompose

the association between PE ratios and subsequent earnings by sources of its change in value. Within this allocation, own innovation and technology gains predict higher subsequent street earnings, while losses from rival innovations predict lower earnings.

Second, as Kogan et al. (2017) observe, whether innovation is socially valuable depends on its contributions to aggregate productivity, as opposed to reallocation of value. Innovation per se need not imply an expansion since firms could instead internalize gains as greater profits; what contributes to growth are incentives created by dynamics between firms. To distinguish the two, I examine whether my measure of micro shocks speak to macroeconomic outcomes by constructing an annual industry level innovation index that aggregates the economic value of patent news received per company weighted by their sales share in the sector. Industries whose firms experience greater losses from rival innovations, conditional on private gains from innovation, see a rise in output and total factor productivity, alongside a negative but less precise association with prices over subsequent years. Taken together with contraction for displaced firms, these results associate rivalry with an expansion of production; the evidence for lower consumer prices is less precise. These results are consistent with the Schumpeterian view that displacement by creative destruction accompanies growth. (Schumpeter, 1942; Aghion et al., 2014)

Third, the economic value from stock prices reflects only a part of the gains to the social value. To interpret my results, I develop a multi-product and multi-sector quality ladder model where firms endogenously enter the market, compete on products to be leaders and earn profits until they are imitated or displaced. A key feature of this model is that innovations provide new ideas to other firms allowing others to innovate with fewer resources both within and across sectors. These sectors, which are connected by supply chains, transmit permanent gains downstream as competition upstream translates into gains for consumers who enjoy lower prices. Households, which own all firms, gain both the value that stock prices capture, including technology spillovers, and the lasting price reductions from creative destruction and imitation. The social value of innovation net of R&D costs therefore includes technology spillovers net of rivals' losses, the propagation of price drops from creative destruction, and the endogenous entry induced by new ideas.

Related literature My first contribution is to measure the external value of innovative output on the same forward-looking dollar scale as its private reward. The empirical spillover literature asks how one firm's research affects the productivity, profits, and research of others (Jaffe, 1986; Bernstein and Nadiri, 1989; Griliches, 1992; Bloom et al., 2013, 2019). I bring to this problem the financial valuation of inventions developed by Pakes (1985); Hall et al. (2005); Kogan et al. (2017), with the external valuation estimated from the affected firms' prices. Relative to regressions on accumulated research expenditures, the object is the expected value of announced research output; private and external rewards refer to the same news and the same valuation date. Relative to studies of patent-announcement spillovers (Austin, 2000; Walter, 2024; Aghdasi and Tagade, 2025),

the contribution is a joint account of the dollars created and destroyed, which permits comparison of an innovator's private success with its contribution to other producers. This distinction also separates the approach from Mukherjee et al. (2026), who recover external profits and consumer surplus from new-product valuations through a demand system. Here, external profits provide additional empirical restrictions on the model rather than being inferred from the innovator's gain. The measure consequently complements evidence on where knowledge travels through citations, researchers, and technology transactions (Jaffe et al., 1993; Zacchia, 2020; Arqué-Castells and Spulber, 2022) with evidence on how its expected economic rewards are distributed.

The second contribution is to distinguish the economic content of innovation gains from that of innovation losses, and use both to study growth. In the tradition of Caballero and Jaffe (1993), knowledge accumulation and the destruction of existing rents must be measured together to understand technological progress. Quantitative models infer their importance from firms' research and growth histories (Klette and Kortum, 2004; Lentz and Mortensen, 2008; Akcigit and Kerr, 2018; Garcia-Macia et al., 2019); I add evidence from separately measured revaluations of innovators, technology recipients, and displaced rivals. Relating these values to subsequent firm and industry outcomes permits an empirical distinction between the loss of business at a firm and a loss of productive capacity in the economy. It also gives an economic interpretation to the information transmitted across linked stocks (Cohen and Frazzini, 2008; Lee et al., 2019): the relevant news can concern the recipient's opportunities to build on knowledge or the erosion of its existing rents. Relative to the use of valuation ratios to infer growth opportunities (Boppart et al., 2026), the measure distinguishes these sources of valuation before examining what they predict. The model then carries this distinction into welfare.[3] Griliches (1979); Pakes and Schankerman (1984) explain why the depreciation of private returns need not imply the depreciation of knowledge. I make that distinction quantitative by using corporate valuations to discipline a quality-ladder model in which the end of a technology lead transfers benefits to buyers. With production-network propagation (Hulten, 1978; Baqaee and Farhi, 2020), this supplies a mapping from measured innovation news to consumption gains that complements aggregate calculations of the social return (Nordhaus, 2004; Jones and Summers, 2022).

The third contribution is to give the opposing research incentives created by spillovers and competition an empirical valuation basis. In cumulative innovation, an early inventor may fail to capture the profits of later inventions it enables, even when the products do not compete (Scotchmer, 1991; Green and Scotchmer, 1995). Whether firms underinvest depends on what they fail to appropriate and what they take from others (Spence, 1984; Jones and Williams, 2000; Arora et al., 2021); whether diversified ownership improves those incentives depends on which of these external effects it internalizes (Hansen and Lott, 1996; López and Vives, 2019). Antón et al. (2025)

[3] Kogan et al. (2020) also distinguish gains to stockholders from the gains of innovation, through innovators' inability to sell claims on future inventions. Here, the additional household gains arise from lower prices as technological improvements outlast private rents.

establish this distinction theoretically and empirically: common ownership is more positively associated with innovation when technological proximity is high, and more negatively associated when product-market proximity is high. My contribution is to estimate the economic value of both external effects and use their balance to discipline the research objective of a diversified shareholder. Holding product-market conduct fixed, the comparison isolates the incentive to create knowledge for other portfolio firms from the incentive to protect their existing profits. It therefore complements the product-market welfare analysis of Ederer and Pellegrino (2026) and the dynamic ownership counterfactuals of Okumura (2026), while separating corporate gains from the consumption benefits that even a fully diversified shareholder does not internalize. The same distinction matters for innovation policy: value received from others rewards a firm's position in the network, whereas value generated for others enters the case for supporting its research. Measuring both supplies a market-value counterpart to the knowledge-network allocation problem of Liu and Ma (2024) and an additional source of empirical discipline for the social–private research wedges studied by Hopenhayn and Okumura (2026). The contribution is thus to identify and value the benefits omitted by different research objectives, and to trace their consequences for the level and allocation of R&D.

2 Valuing innovation across firms

Innovations improve the prospect of monopoly rents, and chages in stock prices provide a lens to measure this change in the future flow of profits. But a firm's technology may benefit its users, open research opportunities for other innovators, and displace competing products. Measuring the value of innovation therefore requires distinguishing where an invention originates, from the gains and losses it induces on other firms. Therefore, comparing the value the same underlying innovation creates and destroys for others relative to its private gains provides a measure of its social value.

Let a_{jt} denote innovation announced by firm j on date t. Firm i's stock return r_{it} on that date can be decomposed into the private response to its own innovation $\Gamma_{ii}a_{it}$, to other firms' innovations $\Gamma_{ij}a_{jt}$, and a residual component ε_{it} from news unrelated to these innovations:

$$r_{it} \;=\; \Gamma_{iit}a_{it} \;+\; \sum_{j\neq i}\Gamma_{ijt}a_{jt} \;+\; \varepsilon_{it}$$

The valuation multiplier Γ's diagonal elements describe private responses and off-diagonal elements describe external responses. If V_{it^-} is firm i's pre-innovation news equity value, then the

dollar change in its value from these innovations is

$$\Delta V_{it} = \sum_j \Delta V_{ijt} = \sum_j \underbrace{V_{it^-}\Gamma_{ij}}_{\substack{\text{Value weighted} \\ \text{multiplier}}} \times \underbrace{a_{jt}}_{\text{Innovation}} \tag{1}$$

Therefore,firm j's total effect on the market per unit of innovation is the sum of its value weighted effect on the market:

$$\underbrace{V_{t^-}\underline{\Gamma}_j}_{\substack{\text{Total} \\ \text{value}}} \equiv \underbrace{V_{jt^-}\Gamma_{jj}}_{\substack{\text{Private} \\ \text{value}}} + \underbrace{\sum_{i\neq j} V_{it^-}\Gamma_{ij}}_{\substack{\text{External} \\ \text{value}}}$$

where $V_{t^-} = \sum_i V_{it^-}$ is the total stock market capitalization. The first main goal of this paper is to measure the dollar value of innovations created and destroyed for other firms relative to the private value of the innovator.

Second, for the same underlying innovation, the value a firm creates for others versus the value it creates for itself equals

$$\rho_{jt} \equiv \frac{V_{t^-}\underline{\Gamma}_j}{V_{jt^-}\Gamma_{jj}} - 1$$

If $\rho_{jt} > 0$, it means that a firm is *creative* a market surplus that is at least twice its private gain net of business stealing. Conversely, if $\rho_{jt} < 0$, it means that *destroying* value of its rivals is a firm's dominant footprint from innovations. If $\rho_{jt} = -1$, the market is zero sum where gains for innovators equal losses for their rivals. Firms high on ρ are therefore favorable to a representative shareholder who priorizies maximizing the total market value as opposed to firm owners who maximize only their own private value (reflected in the denominator of ρ). Therefore, ρ provides a market based measure of the aggregate importance of a firm.

There are a few benefits of this measuring this ratio. One, at a point in time, it is invariant to a firm's size of innovation and instead depends on the firm's location in the economy defined by its economic ties to other firms. Two, it abstracts away from the choice of empirical measurement of the shock itself by instead relying on ratios. Three, it provides a common unit free measurement across firms and time periods, which is useful for comparing the social value of innovations across sectors and time. Finally, it abstracts away from concerns about anticipation, which I discuss below.

Anticipation Investors may recognize an innovation's prospects well before its announcement. Consider an announcement that resolves uncertainty about the realization of innovation for firm j. Let $\overline{p} < 1$ denote its prior probability of realization, and let ξ_{ijt} denote the incremental

capitalized value of realization to firm i, relative to nonrealization. If the announcement resolves this uncertainty without otherwise revising the conditional values, the realized change in firm i's value is

$$\Delta V_{ijt} = (1 - \overline{p})\xi_{ijt}$$

So the observed dollar changes reveal only the unexpected portion of value. Because the same announcement resolves uncertainty for every affected firm, under a common anticipation factor, the ratio of external to private value is

$$\rho_{jt} = \frac{(1 - \overline{p}) \sum_{i \neq j} \xi_{ijt}}{(1 - \overline{p})\xi_{jjt}} = \frac{\sum_{i \neq j} \xi_{ijt}}{\xi_{jjt}} = \frac{V_{t^-}\Gamma_j}{V_{jt^-}\Gamma_{jj}} - 1$$

which is invariant to the anticipation. So an announcement does not require to reveal everything an innovation is worth to reveal how its value is divided between the innovator and other firms. Recovering relative incidence requires less information than recovering full dollar values by fully addressing anticipation.[4]

Aggregate external to private value How much value do new innovations create and destroy? The second main goal of this paper is to measure the sum total creation and destruction of value in the economy by innovations. Therefore, my final construction is the aggregate external to private value ratio, which is the sum of all external value created by innovations relative to the sum of all private value created by innovations:

$$\overline{\rho} = \frac{\sum_{i \neq j,t} V_{it^-}\Gamma_{ij}a_{jt}}{\sum_{j,t} V_{jt^-}\Gamma_{jj}a_{jt}}$$

The next sections of the paper describes how I empirically measure this ratio, and what I discover about the how innovations have created and destroyed value for the US economy over the last four decades across different industries.

My third goal, is to demonstrate that the numbers I measure capture economically meaningful information about subsequent performance of firms and industries.

Interpreting measurements from excess returns Recovering relative value requires specifying which returns are used in measurement. The standard procedure is to use market adjusted returns, which removes common market news from the returns of each firm. The corresponding

[4]Indeed, this does not hold when anticipations vary by innovation, firm or time. However, the common anticipation provides a useful benchmark which aligns with the treatment of Kogan et al. (2017). The one key difference is the window between pre versus post American Inventors Protection Act (AIPA) regime where they report the surprise on announcement did not vary by much. After the regime, most patent publications became publicly available pre grant, therefore the grant itself would still retain a common surprise within same reference dates.

bilateral excess value multiplier is then the bilateral multiplier excess of the aggregate value multiplier:

$$r^e_{it} \equiv r_{it} - r^m_t \qquad\qquad \Gamma^e_{ijt} \equiv \Gamma_{ijt} - \underline{\Gamma}_{jt}$$

Market subtraction removes the common value creation while preserving redistribution. If an in innovation raises all firms' returns by the same percentage, then that rise disappears from market adjusted returns. Conversely, a pure redistribution of market value implies $\underline{\Gamma}_{jt} = 0$, while preserving $\Gamma^e_{ijt} > 0$. This asymmetry *inflates* estimates of rivalry effects by construction. While this bias is inconsequential for small firms that occupy a small share of total stock market capitalization, it is worth keeping in mind that the market-adjusted response is not an absolute, but a relative measure biased against measurement of value creation. However, such adjustment is necessary empirically to eliminate unrelated news dominating stock returns, where innovation news are a small part of it. The next section describes how I implement this measurement in practice.

Estimating spillovers in stock returns requires observable news about innovations, measures of the economic relationships through which they affect other firms, and returns that distinguish their consequences from unrelated information. Patent grants provide a setting in which these requirements can be brought together as they provide a dated public announcement about an invention and its legal protection, attributable to an identifiable firm. Following Kogan et al. (2017), who use the innovator's stock-market response to measure private economic value, I estimate how firms connected through technology, product markets, and supply chains move. In the next section, I develop the empirical specification, constructs for connections between firms, and explain the variation used to separate responses to innovation from common news.

3 Empirical strategy

Implementing this measurement requires identifying which firms receive innovation news, which other firms are exposed to it, and how their valuations respond. I use weekly patent grants to date the news and predetermined technological, product-market, and supply-chain relationships to measure exposure. The sample includes firms without patents because an invention can change their profits without inducing an invention of their own. The empirical challenge is to distinguish responses to these grants from common news and information already reflected in connected firms' prices.

3.1 Data and economic coverage

I use the universe of nonutility firms listed on the three major stock exchanges in the United States (NYSE, AMEX, and Nasdaq) over the 44-year period between 1981 and 2024, sourcing daily stock returns and market capitalization from CRSP and balance sheets, income statements, and

business-segment records from Compustat. Measuring how innovations revalue both innovating companies and the rest of the corporate sector requires data that span both groups. A firm that never patents can still lose market share when a product-market rival patents a substitute, or face cost and demand shifts when its suppliers and customers innovate. Excluding non-patenting firms from the panel would therefore truncate the corporate incidence of innovation, so my sample retains all eligible listed firms regardless of whether they patent.

To track inventions across this corporate population, I link over 3 million patents granted by the U.S. Patent and Trademark Office (USPTO) between 1976 and 2024 to their listed owners at their grant date by combining USPTO's PatentsView, Orbis Intellectual Property, Kogan et al. (2017), and DISCERN (Arora et al., 2021). Because large conglomerates file patents through subsidiaries, I link assignees to consistent identifiers of a listed company using dated corporate ownership trees, name-based disambiguation, and official histories of corporate name changes to avoid attribution to a distant holding company not directly involved in innovation. Similarly, many innovative firms build large patent portfolios before going public, which I track through consistent identifiers.[5] I classify patents into technology fields using their primary Cooperative Patent Classification (CPC) subclasses, and I classify firms into operating industries using a shared Compustat–CCM–CRSP company reference for Standard Industrial Classification (SIC) and North American Industry Classification System (NAICS) codes.[6]

Listed firms in the sample account for roughly one-third of USPTO grants in the early 1980s, nearly one-half in the mid-2000s, and 27 percent by 2024 (Appendix Figure A4). Their patenting shifts toward semiconductors, electronics, and software and away from traditional manufacturing and chemicals over the sample period (Appendix Figure A5).

Within the firms in my sample, there is substantial heterogeneity in the distribution of patenting activity, which is summarized in Table 1. Firms granted at least one patent during the preceding five calendar years account for 45 percent of nonutility listed companies and 85 percent of their total market capitalization in 2024, up from 34 percent of companies and 74 percent of market capitalization in 1981. Disaggregating the universe by five-year patenting volume reveals a sharp asymmetry between where corporate inventions originate and where their spillovers can land. Patenting has concentrated heavily in the upper tail of large corporations: firms granted more than 1,000 patents over the preceding five years represent just 2 percent of listed companies in 2024, yet account for over 46 percent of total market capitalization, nearly tripling their capitalization share in 1981. Firms with more than 100 grants represent 8 percent of companies but over two-thirds of market value. Corporate innovation thus originates in the right tail of research-intensive firms, but its economic consequences propagate across a broad corporate population that rarely or never

[5] So a patent linked to an eventually listed firm enters my estimation when it is listed, but its history contributes to the measurement of technological proximity, for instance.

[6] Alternative attributions, such as using all CPCs listed on each patent, yield statistically indistinguishably close measures of similarities between firms.

TABLE 1: Patenting concentration across the listed corporate universe

		Share of listed companies (%)					Share of market capitalization (%)				
		Five-year patent grants					Five-year patent grants				
Year	Listed firms	No patents	1 to 10	11 to 100	101 to 1,000	Above 1,000	No patents	1 to 10	11 to 100	101 to 1,000	Above 1,000
1981	4,222	65.4	20.9	9.6	3.6	0.5	26.1	14.9	15.5	25.6	17.8
1990	5,341	69.2	20.9	7.4	2.2	0.4	30.8	16.4	12.9	24.7	15.3
2000	6,332	63.6	22.6	10.7	2.6	0.5	27.6	16.0	12.3	21.0	23.1
2010	3,877	55.8	23.1	14.3	5.7	1.1	21.9	18.6	14.1	20.3	25.1
2020	3,448	50.9	21.2	17.6	8.2	2.0	15.4	9.6	10.4	24.8	39.9
2024	3,799	54.6	20.5	16.5	6.4	2.0	15.2	6.1	10.6	21.5	46.5

Notes: Firms represent the ordinary common-stock companies on the NYSE, AMEX, and Nasdaq at the last trading close of June, linked to historical patent ownership at the grant date, excluding utility companies. Firms are grouped into mutually exclusive bands by the number of patents granted by the USPTO during the preceding five completed calendar years (the first complete five-year lookback is 1981, using grants from 1976 to 1980). Shares of listed companies are relative to all nonutility listed firms at the end of June; market capitalization shares are relative to total observed June market capitalization. Appendix A documents matching and coverage.

patents.[7]

3.2 Economic linkages and predetermined networks

An invention by one firm can affect another firm through four economic relationships: technological proximity, product-market rivalry, upstream supplier links, and downstream customer links. Firms can reorganize their research portfolios, product lines, and supply chains after an innovation arrives. I therefore construct the network profiles from patent histories and financial reports preceding the grant year, so the measured relationships do not incorporate that subsequent reorganization. Reported business-segment codes and sales are retained; when company classification is needed, the shared reference attaches current company codes to dated identities. This fallback is retrospective, rather than information necessarily available at the time.

Technological proximity and product-market rivalry separate the opportunity to build on another firm's knowledge from competition for the same customers (Jaffe, 1986; Bloom et al., 2013). I measure technological proximity as the cosine similarity between firm i's and firm j's patent distributions across primary Cooperative Patent Classification (CPC) subclasses over the

[7]Appendix Table A2 shows that this concentration extends to sales and operating earnings, and Appendix Figure A1 plots the annual time series.

five completed calendar years preceding the year of grant date t:

$$\text{Technological proximity}_{ijt} = \frac{\sum_k T_{ikt} T_{jkt}}{\sqrt{\sum_k T_{ikt}^2}\sqrt{\sum_k T_{jkt}^2}} \in [0,1]$$

where T_{ikt} is the share of firm i's patents granted during those five preceding calendar years assigned to primary CPC subclass k.[8] Firms with similar patenting portfolios draw on related scientific principles, engineering methods, and specialized R&D labor, making them more likely to learn from and build upon each other's inventions. The cosine measures similarity in the composition of research: it equals one for identical patent shares and zero when the portfolios share no subclass, irrespective of the firms' total patent counts. Such proximity can also expose firms to common research opportunities and market sentiment. The network identifies potential recipients of knowledge; the grant-date regressions must distinguish their response to a neighbor's patent news from those shared influences.

Second, I measure product-market rivalry as the cosine similarity between firm i's and firm j's business-segment sales distributions across three-digit SIC industries over the five fiscal years preceding the year of grant date t:

$$\text{Rivalry}_{ijt} = \frac{\sum_s S_{ist} S_{jst}}{\sqrt{\sum_s S_{ist}^2}\sqrt{\sum_s S_{jst}^2}} \in [0,1]$$

where S_{ist} is the share of firm i's business segments sourced from Compustat to three-digit SIC industry s pooled over the preceding five fiscal years. For periods when firms do not have a specific sector associated with their segments, or for the part total sales that are not accounted for by their segment contributions, I use the firms' primary sector. Using shares gives the same cosine as using sales levels because each firm's total sales cancel from the numerator and denominator. Firms selling into the same industries compete for the same customers and are therefore exposed to business stealing and price competition when a rival innovates. Business-segment sales locate a multiproduct firm in each market in which it operates, rather than assigning all its activity to its principal industry. Two firms with different principal industry codes can therefore compete in some of their product lines, while two firms in the same broad industry can have quite different sales portfolios. Common demand shocks can also move their values together, which makes the timing and controls in the return regression important for interpreting the rivalry response.

Using a five-year lookback window for both horizontal networks smooths year-to-year fluctuations in patenting and segment reporting while measuring technology and product portfolios from activity preceding the grant year. Although technology and rivalry grant exposures are posi-

[8] For grant dates in 2024, for instance, the patent histories cover 2019 to 2023 period. Each patent is assigned to its primary four-character CPC subclass in the current PatentsView classification; while the set of prior grants is predetermined, these unified CPC subclass labels are applied retrospectively across the sample.

tively correlated (within-date correlation 0.53 where both are observed), substantial independent variation separates the two channels: firms frequently rely on shared semiconductor, chemical, or software technologies while selling into distinct markets, or compete for the same customers using different technical approaches.

The distinction between technologies and markets is especially important for large firms whose research and products span several industries. A shared semiconductor or software technology can connect firms that sell different products; competition for the same customers can connect firms using different technologies. A single industry classification cannot represent both relationships. Figure 1 maps the two networks in 2024, with firms colored by sector. Every positive measured link is retained, and the same layout algorithm is applied to both networks. These links measure where a grant could have consequences; which linked firm receives a patent on a particular Tuesday determines exposure to that week's news.

Vertical links capture direct supply-chains between firms. When a firm's supplier innovates (upstream innovation), a firm may benefit from cheaper or better inputs or the supplier may capture the surplus through higher markups. When a firm's customer innovates (downstream innovation), it may spur greater demand or input substitution away from a focal firm. I measure bilateral supply-chain links from Compustat customer-segment disclosures over the two fiscal years preceding the grant year: for supplier links, I use the cost based input-output measure by dividing disclosed supplier sales by the buyer's operating expenses; for customer links, I use the bilateral sales relative to the firm's total sales:

$$\text{Supplier exposure}_{ijt} = \frac{\text{Sales } j \to i \text{ in prior two fiscal years to } t}{\text{Operating expenses of } i \text{ in prior two fiscal years to } t}$$

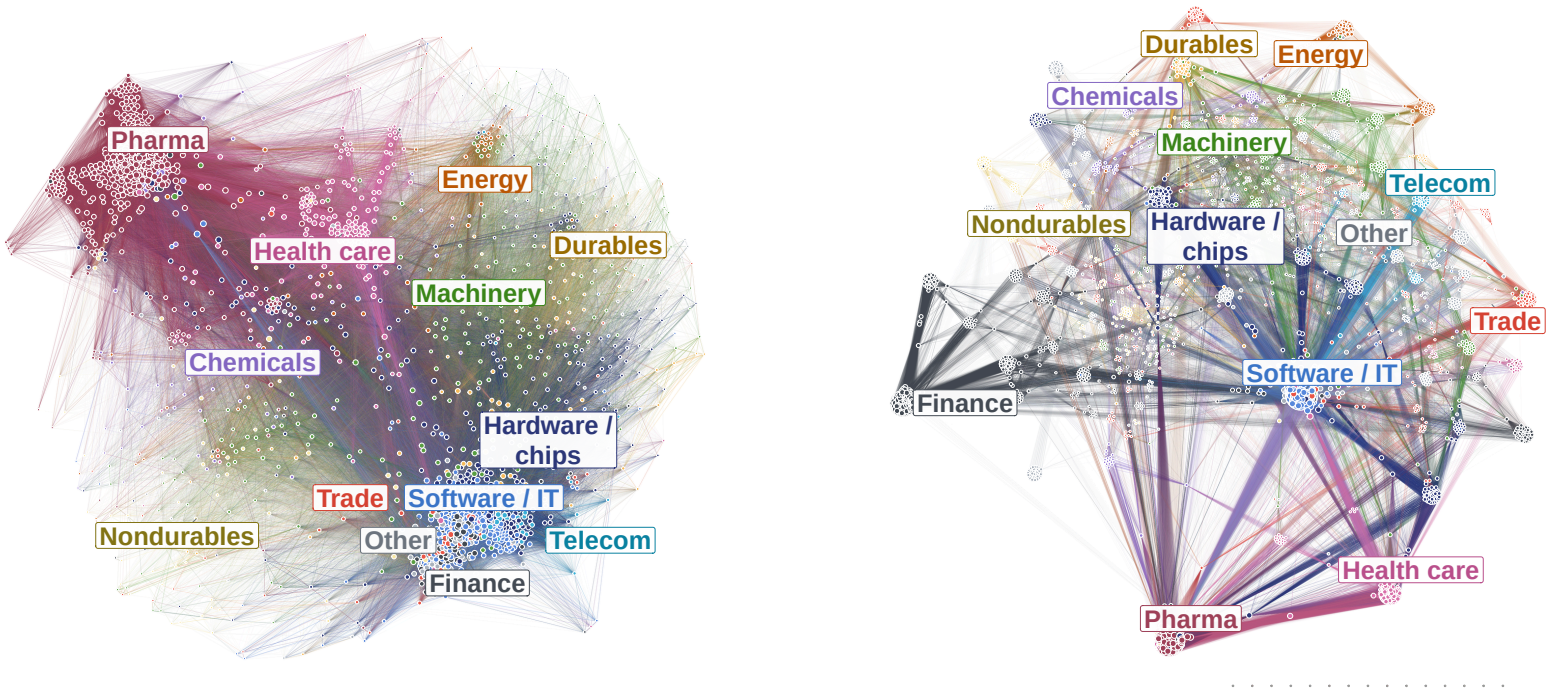
and

$$\text{Customer exposure}_{ijt} = \frac{\text{Sales } i \to j \text{ in prior two fiscal years to } t}{\text{Total sales of } i \text{ in prior two fiscal years to } t}$$

Because public companies are required to report individual customers in their 10-K filings only when a customer accounts for at least 10 percent of consolidated revenue, disclosed bilateral links capture major supply contracts rather than the universe of input-output transactions.

3.3 Patent grants and stock-market returns

I use patent grant dates to measure how the stock market prices news of an invention for both inventing and their peer firms. After firms apply for patents, a USPTO examiner determines whether the application meets the standards of novelty and non-obviousness of the invention and the claims on which it can earn a right to intellectual property. If the application passes these tests, the patent office issues a Notice of Allowance, giving the applicant three months to pay the issue fee and complete administrative requirements. Once those steps are complete, and the claims



(a) Technological proximity

(b) Product-market rivalry

FIGURE 1: Technological proximity and product-market rivalry in 2024

Notes: Each node is a firm in my sample, and each edge is the measured link between them by technological proximity and product-market rivalry using data over 2019–2023. Rivalry uses overlap in Compustat segment-sales shares, assigning each segment to its primary SIC3 for this illustration. Estimation uses the full split segment-code vector. Technological proximity is based on overlap in technologies, sources from patent data from USPTO PatentsView. Unavailable business segment allocations use the company industry. Colors identify the thirteen reporting sectors defined in Appendix C.2. Node area follows square-root weighted degree, with a minimum visible size.

on which an invention is granted a patent are decided, the USPTO assigns it to a weekly batch of patent grants that are published in the *Official Gazette* every Tuesday. Because each Tuesday edition announces all utility patents granted that week across all firms and technology classes simultaneously, the weekly calendar provides a common, observable sequence of event dates that I use to measure the market's response to patent news.

What the market prices on a Tuesday for each firm upon a patent grant depends on the information available about them before their grant. Prior to November 2000, U.S. patent applications remained confidential until the patent was granted. After the American Inventors Protection Act (AIPA), most utility applications filed on or after November 29, 2000 are published roughly 18 months after their earliest filing date. Furthermore, subsequent prosecution records, such as the Notice of Allowance and the advance Issue Notification, can also convey information before formal issuance.[9] Even so, the patent grant itself remains a critical economic milestone in the timeline of an invention, as it reflects the date on which a firm's legal right to monopoly on using the technology and exclude competitors becomes effective. Therefore, a firm's returns in the window after the grant measures the value of the *residual uncertainty* that is resolved upon patent issuance.[10]

For each firm i and grant date t, I measure the cumulative abnormal stock return r_{it} over the three trading days from each Tuesday grant date. The three-day window allows prices to adjust while limiting exposure to unrelated news; further, the window ends before the next batch of patents are granted and avoids confounding run-ups. For my baseline specification, I use the three-factor Fama and French (1993) returns that account for market, size, and value factors with firm-specific loadings estimated over a rolling 252-trading-day window ending ten trading days before the return date; the ten-day buffer prevents pre-grant return drift from contaminating the factor loadings.[11]

3.4 Estimating equation and identifying variation

Patent grants vary substantially between firms on any given Tuesday, and within firms between Tuesdays. On a typical Tuesday, 94 percent of listed firms receive no patents, while the top 1 percent of patentees receive at least one grant almost every week (see Appendix Figures A6 and A7). Even among prolific innovators, administrative queueing between allowance, fee payment, and weekly *Official Gazette* production generates sizable week-to-week dispersion in the number of patents and legal claims issued to a given firm within a calendar year.[12]

[9] See the USPTO's *Manual of Patent Examining Procedure*, Section 1120 on application publication, Section 1303 on allowance, and Section 1306 on issuance. The weekly calendar is described on the Official Gazette page.

[10] This also follows evidence by Kogan et al. (2017), who find that firms' return volatility upon grant does not significantly decrease after the institutional change. Patent applications also carry information upon publication, as Baruffaldi and Simeth (2020), Hegde et al. (2023), Beyhaghi et al. (2023), and Houston and Roskelley (2024) find.

[11] Appendix B details the return construction, history requirements, and winsorization.

[12] Appendix Figures A8–A10 document this within-year weekly dispersion across patenting frequency, annual volume, firm size, and individual histories for Apple, 3M, and Pfizer as an illustration.

I measure firm i's grant activity on Tuesday t as $\text{Grants}_{it} = \log(1 + G_{it})$, where G_{it} is the number of patents granted to firm i in date t's batch. Adding one in the log specification allows comparison with non-grant firm-Tuesdays, and the log transformation prevents highly skewed weekly batches at the largest firms from dominating the variation.[13] Because patents vary in the breadth of their legal exclusion rights and quality, I also estimate every specification by replacing patent numbers with the total number of legal claims summed across the firm's granted patents on date t.

To estimate the stock-market response to a firm's own patent grants and to its connected firms, I combine news of grants to each. Firm i's exposure to peers' patent grants through channel c (technological proximity T, product-market rivalry R, supplier links S, and customer links C) is

$$X_{it}^{c} = \sum_{j \neq i} \text{Network}_{ijt}^{c} \times \text{Grants}_{jt} \qquad c \in \{T, R, S, C\} \tag{2}$$

where each granting peer j contributes in proportion to the strength of its predetermined link to receiver i, so a firm can experience substantial peer exposure on Tuesdays when it receives no patent of its own. While the weights Network_{ijt}^{c} remain fixed within each calendar year, weekly grants Grants_{jt} shift the source of shocks from Tuesday to Tuesday. A firm can be exposured to peer patents in a week when it receives no patents itself. I estimate

$$r_{it} = \beta_0 \text{Grants}_{it} + \sum_{c \in \{T,R,S,C\}} \beta_c X_{it}^{c} + \text{Controls}_{it}^{\top} \gamma + \alpha_t + N_{it}^{\top} \lambda_t + \varepsilon_{it} \tag{3}$$

where each observation is a firm i on a Tuesday grant date t, β_0 measures the return response to own patent activity, and β_c measures the return response to peer patenting through channel c holding own grants and the other three network channels fixed. Equation (3) identifies β_c by comparing firms on the same Tuesday whose specific linked neighbors receive different patents in a given week. Date fixed effects α_t absorb neutralize common news affecting all firms. Because a centrally located firm is mechanically exposed to more grants even when activity rises uniformly across sources, recentering by their network spans removes the variation that emerges from the scale of exposure (Borusyak et al., 2022, 2025). To do so, the vector N_{it} includes firm i's technology and rivalry network sums. Several firms do not have a patenting history; to account for them, I use a missing technology profile indicator interacted with grant date. Identification then comes from differences in which specific neighbors receive patents on Tuesday t, rather than from cross-sectional differences in network centrality.

The headline estimation controls for information already visible to the market such as firms capitalization, book-to-market, own and network-weighted returns over the preceding quarter,

[13] Because the log transforms the right hand side variable rather than the dependent variable, this is not subject to the outcome-transformation concerns analyzed by Chen and Roth (2024). To address sensitivity to measurement, I estimate specification (2) using alternative metrics of grant news which I discuss in the next section.

and lagged industry and granting and nongranting CPC-portfolio returns. Evidence of gradual information diffusion along customer–supplier links (Cohen and Frazzini, 2008; Menzly and Ozbas, 2010) and technological links (Lee et al., 2019) motivates these controls: a connected firm's return during the grant window could reflect an run ups or reversals from earlier announcement still that leak into current return. In section 3.5, I examine whether these prior movements, contemporaneous portfolio returns, or other forms of connectedness affect my headline estimates.

Coefficients β provides a feasible estimation of the valuation multipliers Γ in Section 2 conditional on return adjustment, event timing and other controls, as bilateral multipliers cannot be directly estimated due to dimensionality, and the effect on intercept cannot be directly recovered. The results of the estimation are presented in Table 2 where I use standardized controls.

Stock returns are positively associated with a firm's own patent grants, consistent with Kogan et al. (2017), while patents granted to technologically related firms and product-market rivals have opposing effects (Table 2). Conditional on own grants and the other channels, a standard-deviation increase in technological exposure is associated with a 5.08-basis-point gain, whereas the corresponding increase in rivalry exposure is associated with a 3.65-basis-point loss in column (3).[14] Weighting grants by legal claims gives similar results in column (6). Supplier and customer effects are small and imprecise. The opposing technology and rivalry responses are consistent with the knowledge-spillover and business-stealing effects distinguished by Bloom et al. (2013).

3.5 What explains the return responses?

Connected firms share investors, locations, and exposure to common news as well as technologies and product markets. The economic interpretation of the return responses therefore depends on distinguishing these sources of comovement. I provide several comparisons that address three questions: whether shared information explains responses in returns, whether the economic content of the links matters, and whether the measurement choices determine the result.

3.5.1 Shared information and connectedness

First, overall connectedness does not account for the opposing responses. Predetermined weights can create nonrandom exposure even when the underlying shocks are exogenous (Borusyak et al., 2025). Allowing total network exposures to have separate coefficients on every grant date amplifies the detected response for both technology spillovers and rivalry on identical observations (Appendix Table B1). These controls absorb differences in expected exposure arising from network connectedness.

Earlier news at connected firms could continue reaching prices during the grant window.

[14] Coefficients are in basis points per within-date standard deviation of exposure. These standard deviations differ across channels, so the standardized coefficients do not compare the effects of a single patent. Appendix Table B4 reports the standard deviations and unstandardized coefficients used to estimate dollar values.

TABLE 2: Patent grants and stock-market responses

Dependent variable: three-day abnormal return

Measure of grants:	Patents			Claims		
	(1)	(2)	(3)	(4)	(5)	(6)
Own grants	2.44	2.43	2.25	2.82	2.82	2.63
	(0.26)	(0.26)	(0.26)	(0.25)	(0.25)	(0.24)
Technology	3.36	3.36	5.08	3.35	3.35	5.47
	(0.43)	(0.43)	(0.97)	(0.42)	(0.42)	(1.07)
Rivals	−2.42	−2.42	−3.65	−2.62	−2.61	−4.23
	(0.65)	(0.65)	(0.97)	(0.66)	(0.66)	(1.01)
Suppliers	0.00	0.00	0.03	0.04	0.04	0.06
	(0.13)	(0.13)	(0.13)	(0.14)	(0.14)	(0.14)
Customers	−0.09	−0.09	−0.10	−0.18	−0.17	−0.15
	(0.26)	(0.26)	(0.26)	(0.27)	(0.27)	(0.27)
Firm characteristics	Yes	Yes	Yes	Yes	Yes	Yes
Lagged prior returns	Yes	Yes	Yes	Yes	Yes	Yes
Lagged industry, tech returns	No	Yes	Yes	No	Yes	Yes
Network recentering	No	No	Yes	No	No	Yes
R^2	0.01	0.01	0.02	0.01	0.01	0.02
Firms	23,697	23,697	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295	2,295	2,295

Notes: Pooled three-factor abnormal return estimates, 1981–2024. All five channels enter jointly. Return controls use only pre-grant trading days. All columns include date effects, coverage indicators, size, book-to-market, and four windows of own and peer prior returns. Columns (2) and (5) add preceding-five-day industry and CPC portfolio returns; columns (3) and (6) add technology and rivalry network sums interacted with date. Returns are winsorized at 0.5th and 99.5th percentiles with annual cutpoints. Coefficients and two-way firm and date clustered SEs are basis points per within-date exposure SD.

Cohen and Frazzini (2008) document return predictability along customer–supplier links, and Lee et al. (2019) find it among technology peers. I add size and book-to-market, own and network-weighted returns over the preceding quarter, and lagged industry and granting and nongranting CPC-portfolio returns. Technology remains positive throughout the sequence, while rivalry becomes more precisely negative after firm characteristics and prior returns enter; adding the lagged portfolios changes little (Appendix Table B1). The grant response contains information beyond these observed prior price movements.

News common to an industry or technological field could coincide with grants at several connected firms. I add contemporaneous leave-one-out industry returns and separate returns for granting and nongranting CPC portfolios, weighted by patent shares and pre-event capitalization.

Both horizontal responses become smaller but retain their signs and precision (Appendix Table B1). These portfolios may themselves incorporate innovation spillovers, so conditioning on them can remove part of the response of interest. The baseline uses lagged portfolios; the contemporaneous comparison establishes that the opposing signs also survive this broader absorption of common news.

Research location could account for gains attributed to technological proximity. Lychagin et al. (2016) find productivity benefits of inventor proximity beyond technological relatedness. I adapt their distance weighting using inventor addresses on patents granted during the preceding five years, with patent contributions divided across inventors. Worldwide locations, U.S. counties, and counties normalized for research concentration provide three exposure measures. Each allows geographic network size to have its own date-specific coefficient. Technology gains and losses from rival innovations survive all three (Appendix Tables B12 and B13). Research location does not account for the two horizontal responses.

Shared ownership can change firms' incentives to create knowledge and protect existing profits (Antón et al., 2025). I construct ownership links from prior-September 13-F holdings, matched through dated securities and company identifiers, using common managers' holdings as a share of the pair's combined common equity:

$$\text{Common ownership}_{ijt} = \frac{\sum_{m \in \mathcal{M}_{ij,t-1}} (\text{Holdings}_{mi,t-1} + \text{Holdings}_{mj,t-1})}{\text{Common equity}_{i,t-1} + \text{Common equity}_{j,t-1}}$$

where $\mathcal{M}_{ij,t-1}$ contains managers with positive positions in both firms and holdings are measured in dollars. Ownership-weighted grant news and its pair-level interactions with technology and rivalry enter alongside the economic networks. First, exposure on common ownership per se shows a positive association, consistent with Antón and Polk (2014). Second, common ownership attenuates both gains from technology spillovers and losses from rival innovations (Appendix Table B3), consistent with shared owners incorporating information across their holdings.

3.5.2 The economic content of the links

A firm can benefit from another firm's knowledge while competing for its customers. With the same observations and controls, the technology response rises from 3.60 to 5.08 basis points when rivalry and the other channels enter; the rivalry response becomes more negative (Appendix Table B2). The own response also falls by 15.1 percent relative to the own-only specification. Omitting other firms' patents can therefore understate the opposing external effects and attribute part of their value to the firm's own patents.

The identity of connected firms and the strength of their economic connectedness contain different information. To separate them and assess the importance of measured links, I assign equal weights as a comparison to each receiver's existing positive links while preserving its total

network weight. With the same network-by-date controls, both technology gains and rivalry effects attenuate sizably in comparison to the headline estimates while preserving their direction (Appendix Table B1). This suggests that important information is captured beyond existence of exposure by technological proximity and product-market rivalry.

Second, knowledge between firms can cross patent-class boundaries even when firms have little direct portfolio overlap and build on shared co-occurences of technologies. As a consequence, the headline measures could understate the degree of connectedness between firms. To address this, I use the Mahalanobis extension of Bloom et al. (2013) . Let T_{it} be the row vector of firm i's patent shares across CPC fields, measured over the five completed years before year t. Their firm-pair formula, with a time index added, is

$$\text{Mahalanobis}_{ijt} = \frac{T_{it}\Omega_t T'_{jt}}{\sqrt{T_{it}T'_{it}}\sqrt{T_{jt}T'_{jt}}} \qquad \text{where} \qquad \omega_{k\ell,t} \equiv \frac{\sum_f T_{fk,t}T_{f\ell,t}}{\sqrt{\sum_f T^2_{fk,t}}\sqrt{\sum_f T^2_{f\ell,t}}}$$

The matrix $\Omega_t = [\omega_{k\ell,t}]$ is the field co-occurrence term, which measures the degree to which two fields k and ℓ are jointly patented by the same firms f. This is the uncentered correlation between two fields' patent-share vectors across firms which equals zero when no firm patents in both fields and one when their cross-firm share vectors are proportional and each observed field has $\omega_{kk,t} = 1$. Two firms specializing in different fields can be close if other firms commonly combine those fields. The baseline technological connectedness supposes that $\Omega_t = I$. I find that my headline results remain qualitatively and quantitatively similar (Appendix Table B7). The estimated technology spillovers therefore extends to a construct of connectedness that captures related fields rather than direct overlap in patent classifications.

A different source of linkages concerns directed flows of knowledge between firms. Patent citations have been a dominant metric in innovation literature to capture scientific impact and flows of ideas between firms. This contrasts with portfolio similarity which measures shared technological opportunities on related knowledge (Jaffe et al., 1993). Recent work by Fadeev (2026) suggests that these citations additionally capture implicit business ties between firms, reflecting "*creative construction*". I construct exposure from the receiver's prior citations to the source by using a five-year rolling history between pairs of firms normalized by their total citations to all sources. Since firms cite both previously granted patents, as well as applications that are made public, I construct this exposure using both alternative citation metrics, which extends coverage and provides an additional metric beyond Aghdasi and Tagade (2025). Citation exposure predicts gains when it replaces technological similarity. However, when both technology exposure and citations enter, the latter coefficient becomes imprecise and the technology coefficient changes little (Appendix Table B8).

I also provide a structural measure of product-market rivalry based on standard within industry substitution under CES demand. This captures a combination of rival's share in the receiver's

markets and the similarity between their markets:

$$\text{Rivalry}_{ijt} = \sum_{s \in \text{SIC3}} \frac{\text{Sales}_{ist}}{\text{Sales}_{it}} \times \frac{\text{Sales}_{jst}}{\text{Sales}_{st}}$$

I construct this directed pairwise measure by taking the product of the receiver's sales share in each three-digit SIC industry with the source's share of that industry's sales, summed across industries in which the receiver operates. To construct this, I use five years of dated Compustat segment reports available before the grant year. The scale of this metric is much smaller as a consequence in comparison to the headline rivalry measure but they are strongly correlated by order. Holding observations and controls fixed, the alternative continues to suggest a strong rivalry effect (Appendix Table B7).

Incomplete supply-chain coverage could leave vertical effects unmeasured or assign them to overlapping horizontal links. Compustat mainly identifies major customers, so I supplement its links with dated FactSet relationships where they document sales, which adds 1,991 additional firm pair linkages to the existing 16,292 derived from Compustat disclosed relationships over the full sample. Factset's coverage begins in early 2000s, and increases over time, so they are biased towards periods where we have most patenting activity and variation in estimation. Using this augmented dataset, technology and rivalry estimates barely change, while supplier and customer coefficients remain imprecise in pooled and date-by-date regressions (Appendix Table B9).

Knowledge gains may depend on whether the recipient also competes with the innovator. I add an interaction that multiplies technology and rivalry weights for the same source before applying its grant activity, together with its network-sum-by-date control. The interaction is positive for patents and claims; the separate technology coefficient falls and becomes imprecise (Appendix Table B2). Overlapping relationships therefore carry information that an additive specification misses. The baseline separates the average opposing responses, while the interaction allows the gain associated with technological proximity to vary with product-market rivalry.

3.5.3 Measurement and aggregation

Concentrated patenting makes the treatment of large grant batches consequential, which is tamed to a large degree by log transformation. I also estimate using the inverse hyperbolic sine, which offers a smoother transformation around zero, a binary indicator for any patent news, and raw counts for both the number of patents and claims granted by the US Patent Office. Under each measure, the qualitative signs are preserved, and technology is positive and rivalry negative for both patents and claims under every transformation, although rivalry is less precise with raw counts (Appendix Table B6). These transformations impose different relationships between batch size and dollar value, and I discuss this sensitivity in the next section.

A common percentage-return response may misstate value if small and large receivers react

differently. Even though I control size, since large and small firms have systematically different returns, the headline estimates are still imposed to be common across firm sizes. To test for heterogeneity by size, I rank firms by their pre-event (Monday) capitalization, and allow all slopes to vary across four size groups (bottom 50 percent, the next 40, the next 8 and the largest two percent) with separate group-by-date intercepts. Technology gains and losses from rival innovations appear in every group for patents and claims, while own responses decline with size (Appendix Table B5). Although the peer effects continue to be sizable, their changing magnitudes and the declining private response nevertheless matter for the measurement of private and external dollar value.

Changes in the composition of listed firms could give particular dates disproportionate influence on pooled estimates. I use Fama and MacBeth (1973) regressions to estimate a separate cross-section on each retained grant date and average the slopes equally across dates. Every cross-section includes all five channels, lagged controls, network sums, and coverage indicators; inference allows serial dependence over the weekly grant calendar. Technology remains positive and rivalry negative, with responses comparable to the pooled estimates, while vertical coefficients remain imprecise (Appendix Table B4).

Correlated exposure to priced risk could appear as innovation news under an inadequate return benchmark. I compare my headline measures of the three-factor model with a simple market factor alone, and a six-factor model that adds profitability, investment, and momentum (Fama and French, 2015; Carhart, 1997). Under each metric, the signs and magnitudes continue to hold (Appendix Table B10). Therefore, the effects are not driven by a specific choice of the return measurement.

Gradual price adjustment and unrelated news make the observation window an economic choice. I compare the grant day with the three-day baseline and the window through Monday, before the next patent batch. Technology gains and losses from rival innovations are present on the grant day and generally accumulate over the longer windows under both estimators (Appendix Table B11). Because private and external responses accumulate at different rates, however, the window changes the external-to-private value ratio even when it preserves the direction of each channel.

4 The private and external economic value of innovations

The return estimates establish gains from technological spillovers and losses from rivalry, but their relative economic value depends on the size and number of firms affected. Private value scales with the innovator's own market capitalization, while external value accumulates across other firms. To estimate the external-to-private value ratio $\overline{\rho}$ defined in Section 2, I convert the

estimates from specification (3) into dollars using pre-event market capitalizations:

$$\begin{aligned} \text{Private value}_{jt} &= V_{jt^-} \times \widehat{\beta}_0 \times \text{Grants}_{jt} \\ \text{External value}^c_{jt} &= \sum_{i \neq j} V_{it^-} \times \widehat{\beta}_c \times \text{Network}^c_{ijt} \times \text{Grants}_{jt} \qquad c \in \{T, R, S, C\} \end{aligned} \tag{4}$$

where V_{jt^-} and V_{it^-} denote market capitalizations of the granting firm j and a connected firm i on the trading day before date t.[15] I aggregate these estimated values over grant dates in constant dollars and divide each channel's external value by total private value. The channel ratios sum to the empirical counterpart of ρ in Section 2, for the measured network responses:

$$\overline{\rho} = \frac{\text{External value}^c}{\text{Private value}} = \frac{\sum_{t \in [1981,2024]} \sum_j \text{External value}^c_{jt}}{\sum_{t \in [1981,2024]} \sum_j \text{Private value}_{jt}} \qquad c \in \{T, R, S, C\} \tag{5}$$

Other listed firms gain slightly more on net than innovators retain themselves (Figure 2). Technology gains of \$1.72 per private dollar exceed losses from rivalry of \$0.67, leaving \$1.05 of net external value. Estimated gains and losses to suppliers and customers are small.[16] Put differently, innovating firms privately capture only about 49 percent (\$1.00 of \$2.05) of the value that I estimate for their patents from abnormal returns, with external value counted only on the observed networks, while the remaining 51 percent accrues, on net, to other firms.[17]

The ratio measures the distribution of the value of patents. Research-spillover studies instead relate accumulated R&D expenditure to productivity or firm value (Jaffe, 1986; Bloom et al., 2013, 2019). Here, private and external valuations concern the same grant news and capitalize investors' expectations of its future consequences. The ratio reveals how much estimated firm value lies outside the innovator's reward (Appendix F.1).

External value also varies relative to private value over time. Figure 3(a) reports each year's external value per private dollar, separating technology gains and losses from rivalry. Panel (b) shows private value relative to GDP and listed-market capitalization. Together, these comparisons

[15] These dollars are the changes in firm value implied by the estimated abnormal returns, not changes in total firm value: grant-date effects and the three-factor adjustment remove any component that moves every stock on a grant date, through output or the discount rate, so that component enters neither the private nor the external value estimates. The model values own, rivalry, and technology news holding aggregate rates fixed (Section 7.5). It treats changes in consumption relative to sector sales, and the resulting adjustment in entry, separately (Section 7.6).

[16] In cumulative 2025 dollars over the full sample, these estimated values total \$32.7 trillion of private value, \$56.2 trillion of technological gains, \$21.9 trillion of losses from rivalry, and \$34.3 trillion of net external value (Appendix Table C1). Weighting grants by patent claims yields similar external-to-private value ratios: \$1.83 of technological gains, −\$0.76 of losses from rivalry, and \$1.07 of net external value per private dollar.

[17] The value of technological spillovers is measured only on links between two firms that both have patents in the five completed calendar years before the year of the grant, so these estimates cover fewer company-dates than estimates of private value and losses from rivalry: the sample used to estimate dollar values contains 12,532,180 company-dates, but the total value of technological spillovers includes only measured links (Appendix A). A firm without such a profile, as an innovator or as a firm affected by others' patents, adds no estimated value of technological spillovers to the total because its technology gains are unmeasured, not because they are known to be zero. The \$1.72 technology ratio therefore divides technology gains on measured links by private value on all observed grants.

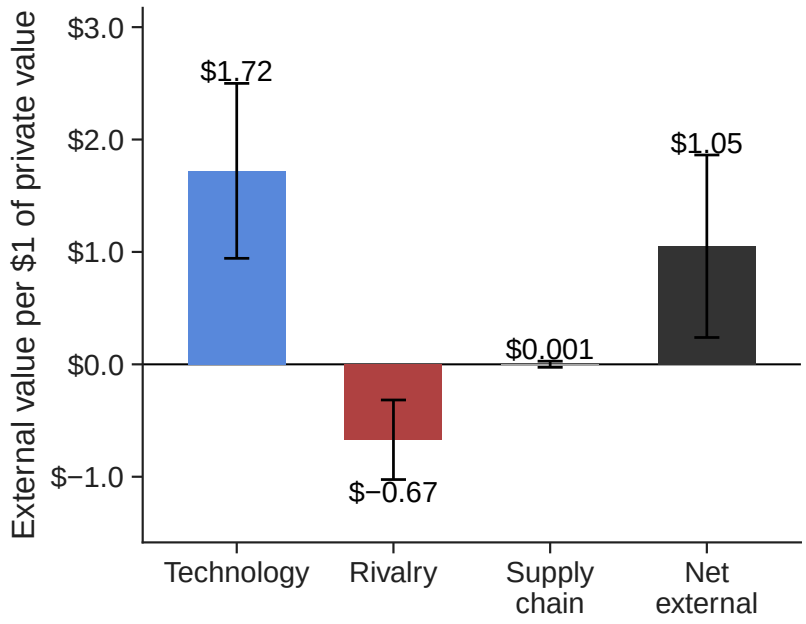


FIGURE 2: External value per dollar of private innovation value

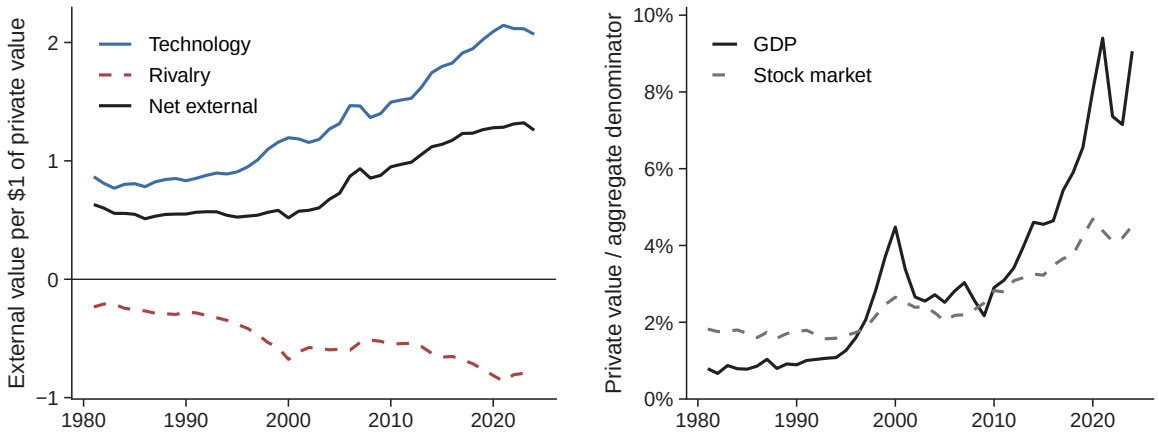
Notes: Patents, 1981–2024. Cumulative emitted external value divided by cumulative private value, both in 2025 dollars. Intervals are conditional 95 percent delta-method intervals.

distinguish changes in external value relative to private value from changes in the scale of private innovation value. Net external value relative to GDP rises from 0.5 percent in 1981 to 2.3 percent in 2000 and 11.4 percent in 2024, or 5.7 percent of listed-market capitalization (Appendix Figure C1). With return coefficients held fixed, these movements reflect changes in grant activity, network exposures, and capitalization.

4.1 Heterogeneous sources of economic value

The sector comparison separates the firms whose patents generate external value from the firms that receive it. I sum each estimated external value External value$^{c}_{ijt}$ by the innovator's sector to measure external value generated, and by the receiving firm's sector to measure external value received. Each estimated effect links an innovator to an affected firm, so both decompositions sum to the same $34.3 trillion. Differences across sectors reflect where knowledge gains and competitive losses occur, together with the scale of the connected firms.

Private patent value and external value rank the leading sectors differently (Table 3). Software and IT services generate the most private value, while hardware, chips, and equipment generate the most net value for other firms. Hardware's external value is $1.55 per private dollar, almost twice software's $0.85. Together with industrial machinery, the two sectors generate 64 percent of net external value. Their role reflects both the scale of their patenting and the gains their patents



(a) External value per private dollar

(b) Private value relative to the economy

FIGURE 3: Annual private and external innovation value

Notes: Patents, 1981–2024. Panel (a): annual emitted external dollars divided by private dollars, with signed rivalry losses. Panel (b): nominal private dollars divided by nominal GDP and daily-mean listed capitalization. Utilities are excluded from innovation dollars and retained in the market denominator.

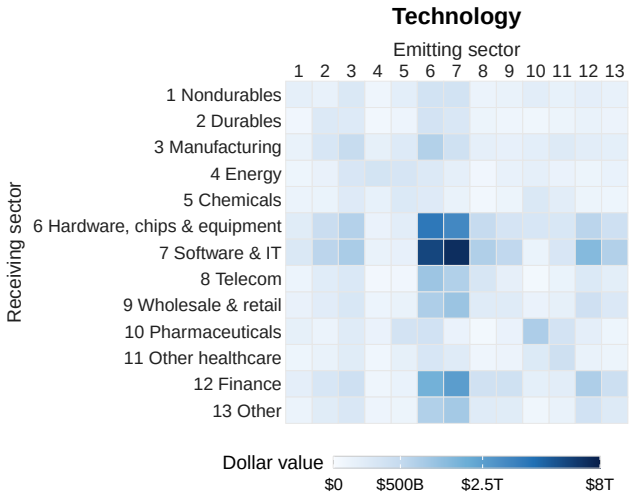
create for connected firms.[18]

Large private patent values can coexist with small net external gains when technological gains are offset by competitive losses. In pharmaceuticals, $0.85 of technology gains per private dollar are offset by $0.68 of losses from rivalry, leaving $0.17 on net. Hardware has larger technology gains relative to the private reward and a smaller fraction lost to rivalry. In sectors where technology neighbors are also competitors, a small net external gain can conceal large technological gains and competitive losses.

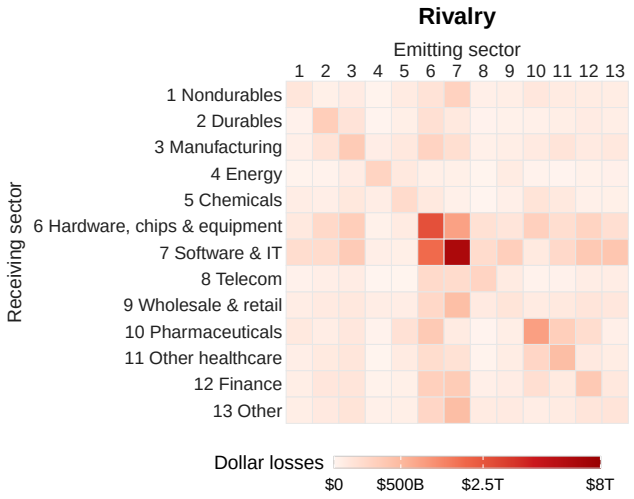
The sectors receiving external value differ from those generating it (Figure 4). Hardware generates 32 percent of net external value but receives 19 percent. Finance and wholesale and retail trade together receive 25 percent while generating 13 percent. Observing where profits appear would therefore give a different picture of innovation from attributing those profits to the inventions that generated them.

This distinction between innovators and firms benefiting from their patents matters for research allocation. A sector may prosper from others' discoveries without generating comparable benefits through its own research. The knowledge-network problem in Liu and Ma (2024) concerns where research creates benefits, which need not be where those benefits are received. The sector comparison identifies where those external benefits originate, rather than assigning them to the sectors in which the resulting profits appear.

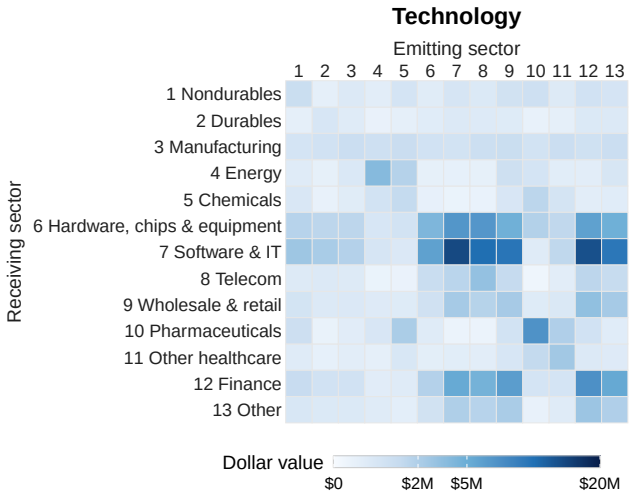
[18] All sectors use the common return coefficients from equation (3). Cross-sector differences therefore reflect grant activity, technological and product-market overlap, and firm values, rather than sector-specific return coefficients. Appendix C.2 reports complete dollar value estimates and patent-claims estimates.



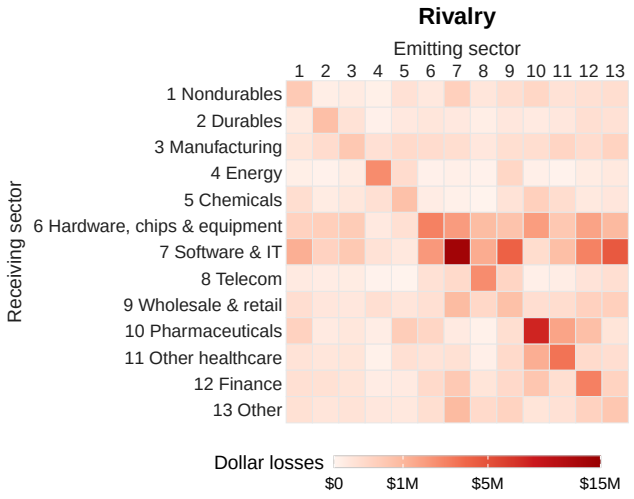
(a) Total dollars



(b) Total dollars



(c) Dollars per source patent



(d) Dollars per source patent

FIGURE 4: Technology gains and losses from rivalry across sectors

Notes: Cumulative 1981–2024 values in 2025 dollars. Rows are receiving sectors; columns are originating sectors, using the same numbered key as the rows. Sources and receivers are split by annual segment-sales shares. Panels (a) and (b) report cumulative technology gains and losses from rivalry. Panels (c) and (d) divide each cell by the allocated patent count in its originating sector; the denominator is constant down each column and identical across channels. Losses from rivalry are displayed as positive magnitudes. Diagonal cells retain effects on other firms in the same sector; own-firm value is excluded. Color intensity uses a square-root scale. These panels use the same modified Fama-French grouping as Table 3; Appendix C.2 provides definitions.

TABLE 3: Private and external value across operating sectors

	Private value ($ trillions)	External dollar value per dollar of private value			Share of net external value (%)	
Operating sector	Total	Technology	Rivalry	Net	Generated	Received
Consumer nondurables	1.04	0.70	−0.20	0.49	1.50	2.68
Consumer durables	0.94	2.30	−0.63	1.67	4.56	1.58
Industrial machinery	3.21	1.22	−0.32	0.90	8.40	5.28
Energy	1.68	0.36	−0.12	0.23	1.14	2.88
Chemicals	1.37	0.91	−0.20	0.70	2.81	2.00
Hardware, chips, equipment	7.10	2.38	−0.82	1.55	32.15	19.13
Software and IT services	9.48	1.80	−0.95	0.85	23.55	26.02
Telecommunications	1.13	1.97	−0.32	1.64	5.43	6.83
Wholesale and retail trade	1.13	1.50	−0.34	1.15	3.80	7.10
Pharmaceuticals	2.11	0.85	−0.68	0.17	1.07	1.50
Other health care	1.28	1.26	−0.79	0.47	1.76	1.00
Finance	1.44	2.88	−0.68	2.20	9.24	18.00
Other industries	0.75	2.84	−0.74	2.10	4.61	6.00
All sectors	32.66	1.72	−0.67	1.05	100.00	100.00

Notes: Patents, 1981–2024. Private value is in trillions of 2025 dollars; external value is per private dollar. Generated and received shares assign net external value to the innovator's and affected firm's sectors, respectively. Firms are allocated by segment sales, with primary-industry fallback. Utilities are excluded. Sector definitions and allocation: Appendix C.2.

Sensitivity to measurement and aggregation Using alternative measurements of returns and patent news, event windows, controls, estimation methods, heteroeneity and sample selection in estimating specification (3) generate a range external-to-private ratios. I provide a range of comparisons to assess the robustness of the headline estimates summarized in C2. The key finding is that net external value remains positive across all specifications, and the ratio of external to private fluctuates but remains close to or above 1 in most cases. However, one test is worth highlighting, which concerns sensitivity to removing the largest and most influential firms. patents of fifty firms raises the ratio to $1.62; also removing the effects of other firms' patents on them gives $0.95 (Appendix Figure C3). Much of the difference comes from retaining gains these firms receive while excluding the private value of their own inventions.

Influential innovators also receive spillovers, so deleting only their patents can give an incomplete picture of concentration. I rank firms by the absolute change in the aggregate ratio when each firm's patents are removed, then exclude either their patents alone or both their patents and the effects of other firms' patents on them. Removing the patents of fifty firms raises the ratio to

$1.62; also removing the effects of other firms' patents on them gives $0.95 (Appendix Figure C3). Much of the difference comes from retaining gains these firms receive while excluding the private value of their own inventions.

Excluding firms listed through ADRs changes the external-to-private ratio from 1.05 to 1.03 (Appendix Figure C2). The net external value therefore does not depend on gains and losses to these firms.

The private valuation can be compared with a method that uses the realized return rather than grant activity to distinguish valuable inventions. I implement Kogan et al. (2017)'s half-normal signal and normal-noise filter on matched firm–grant dates using the same three-factor abnormal returns. Their rank correlations are 0.96 for patent activity and 0.97 for claims (Appendix Figure C4).

5 Firm growth, market power and productivity

A useful measure of innovation's external value should distinguish the subsequent paths of firms that gain knowledge from those that lose business. I test this implication using operating outcomes observed after the grant news. Earnings and sales describe profitability and scale; capital, employment, and R&D describe the resources firms commit. Revenue productivity and inferred markups help characterize operating performance, but neither separately identifies physical efficiency, product quality, or demand. Reading these outcomes together permits a richer interpretation than treating every positive valuation as the same growth signal.

I sum each firm's fitted dollar revaluations over the year and divide by its average market capitalization on the dates used to construct those revaluations. The resulting index measures annual innovation news relative to firm value:

$$\text{Innovation index}_{it}^{c} = \frac{\widehat{\Delta V}_{it}^{c}}{\overline{V}_{it}} \qquad c \in \{O, T, R, S, C\} \tag{6}$$

where the denominator is the firm's average market capitalization on each Monday over the year, which precedes Tuesday patent news:

$$\overline{V}_{it} = \frac{1}{|t|} \sum_{\tau \in t} V_{i\tau^-}$$

This normalization preserves the relative scale of each firm's news, while allowing comparisons across firms of different sizes as they evolve over the course of the year. Importantly, it interprets as the cumulative return change from innovation news that is accounts for firm size at the time of news within the year. I use news from calendar year $t-1$ to predict growth from the baseline

fiscal year t over one, three, and five years:

$$\log\left(\frac{Y_{i,t+h}}{Y_{it}}\right) = \sum_{c\in\{O,T,R,S,C\}} \delta_h^c \text{Innovation index}_{i,t-1}^c + X_{it}^\top \gamma_h + N_{i,t-1}^\top \eta_{t,h} + \alpha_{\text{ind}(i),h} + \tau_{t,h} + u_{i,t+h} \tag{7}$$

The coefficient of interest δ_h^c measures the expected growth in outcome Y over h years associated with one percent change in firm equity from innovations over the year $t-1$. Outcomes span three performance indicators of firms. (1) Growth in operating performance measured by sales and earning; (2) changes to productivity and market power measured by their total revenue productivity estimated using İmrohoroğlu and Tüzel (2014) and markups sourced from De Ridder et al. (2026); (3) growth in production measured by capital, employment, and R&D spending. I conclude controls for firm scale using their baseline capital and employment. Since firms vary widely on their outcomes on despite sharing common scales, I also include a lagged outcome as a control and for past volatility in their returns. Note that the timing of these variables reflect reporting, so their values reflect past outcomes and account for past innovations. To account for systematic variations, I also include firms' three-digit SIC industry and year fixed effects. Standard errors are two-way clustered by firm and base year.[19] These standard controls need not fully reflect a complete comparison between firms, since my shocks are *received* economic value from innovations by connected firms. Since firms differ in their span of exposure, I additionally control for their total network exposure with a separate coefficient in each year. These controls allow subsequent growth to vary with network reach, even when connected firms generate no innovation news.

This specification differs substantially from prior work by Kogan et al. (2017) who were among the first to link the financial value of innovative output to subsequent performance. First, because they lack a measure of social value, they estimate exposure to private value for source firms. This paper advances literature by providing a measure of social value by estimating market value changes for *receiver firms*. Moreover, sources of shocks receive similar treatment since the index (6) treats all sources under a common normalization. Second, their only source of shocks are rivals. This paper by comparison offers a more complete account by incorporating technology spillovers and supply chain effects. Indeed, the results show that these sources of shocks have distinct qualitative predictions for subsequent firm growth.

Sources of gains and losses from innovations capture distinct economic content about firm growth and performance. First, a firm's own innovations anticipate profitability and operating expansion. A gain equal to one percent of equity predicts earnings growth over three years, together with higher sales, capital, employment, and revenue productivity (Table 4). Conversely, rival innovations anticipate a broad contraction with lower sales over three years, earnings, capital,

[19] Samples are common across the one-, three-, and five-year horizons and across patents and claims within each outcome. Logged earnings require positive endpoints. Outcome levels and news are capped at annual 1st/99th percentiles. Appendix D gives the financial-outcome construction and full results.

TABLE 4: Valuation news and firm performance

Dependent variable: Three-year outcome change

	Operating performance		Productivity and margins		Production		
	Sales	Operating earnings	TFPR	Markups	Capital	Employment	R&D
Own	0.90	3.38	1.87	1.57	0.89	1.07	0.47
	(0.33)	(0.49)	(0.26)	(0.46)	(0.37)	(0.30)	(0.44)
Technology	−0.41	−0.14	−0.04	−0.29	0.71	0.27	1.15
	(0.50)	(0.67)	(0.28)	(0.64)	(0.34)	(0.30)	(0.37)
Rivalry loss	−3.42	−3.17	−1.08	−1.11	−3.49	−1.43	−1.52
	(0.64)	(1.00)	(0.38)	(0.57)	(0.56)	(0.47)	(0.69)
R^2	0.11	0.15	0.22	0.15	0.11	0.07	0.08
Firms	9,692	6,821	6,048	7,092	9,862	9,724	5,152
Years	39	39	39	40	39	39	39

Notes: Patents; news in calendar year $t-1$ precedes the baseline fiscal close, and outcomes change from t to $t+3$. Outcomes are log changes multiplied by 100, except markups (level changes ×100). Earnings are operating income before depreciation; capital is gross property, plant and equipment; R&D is spending. News is annual own or received dollars as a percentage of mean equity in news year $t-1$; rivalry is positive for a loss. All five channels enter jointly; supplier and customer coefficients are omitted. Controls include baseline capital, employment, return volatility and the initial outcome, coverage shares in news year $t-1$ and baseline year t, industry and year effects, and news-year network masses interacted with year. Levels and news are capped at annual 1st/99th percentiles. Parentheses report standard errors two-way clustered by firm and year. Appendix D reports other horizons and claims.

employment, research spending, and revenue productivity (Table 4 and Appendix Table D1). Technology spillovers by comparison distinctly anticipate investment in future growth opportunities with 1.15 log points of R&D growth and 0.7 log points of capital growth over three years (see Appendix Table D1 for 1-5 years). Technological opportunities can induce research and capital expansion before it produces observable operating gains.

Research can both generate inventions and develop the ability to use external knowledge (Cohen and Levinthal, 1989; Scotchmer, 1991). Technology spillovers may therefore reflect capabilities and opportunities already visible in prior research expenditure. I test their additional information by controlling for own and leave-one-out industry peer R&D relative to sales ratios measured before the news year. After controlling for R&D, technology continues to anticipate growth in research spending. Observed prior research intensity does not exhaust the information in valuations.

Addressing timing, sample selection and scaling Requiring complete information on outcomes over horizons can select firms differentially over 1 and 5 years. I compare a common set for all one, three, and five-year periods and list results in Appendix Table D8. The expanded three-year sample survives the earnings and revenue productivity associations for both rival and private value of innovations. A second thread source of threat to estimation is extreme valuation news and accounting outcomes potentially reflecting true information. I remove the winsorized outcomes on innovation news and on outcome levels separately keeping other controls and their treatment fixed. Own news continues to predict earnings and revenue productivity, while losses from rival innovations predict contraction at all five years (Appendix Table D8). Markup magnitudes change more when outcome levels are uncapped reflecting tail changes. Third, news that precedes baseline fiscal close still predicts the subsequent operating path. To remove overlap between the news and growth periods, I compare current year and prior year news on identical observations, aligning network mass to the news year and retaining the same financial and coverage controls. Rivalry's sales coefficient strenghtens from -2.9 for current news to -3.4 for prior news, consistent with a gradual decline in market shares over time (Appendix Table D10). The timing comparison supports a predictive interpretation beyond within-period comovement. Lastly, while my index accounts for sources of all news that fluctuate valuations, I further test for denominator sensitivity by using a simple June end or December end capitalization of the prior news year, holding dollar numerators fixed. (Appendix Table D3). These denominators produce skewed indices because mid-year coverage can be incomplete and end year values reflect accumulated responses over the year, but the main results survive qualitatively and preserve evidence of contraction and expansion. Therefore, the results are robust to alternative timing of news, sample selection and scaling.

5.1 Valuation sources and subsequent earnings

Financial analysts use price-to-earnings ratios to assess the growth prospects embedded in stock prices. Does the source of these prospects matter for interpreting a firm's P/E ratio? Current earnings reflect the products and technologies a firm already operates, whereas its price also values opportunities that have yet to generate earnings. Boppart et al. (2026) use this distinction to infer firms' future contributions to growth. Their model connects high valuations relative to current earnings to favorable innovation opportunities, distinguishing expansion in the number of products from improvements in their profitability. In this section, I examine how street earnings growth associated with valuation decompose into the sources of innovation news.

Two firms can trade at the same multiple of current earnings even though their valuations reflect different combinations of their own and peer patenting. Let V_{it} denote current equity, $V_{i,t-1}$ equity in the preceding year, and let $\widehat{\Delta V}^{c}_{it}$ be the dollar news over the year t from from own oer peer innovations (c being own innovation, technology, rivalry, suppliers, and customers). Then:

$$\underbrace{V_{it}}_{\text{Current value}} = \underbrace{V_{i,t-1}}_{\text{Prior value}} + \sum_{c} \underbrace{\widehat{\Delta V}^{c}_{it}}_{\substack{\text{Change due to} \\ \text{innovation}}} + \underbrace{\Delta V^{\text{other}}_{it}}_{\text{Other changes}}$$

If all components have the same earnings loading on the P/E ratio, then their origin adds no information to a linear forecast based on total P/E. To asses this decomposition, I estimate

$$\begin{aligned}\frac{1}{h}\log\left(\frac{\text{Street earnings}_{i,t+h}}{\text{Street earnings}_{it}}\right) = \beta^{\text{prior}}_{h}\frac{V_{i,t-1}}{V_{it}}\ln\log(\text{P/E}_{it}) + \sum_{c}\beta^{c}_{h}\frac{\widehat{\Delta V}^{c}_{it}}{V_{it}}\log(\text{P/E}_{it}) \\ + +\beta^{\text{other}}_{h}\frac{\Delta V^{\text{other}}_{it}}{V_{it}}\log(\text{P/E}_{it}) + X_{it}^{\top}\gamma_{h} + \tau_{t,h} + \mu_{m(i,t),h} + \varepsilon_{i,t+h}\end{aligned} \tag{8}$$

Street earnings are positive IBES annual earnings per share on a consistent share basis.[20] Different coefficients of β would imply different earnings forecasts for firms with the same total P/E, but with different contributions of own innovation, and by technology neighbors and rivals. The remaining valuation includes earlier and unmeasured innovation news, so the exercise isolates the information in measured patent announcements rather than dividing firm value into innovative and noninnovative activities. Controls X_{it} include financial characteristics, coverage measures, and a cubic in the estimated firm discount rate; $\tau_{t,h}$ and $\mu_{m(i,t),h}$ are calendar-year and fiscal-end-month effects. Standard errors are clustered by firm and fiscal year. Both the outcome and valuation components are multiplied by 100 in estimation, which leaves the reported slopes unchanged. For intuitive interpretation, I use signed dollars for rivalry. Appendix D.4 describes the earnings and controls. The results are presented in Table 5 for a three year horizon.

[20] I require positive earnings for the log transformation to be well-defined, which skews in favor of firms that are profitable.

TABLE 5: Price-to-earnings decomposition and annualized three-year street earnings growth

Dependent variable: Annualized log growth in street earnings

	(1)	(2)	(3)	(4)	(5)
Log P/E	0.22				
	(0.01)				
Prior equity		0.23	0.22	0.23	0.23
		(0.01)	(0.01)	(0.01)	(0.01)
Total change in equity		0.21			
		(0.01)			
Own innovation			0.32		0.37
			(0.06)		(0.06)
Technology				0.27	0.24
				(0.03)	(0.03)
Rivalry				−0.39	−0.40
				(0.05)	(0.05)
Remaining change in equity			0.21	0.22	0.22
			(0.01)	(0.01)	(0.01)
Supplier/customer terms	No	No	No	Yes	Yes
Firms	2,746	2,746	2,746	2,746	2,746
Years	41	41	41	41	41
R^2	0.26	0.26	0.26	0.26	0.26

Notes: All columns use identical firm years, financial and coverage controls, a discount rate cubic, and calendar year and fiscal end month effects. Valuation components use dollars between consecutive fiscal closes and sum to the same log P/E. Rivalry enters as a positive loss; supplier and customer coefficients are omitted from display. Coefficients and standard errors are annualized. Parentheses report two-way firm/fiscal-year clustered standard errors conditional on estimated inputs.

The main takeaway from this analysis is that my estimates of dollar values have qualitatively distinctive predictions from the standard P/E associations to future earnings. In the full specification, annualized own and rival coefficients move in opposite directions by a near identical amount of 0.37 and −0.40, while differing considerably from the composite loading of .22. Technology spillovers by comparison behave identically as the composite loading. This suggests that appropriability due to innovations has a different signature than standard forecasts, whereas future opportunities behave as anticipations. These results provide complementary evidence to the previous section on operating performance, and to the structural insight by Boppart et al. (2026) suggesting innovation related information is distinct from other sources of growth.

6 From micro to macro: Prices and productivity

The previous section provides a unanimous picture of how innovation affects subsequent firm growth. However, it speaks little to the broader question of how dynamics between firms affect aggregate productivity and prices, and there is no guarantee that more at one firm alone is enough: a firm may internalize all gains as monopoly rents through increased market power.

A consistent prediction among Schumpeterian models is that it is the churn between rivals that drives productivity and consumer welfare. A negative firm level rivalry effect need not imply that competitive innovation shrinks an industry or harms buyers. An innovator can take business from incumbents by offering a better or cheaper product, expanding industry production even as displaced rivals contract. Firm-level regressions among listed corporations cannot measure output reallocation to unlisted producers or changes in industry-wide metrics. I therefore use my measure to examine predictions for industry level prices and total factor productivity (TFP).

To do so, I first construct sector level innovation indices as a sales weighted share of firm level innovation index in each BEA industry:

$$\text{Sector index}^{c}_{st} = \sum_{i \in s} \frac{\text{Sales}_{ist}}{\text{Sales}_{st}} \times \text{Innovation index}^{c}_{it} \qquad c \in \{O, T, R, S, C\} \tag{9}$$

The underlying firm indices are annual dollar news divided by mean equity per firm and source of innovation news (as in (6)), and the sales shares are use their sector specific operating segments. Using these sector indices, I estimate separate regressions for output prices and TFP, relating the industry index in year $t-1$ to their changes over years t to $t+h$:

$$\log\left(\frac{Y_{s,t+h}}{Y_{st}}\right) = \sum_{c \in \{O,T,R,S,C\}} \beta^{c}_{h} \text{Sector index}^{c}_{s,t-1} + X^{\top}_{s,t-2}\gamma_h + N^{\top}_{s,t-1}\eta_h + \alpha_{s,h} + \tau_{t,h} + \varepsilon_{s,t+h} \tag{10}$$

Here, Y_{st} denotes either the industry's output-price index or its TFP index. Both cover listed and unlisted producers, while the news index comes from listed firms. The regressions therefore relate the observed part of industry innovation news to the broader industry's subsequent prices and productivity. Both regressions control for industry conditions before the news: output and input price inflation, real gross-output growth, sales concentration, and the output-price level. Growth rates end in $t-2$, and levels are measured in $t-2$. Prior output growth accounts for the industry's recent expansion, which can predict subsequent prices and productivity. The TFP regression additionally includes prior TFP growth and its log level. I also control for the four network masses, aggregated with the same sales weights and contributors as the innovation indices in $t-1$. Each has one coefficient across years. Sector and year effects absorb persistent industry differences and common national movements, and each sector-year receives equal weight.[21]

[21] Log-level controls are multiplied by 100. Standard errors use the two-way sector/year cluster jackknife and a Student-t reference with min(industries, years) $-$ 1 degrees of freedom. Inference conditions on the return coefficients

I use the integrated total factor productivity (TFP) index from the BEA-BLS industry production accounts which measures real gross output relative to the combined inputs of capital, labor, energy, materials, and purchased services. Accounting for these inputs distinguishes productivity growth from expansion achieved simply by employing more workers, installing more capital, or purchasing more materials. Because the industry accounts include both listed and unlisted producers, they capture productive gains beyond the firms whose stock-market responses supply the innovation measure.[22] Output prices are BEA's chain-type price indices for gross output, which combine the prices of goods and services each industry produces. These products are purchased by households and by other industries as intermediate inputs. A price decline therefore benefits buyers directly and can reduce production costs elsewhere. Productivity and prices give the industry exercise two distinct economic purposes: productivity measures how much output the industry obtains from its inputs, while prices track the terms on which its products become available to buyers. Although there are limitations on how price indices bundle goods and services to remain comparable over sectors and time, my short horizons and within industry comparisons allow me to compare similar bundles. Together, they connect the contraction of displaced firms to improvements in production and the benefits reaching their customers.[23]

This timing separates the news from the growth period and avoids conditioning on levels realized during or after the news year. It also defines the estimand: subsequent growth conditional on the industry's pre-news position, rather than the cumulative effect of all earlier innovations. Unobserved demand and research opportunities can still affect both the news and subsequent growth, so the estimates remain predictive associations. The results are in Table 6.

The key takeaway is that a one percentage point increase in the rivalry index predicts 2.5 log points higher TFP over three years and 2.06 log points lower output prices. Gains from own innovations, by comparison, have weak association, consistent with the idea that they are likely to internalize the monopoly rents. Competition can erode incumbents' profits while increasing pressure on the industry's ability to produce. The combination of declining firm earnings and rising productivity is consistent with the displacement of existing businesses by more productive production.

The productivity association appears when rivalry enters the regression and persists after the other channels are included on the same observations (Appendix Table D23). Measuring only the innovator's private reward would omit this information. The comparison extends the link between patent values and subsequent growth in Kogan et al. (2017) by showing what competitors' losses reveal about productivity beyond the innovating firm. Technology gains have a different subsequent pattern: they anticipate research and capital investment by firms, but their industry TFP coefficients are negative, including a precisely estimated one-year association (Appendix

used to construct news.

[22] BEA-BLS industry production account methodology.

[23] BEA guide to the GDP-by-Industry accounts.

TABLE 6: Prior innovation news, industry prices, and productivity

Dependent variable: 3-year cumulative log growth ×100

	Output prices	TFP
Own	−0.32	0.30
	(0.47)	(0.41)
Technology	−0.34	−0.75
	(1.04)	(0.45)
Rivalry loss	−2.06	2.52
	(1.07)	(0.76)
R^2	0.48	0.45
Industries	57	51
Years	23	22
Base years	2000–2022	2000–2021

Notes: The four sales-weighted network masses enter as controls. Patents; news is dated $t-1$, and growth runs from t to $t+3$. All five indices enter jointly; supplier and customer coefficients are omitted. Coefficients are per percentage point of the sales-weighted news index. Controls include growth ending in $t-2$, sales concentration in $t-2$, each outcome's own log level in $t-2$, with sector and year effects. Parentheses report two-way sector/year cluster-jackknife standard errors, conditional on the return coefficients. R^2 includes fixed effects. Appendix Tables D17–D20 report all horizons, claims, and timing comparisons. Appendix Table D19 reports the same-sample comparison without level controls and the level coefficients.

Table D17). The evidence therefore distinguishes opportunities that induce further investment from the more immediate productivity gains associated with competitive displacement in product markets.

The positive rivalry to TFP prediction survives changes in the timing and controls. I compare current and prior news, move growth and concentration controls before the news, and include the outcome's pre-news level on identical sector–year observations (Appendix Tables D19 and D20). Claims give a similar pattern. The negative price association is also preserved across these comparisons. The productivity result also survives alternative equity denominators. Replacing mean equity with June end or December end equity preserves the association, holding the annual dollar values and segment-sales weights fixed (Appendix Tables D21 and D22).

Taken together, these findings provide a third piece of corroborative evidence that my measure of the external value of innovations derived from stock price movements to patent announcements captures subtantial information on productivity and growth. In the next section, I turn to an endogenous growth model that uses these findings to provide a framework for evaluating the social value of innovation from the market values of firms.

7 A model of creation, destruction, and social value

So far the empirical evidence is unanimous that by using changes to stock prices of firms to news of innovations, we learn a substantial amount about how innovations affect scale, productivity and operations of both inventing and connected firms. Importantly, sources of these gains and losses provide predictive content on quite different features of firms and industries. Innovation per se may create value for inventing firms by raising their scale, but it need not translate into aggregate consumer gains immediately as innovators may internalize those gains through monopoly rents. Rivalry, on the other hand, may harm individual firms but lead to aggregate gains through creative destruction. Technology's dominant role is reflected in spurring greater R&D investments. In this section, I use these findings to build a model that bridges what we learn from market values of firms to understand the social value of innovation.

In the model, firms hold multiple products and compete in prices. A firm that improves a product leads it and earns profits until other producers learn to make the same quality or another firm improves the product and takes it. Buyers gain from this improvement: when the lead diffuses, the price falls to the cost of production. When a different firm improves a product, buyers enjoy a better product for the same price. Firms operate within sectors, where sectors are connected by a production network through which better products and prices propagate. Innovations also play a second role: they provide new ideas, which make the research of the firms that receive them more productive. Therefore, new innovations raise the value of benefiting firms who invest more in research, and profit only later when their research succeeds. The economy combines features of quality ladders (Klette and Kortum, 2004), knowledge diffusion (Akcigit and Kerr, 2018; Liu and Ma, 2024), and escape competition (Aghion et al., 2005).

7.1 The economy

Time is continuous. A representative household owns all firms, supplies one unit of labor inelastically, and maximizes

$$\mathcal{U} = \int_0^\infty e^{-\rho t} \ln C_t \, \mathrm{d}t$$

where C_t is consumption and $\rho > 0$ is the rate of time preference. A competitive firm makes the final good combining goods from all sectors

$$Y = \prod_s \left(\frac{x_s}{b_s}\right)^{b_s} \qquad \sum_s b_s = 1$$

where x_s is the amount of sector s's good that it uses and b_s is the sector's share of final spending. The final good is the numeraire, so the aggregate price index is 1. Final output is consumed or

spent on research and entry. Unless specified otherwise, parameters will differ across sectors, and I drop their sector subscripts when the sector is clear.

Products and production Each sector's good combines a unit continuum of products with equal weights,

$$\exp \int_0^1 \ln(q_\iota y_\iota) \, \mathrm{d}\iota$$

where y_ι is the quantity of product ι and q_ι its best quality. Buyers therefore spend the same amount on every product of a sector. That amount is $\lambda_s Y$, where λ_s is the sector's sales as a share of output.

Every producer of a product in sector s uses the same constant-returns-to-scale Cobb-Douglas production technology, in which labor has the share $\alpha_s > 0$ and the intermediate good of sector s' has the share $\widetilde{\Omega}_{ss'}$. Therefore, with inputs normalized as in the final good's technology, a unit of the product costs

$$w^{\alpha_s} \prod_{s'} P_{s'}^{\widetilde{\Omega}_{ss'}} \qquad \text{where} \qquad \alpha_s + \sum_{s'} \widetilde{\Omega}_{ss'} = 1$$

to produce, where $P_{s'}$ is the price of sector s''s good. Producers of a product differ only in the quality that they can make, and sectors buy from one another as in a production network.

Competition and diffusion Each product improvement makes the technology that it replaces available to all firms, so a competitive fringe can always make a product one step below its best quality. The firm that made the latest improvement *leads* it, so it alone can make the best quality, which exceeds the fringe's by the step $\gamma > 1$. However, the innovation demonstrates what is feasible, and other producers reach the same quality by their own methods, even when the original method is protected. So the lead diffuses to the fringe at the rate δ, and the product is *neck and neck* once the best quality has fully diffused to the fringe. Diffusion does not raise any product's best quality, but rather it only lets the fringe produce it. Producers compete in prices, and leaders charge the marginal cost of the next best producer, keeping the difference as profit.

Research Each firm belongs to one sector, can own any number of products within it, and is defined by the set of products that it holds. On each product that it holds, a firm can run two kinds of research: internal research, which improves a product that it holds, and external research, which improves a product of the sector that it does not yet hold. The firm chooses the rates of both kinds of research, which are costly. External research succeeds at the Poisson rate ζ, which is chosen by the firm, and a success improves a random product of the sector by one step. The innovator becomes the product's leader through *takeover* innovation. Internal research improves

one of the firm's own products by one step at the Poisson rate ζ^o chosen by the firm. When a firm leads a product, it does not improve the product further in equilibrium, because the improvement would make its current technology available to the fringe and its lead remains unchanged at one step. On a neck-and-neck product, on the other hand, internal research restores its lead. This *escape competition* research is done only by an existing holder, because research capacity on a product stays with its holder after its technology diffuses. A firm therefore leads some of its products, is neck and neck on the others, and belongs to the fringe of every other product of its sector.

Research investment uses the final good. On a product of sector s, external research at the rate ζ and internal research at the rate ζ^o cost

$$\lambda_s Y \chi \frac{\zeta^{1+\phi}}{1+\phi} \qquad \text{and} \qquad \lambda_s Y \chi \frac{(\zeta^o)^{1+\phi}}{1+\phi} \tag{11}$$

respectively, where $\chi > 0$ scales the cost and $\phi \geq 1/2$ is the elasticity of the marginal cost of research. Costs are proportional to the product's sales and a firm's research capacity grows with the products that it holds.

Entry New firms enter by spending the final good. An entrant that spends $\lambda_s YF$ per unit of time succeeds at a unit Poisson rate. A success is a takeover of a random product of sector s, and it makes the entrant a leader on that product. Staying out is worth zero, so entry is positive only if a new product is worth its entry cost, $\lambda_s YF$. Firms' external research and entry collectively take each product of sector s at the rate h_s, which I call the sector's *takeover rate*. Of that takeover rate, entrants account for ζ_s^e.

Ideas Each innovation, a takeover or an escape, also brings new ideas to the research on other products. While the research on a product has these *fresh ideas*, its cost scale falls from χ to χ^f, with $0 < \chi^f < \chi$, so the costs (11) of external research at the rate ζ and of escape research at the rate ζ^o fall by

$$\lambda_s Y(\chi - \chi^f) \frac{\zeta^{1+\phi}}{1+\phi} \qquad \text{and} \qquad \lambda_s Y(\chi - \chi^f) \frac{(\zeta^o)^{1+\phi}}{1+\phi} \tag{12}$$

the same fraction, $1 - \chi^f/\chi$, of what each costs without fresh ideas. The ideas of the innovations of sector s' reach the research on the products of sector s with the weight $\kappa_{ss'} \geq 0$, which measures how much research in sector s learns from sector s'.

Fresh ideas last for a while. An idea gives a head start on improvements that have not been made yet, and as the field works through them, the head start is used up and research on the product costs what it did before. I let fresh ideas become obsolete in this way at the rate $\nu > 0$, the same in every sector, so they stay fresh for $1/\nu$ years on average. They also end when another firm takes the product, because they belong to the holder's research on it, and that research ends. An

escape keeps them, because the holder's research continues. If fresh ideas never became obsolete, $\nu = 0$, the research on a product would keep them until the product is taken; if they became obsolete at once, they would never lower a cost.

Shares of products Each product has two characteristics: whether it is led or neck and neck, and whether its research has fresh ideas. Let n_s be the share of sector s's products that are neck and neck, k_s the share whose research has fresh ideas, and n_s^f the share that are both. The shares of the other groups follow from these three: $1 - n_s - k_s + n_s^f$ of the products are led without fresh ideas, $k_s - n_s^f$ are led with them, and $n_s - n_s^f$ are neck and neck without them. When the holders of neck-and-neck products escape at the rate ζ_s^o without fresh ideas and ζ_s^{of} with them, sector s has $h_s + \zeta_s^o(n_s - n_s^f) + \zeta_s^{of} n_s^f$ innovations per product and unit of time, takeovers and escapes, and fresh ideas arrive on the research of each product of sector s at the rate

$$a_s = \sum_{s'} \kappa_{ss'} \left[h_{s'} + \zeta_{s'}^o (n_{s'} - n_{s'}^f) + \zeta_{s'}^{of} n_{s'}^f \right] \tag{13}$$

Leads diffuse at the rate δ, and a neck-and-neck product is led again after an escape or a takeover. Fresh ideas arrive at the rate a_s and end when they become obsolete or the product is taken. The shares therefore move as

$$\begin{aligned} \dot{n}_s &= \delta(1 - n_s) - h_s n_s - \zeta_s^o (n_s - n_s^f) - \zeta_s^{of} n_s^f \\ \dot{k}_s &= a_s(1 - k_s) - (\nu + h_s) k_s \\ \dot{n}_s^f &= \delta(k_s - n_s^f) + a_s(n_s - n_s^f) - (\nu + h_s + \zeta_s^{of}) n_s^f \end{aligned} \tag{14}$$

where dots denote derivatives with respect to time. A product becomes neck and neck with fresh ideas when the lead of a led product with fresh ideas diffuses, or when ideas arrive on a neck-and-neck product without them, and it leaves that state when its ideas become obsolete, the product is taken, or its holder escapes. Sales shares, labor's share of output, and spending on research and entry depend on the states of individual products only through these three shares in each sector, which are therefore the economy's aggregate state.

7.2 Prices and output

Buyers spend $\lambda_s Y$ on a product of sector s whatever its price, so a higher price costs its producer no revenue. The leader of a led product therefore charges the highest price at which the fringe cannot undercut it for a unit of quality, γ times the unit cost. A product's markup μ_ι, its price over its unit cost, is therefore γ when the product is led, and the leader's profits are its sales less its costs, $\lambda_s Y(1 - 1/\gamma)$. When the product is neck and neck, its producers make the same quality at the same cost, competition in prices drives its price down to the unit cost, the markup is one, and nobody earns profits on it.

The price of a sector's good is the geometric mean of its products' prices per unit of quality, and each price is the product's markup times its unit cost, so

$$\ln P_s = \alpha_s \ln w + \sum_{s'} \widetilde{\Omega}_{ss'} \ln P_{s'} - \int_0^1 \ln \frac{q_\iota}{\mu_\iota} \, \mathrm{d}\iota_s$$

where the integral runs over the products of sector s. Let $\widetilde{\lambda}_s$ be the sector's share in the cost of the final good, counting the inputs that other sectors buy from it: the s-th element of $b'(I - \widetilde{\Omega})^{-1}$, where b is the vector of the final spending shares b_s and $\widetilde{\Omega}$ the matrix of the input shares $\widetilde{\Omega}_{ss'}$. Summing these equations with the weights $\widetilde{\lambda}_s$, and using that the final good is the numeraire, gives the wage

$$\ln w = \sum_s \widetilde{\lambda}_s \int_0^1 \ln \frac{q_\iota}{\mu_\iota} \, \mathrm{d}\iota_s \tag{15}$$

It rises with the quality of every product and falls with its markup, so an improvement raises the wage only as far as it lowers the product's price per unit of quality. A takeover of a led product raises the product's quality without raising its markup, because the new leader is again one step ahead of the fringe, and the wage gains at once. A new lead on a neck-and-neck product raises the quality and the markup by the same factor, and the wage gains only when the lead diffuses and the markup falls back to one.

A product with the markup μ_ι spends the fraction $1/\mu_\iota$ of its sales on labor and goods, the share α_s of that on labor and the share $\widetilde{\Omega}_{ss'}$ on the good of sector s'. Each sector sells its good to final demand and to the producers of every sector, and all labor works in production, because research and entry use the final good. Sales shares and labor's share of output, Λ, therefore solve

$$\lambda_s = b_s + \sum_{s'} \lambda_{s'} \widetilde{\Omega}_{s's} \int_0^1 \mu_\iota^{-1} \, \mathrm{d}\iota_{s'} \qquad\qquad \Lambda = \sum_s \alpha_s \lambda_s \int_0^1 \mu_\iota^{-1} \, \mathrm{d}\iota_s$$

Producers hire $\Lambda Y/w$ units of labor, and the household supplies one unit, so output is $Y = w/\Lambda$. A dollar of profit on a product is a dollar that the product does not spend on labor or on the goods of other sectors, so markups lower the sales of suppliers and labor's share of output. Output, the sectors' sales less their purchases of goods, is labor income plus profits.

7.3 Firm value, entry, and equilibrium

A firm chooses its research to maximize the present value of its profits less its research spending, taking as given the paths of the takeover rate h_s, of the arrival rate of ideas a_s, and of the interest rate. A product brings its holder two things: its profits, net of the escape research that can restore its lead, and the external research that the firm runs on it. Let V_1 and V_0 be the values of the profits of a led and of a neck-and-neck product whose research has no fresh ideas, and V_1^f and

V_0^f the same values when its research has fresh ideas, one value for each group of products. Let W_s and W_s^f be the values of the external research on a product without and with fresh ideas. A product that a firm takes is led and its research starts without fresh ideas, so a new product is worth $v_s \equiv V_1 + W_s$.

Profits and research costs are proportional to a product's sales, $\lambda_s Y$, so I measure all values per dollar of those sales, on which a led product earns profits of $1 - 1/\gamma$. Values in dollars earn the interest rate, which by the household's Euler equation is ρ plus the growth rate of consumption. Per dollar of sales they are therefore discounted at

$$\rho + \frac{\mathrm{d}}{\mathrm{d}t} \ln \frac{C}{\lambda_s Y} \tag{16}$$

When the rates and the shares are constant, consumption and sales grow at the same rate, the discount rate is ρ, and the values are constant. The values of a product's profits then solve

$$\begin{aligned}
\rho V_1 &= \underbrace{1 - 1/\gamma}_{\text{profits}} - \underbrace{\delta(V_1 - V_0)}_{\text{diffusion}} + \underbrace{a_s(V_1^f - V_1)}_{\text{ideas arrive}} - \underbrace{h_s V_1}_{\text{takeover}} \\
\rho V_0 &= \underbrace{\max_{\zeta^o \geq 0} \left[\zeta^o (V_1 - V_0) - \chi \frac{(\zeta^o)^{1+\phi}}{1+\phi} \right]}_{\text{escape research}} + \underbrace{a_s(V_0^f - V_0)}_{\text{ideas arrive}} - \underbrace{h_s V_0}_{\text{takeover}} \\
\rho V_1^f &= 1 - 1/\gamma - \delta(V_1^f - V_0^f) - \underbrace{\nu(V_1^f - V_1)}_{\text{ideas become obsolete}} - h_s V_1^f \\
\rho V_0^f &= \max_{\zeta^o \geq 0} \left[\zeta^o (V_1^f - V_0^f) - \chi^f \frac{(\zeta^o)^{1+\phi}}{1+\phi} \right] - \nu(V_0^f - V_0) - h_s V_0^f
\end{aligned} \tag{17}$$

A led product earns its holder these profits until its lead diffuses, when its value falls to V_0 or V_0^f, or until another firm takes the product, when the holder loses it. A neck-and-neck product earns nothing, and its value is the holder's chance to restore the lead by escape research, net of what that research costs. The values of the external research on a product solve

$$\begin{aligned}
\rho W_s &= \underbrace{\max_{\zeta \geq 0} \left[\zeta v_s - \chi \frac{\zeta^{1+\phi}}{1+\phi} \right]}_{\text{external research}} + \underbrace{a_s(W_s^f - W_s)}_{\text{ideas arrive}} - \underbrace{h_s W_s}_{\text{takeover}} \\
\rho W_s^f &= \underbrace{\max_{\zeta \geq 0} \left[\zeta v_s - \chi^f \frac{\zeta^{1+\phi}}{1+\phi} \right]}_{\text{external research}} - \underbrace{\nu(W_s^f - W_s)}_{\text{ideas become obsolete}} - \underbrace{h_s W_s^f}_{\text{takeover}}
\end{aligned} \tag{18}$$

External research adds new products at the rate that the firm chooses, each worth v_s, and it ends when another firm takes the product. When the rates or the shares change over time, every line of (17) and (18) has the discount rate (16) in place of ρ and the change of the value over time

subtracted on its left side. The first-order conditions give the research rates at each date,

$$\zeta^o = \left(\frac{V_1 - V_0}{\chi}\right)^{1/\phi} \qquad \zeta^{of} = \left(\frac{V_1^f - V_0^f}{\chi^f}\right)^{1/\phi} \qquad \zeta_s = \left(\frac{v_s}{\chi}\right)^{1/\phi} \qquad \zeta_s^f = \left(\frac{v_s}{\chi^f}\right)^{1/\phi} \tag{19}$$

Escape research runs until its marginal cost equals the value of a lead, $V_1 - V_0$ or $V_1^f - V_0^f$, and external research until its marginal cost equals the value of a new product.

Free entry With positive entry, a new product is worth its entry cost at every date, $v_s = F$. External research then runs at the rates $\zeta = (F/\chi)^{1/\phi}$ without fresh ideas and $\zeta^f = (F/\chi^f)^{1/\phi}$ with them, and it earns profits, the value of its successes less its cost, of

$$\Pi_s \equiv \frac{\phi F \zeta}{1+\phi} \qquad \Pi_s^f \equiv \frac{\phi F \zeta^f}{1+\phi}$$

per dollar of the product's sales. Firms' external research takes each product at the rate $\zeta + (\zeta^f - \zeta)k_s$, and entrants supply the rest of the takeover rate, $\zeta_s^e = h_s - \zeta - (\zeta^f - \zeta)k_s$. Adding the first lines of (17) and (18), written with the discount rate (16), and using that $V_1 + W_s$ stays at F, gives at every date

$$\rho + \frac{\mathrm{d}}{\mathrm{d}t} \ln \frac{C}{\lambda_s Y} + h_s = \frac{1 - 1/\gamma + \Pi_s - \delta(V_1 - V_0) + a_s(V_1^f - V_1) + a_s(W_s^f - W_s)}{F} \tag{20}$$

Free entry ties the takeover rate to the discount rate: the faster the values of a sector's products are discounted, the more slowly the products must be taken for a new product to stay worth its entry cost.

Definition 1. An *equilibrium* is a path of the takeover, entry, escape, and external research rates, of the arrival rates of ideas, of consumption, and of the shares n_s, k_s, and n_s^f, from given initial shares, such that at every date (i) every firm chooses its research to maximize its value, given the paths of the rates and of the interest rate; (ii) a new product of sector s is worth at most its entry cost, $\lambda_s Y F$, and exactly its entry cost if entry is positive; (iii) ideas arrive at the rates (13); (iv) the shares follow (14); (v) prices, the wage, and sales shares are those of Section 7.2; and (vi) the household consumes output less the spending on research and entry.

Condition (i) holds when the values solve (17) and (18) at the rates (19), and in a sector with positive entry condition (ii) is (20).

7.4 The steady state

A *steady state* is an equilibrium in which the rates and the shares are constant. By (14), the shares are then $k_s = a_s/(a_s + h_s + \nu)$ and the solution n_s and n_s^f of the two linear equations that set $\dot{n}_s$ and $\dot{n}_s^f$ to zero. The distribution of markups is constant, and the average log quality of sector s rises by one step at every takeover and every escape, at the rate $[h_s + \zeta^o(n_s - n_s^f) + \zeta^{of} n_s^f] \ln \gamma$. By (15), the wage grows at the rate

$$g = \sum_s \widetilde{\lambda}_s [h_s + \zeta^o(n_s - n_s^f) + \zeta^{of} n_s^f] \ln \gamma$$

and so do output, profits, research, and the value of all firms. Growth comes only from improvements, one step at every takeover and every escape; diffusion lowers markups but raises no quality. Consumption is a constant share of output, so the interest rate is $\rho + g$ and the discount rate (16) is ρ.

On a steady state the values per dollar of sales are constant. For a product ι, let $V(\iota)$ be V_1, V_0, V_1^f, or V_0^f by whether it is led and whether its research has fresh ideas, and $W(\iota)$ be W_s or W_s^f by whether its research has fresh ideas. Each product brings its holder these two things whatever else the firm holds, because research capacity and research costs are proportional to products and a success takes a random product of the sector. Each product that a firm holds is taken at the rate h_s, and the firm's research on it adds products at most at the rate ζ_s^f. The firm's expected number of products therefore grows at most at the rate $\zeta_s^f - h_s$. When that rate is below ρ, the present value of the products that the firm expects to hold at distant dates tends to zero, and its value is finite.

Lemma 1. *On a steady state with $\zeta_s^f < \rho + h_s$, a firm of sector s that chooses its research to maximize its value is worth*

$$V = \lambda_s Y \sum_\iota \Big[\underbrace{V(\iota)}_{\text{current product}} + \underbrace{W(\iota)}_{\text{its research}} \Big] \tag{21}$$

where the sum runs over the products that it holds, and the values are constant and solve (17) and (18) at the rates (19). The values of a lead without and with fresh ideas, $V_1 - V_0$ and $V_1^f - V_0^f$, are the unique positive solution of

$$\begin{aligned} (\rho + h_s + \delta + a_s)(V_1 - V_0) + \frac{\phi}{1+\phi} \chi^{-1/\phi} (V_1 - V_0)^{(1+\phi)/\phi} &= 1 - 1/\gamma + a_s(V_1^f - V_0^f) \\ (\rho + h_s + \delta + \nu)(V_1^f - V_0^f) + \frac{\phi}{1+\phi} (\chi^f)^{-1/\phi} (V_1^f - V_0^f)^{(1+\phi)/\phi} &= 1 - 1/\gamma + \nu(V_1 - V_0) \end{aligned} \tag{22}$$

and $V_1^f - V_0^f < V_1 - V_0$. *Fresh ideas are worth*

$$\begin{aligned} W_s^f - W_s &= \frac{\phi}{\rho + h_s + a_s + \nu} \cdot \frac{\upsilon_s (\zeta_s^f - \zeta_s)}{1 + \phi} \\ V_0^f - V_0 &= \frac{\phi}{\rho + h_s + a_s + \nu} \cdot \frac{(V_1^f - V_0^f)\,\zeta^{of} - (V_1 - V_0)\,\zeta^o}{1 + \phi} \end{aligned} \tag{23}$$

to the external research on a product and to the escape research on a neck-and-neck product, and $V_1^f - V_1 = \delta(V_0^f - V_0)/(\rho + h_s + \delta + a_s + \nu)$ *to a led product.*

A firm's value is therefore linear in the products that it holds, as in Klette and Kortum (2004), and external research per product does not depend on the size of the firm. Faster diffusion lowers the values of a lead and with them escape research. It also lowers the value of a led product, V_1, and, at a given takeover rate, the value of a new product. Research earns ϕ times its cost, because spending on it is the fraction $1/(1 + \phi)$ of the value of its successes.

Fresh ideas make escape research cheaper. A holder with them escapes faster, $\zeta^{of} > \zeta^o$, and loses less when its lead diffuses, so its lead is worth less, $V_1^f - V_0^f < V_1 - V_0$. In both values of (23), the second factor is the rise in research spending on the product that fresh ideas bring, and the ideas earn ϕ times that rise for as long as they would have stayed fresh. A led product gains from them only if its lead diffuses while they are fresh.

On a steady state with positive entry, the discount rate is ρ, and (20) is the free-entry condition

$$F = V_1 + W_s \tag{24}$$

rearranged, in every sector. In (24), V_1 follows from (17) and (22), and W_s solves (18) with $\upsilon_s = F$. Both depend on the takeover rate h_s and on the arrival of ideas a_s, and so do the escape rates, by (22) and (19), and the shares. A steady state with positive entry is therefore a list of takeover rates h_s and arrival rates a_s that satisfy (24) and (13) in every sector and at which $\zeta_s^e > 0$ and $\zeta_s^f < \rho + h_s$.

Firms' research takes each product at most at the rate ζ_s^f, the rate at which research with fresh ideas succeeds. If products were taken only that fast and no ideas arrived, a new product would be worth $V_1 + \Pi_s/(\rho + h_s)$ at $h_s = \zeta_s^f$ and $a_s = 0$, and ideas would only raise its value. When this exceeds F, firms' research alone cannot bring the value of a new product down to its cost, and entrants supply the remaining takeovers.

Faster takeovers shorten the life of a new product and lower its value, so for given ideas exactly one takeover rate makes a new product worth its entry cost. Innovations and ideas then feed each other: more takeovers and escapes send more ideas to every sector, and more ideas make research more valuable, which raises the takeover rate that free entry allows and speeds the escapes of neck-and-neck products. The feedback cannot run away, because even a product whose lead never diffused and whose research always had fresh ideas would have a finite value. The takeover rate

of each sector therefore stays below the rate $\overline{h}_s$ at which such a product would be worth its entry cost, and a steady state exists. It is also unique, because the marginal cost of research rises steeply enough, $\phi \geq 1/2$. A sector's innovations then rise with the ideas that it receives: more ideas raise its takeover rate and, at a given takeover rate, its escapes, and the added takeovers crowd out escapes by less than one for one. They rise less than in proportion, because a proportionally higher takeover rate needs more than proportionally more ideas to be sustained, and at a given takeover rate ideas raise escapes at most in proportion. Every innovation leaves ideas in proportion, so no second list of rates can satisfy free entry in every sector.

Lemma 2. *Let $F < V_1 + \Pi_s/(\rho + h_s)$ at $h_s = \zeta_s^f$ and $a_s = 0$ in every sector.*

(i) A steady state with positive entry exists. Every list of rates that satisfies free entry and (13) is one, and in every sector its rate h_s exceeds ζ_s^f and is less than the rate $\overline{h}_s$ at which $F = (1 - 1/\gamma + \Pi_s^f)/(\rho + \overline{h}_s)$.

(ii) The steady state with positive entry is unique.

(iii) On a steady state with positive entry the distribution of firms is constant, and the household consumes its labor income plus ρ times the value of all firms.

Because entry holds the value of a new product at its cost, faster diffusion lowers the takeover rate, for given ideas, and leaves the value of a new product unchanged. Individual firms keep gaining and losing products, leads, and ideas, while the distributions of markups and of firms stay constant.

7.5 How valuable is innovation to firms?

An innovation happens on one product and changes the values of three kinds of firm: the innovator, the former holder of the product, and the firms whose research receives its ideas. One product is too small to move the takeover rates, the escape rates, or the arrival rates of ideas, so by Lemma 1 each of these firms gains or loses exactly the change in the value of the product, or of the research on a product, that the innovation touches. Let ξ^O, ξ^R, and ξ^T be the dollar values of the innovation's own, rivalry, and technology news.

Proposition 1. *On a steady state with positive entry, consider an innovation on a product ι of sector s.*

(i) Own. *The innovator gains*

$$\xi^O = \lambda_s Y F \quad \textit{from a takeover} \qquad \xi^O = \lambda_s Y (V_1 - V_0) \textit{ or } \lambda_s Y (V_1^f - V_0^f) \quad \textit{from an escape}$$

the second if the product's research has fresh ideas.

(ii) Rivalry. *A takeover costs the product's former holder the product and its research on it,* $\xi_\iota^R = \lambda_s Y[V(\iota) + W(\iota)]$. *An escape costs no firm anything, because the fringe earned nothing. Per product and unit of time, own gains less losses from rivalry in sector* s *are*

$$\begin{aligned}\lambda_s Y\Big[&(\zeta^o + h_s)(n_s - n_s^f)(V_1 - V_0) + (\zeta^{of} + h_s)\, n_s^f (V_1^f - V_0^f) \\ &- \frac{h_s a_s}{a_s + h_s + \nu}(V_1^f - V_1 + W_s^f - W_s)\Big]\end{aligned} \tag{25}$$

(iii) Technology. *When the innovation's ideas arrive on a product* ι *of sector* s' *whose research has no fresh ideas, the firm that holds the product gains*

$$\xi^T = \lambda_{s'} Y\big[W_{s'}^f - W_{s'} + V^f(\iota) - V(\iota)\big] \tag{26}$$

where $V^f(\iota)$ *is the value of the product in its state with fresh ideas. On a neck-and-neck product, by* (23)*,* ξ^T *is* $\phi/(\rho + h_{s'} + a_{s'} + \nu)$ *times the rise in the research spending on the product, external and escape. On a led product,* $V_1^f - V_1$ *takes the place of the escape part. The product's sales and profits do not change when the ideas arrive.*

Own news and rivalry Own news measures what an innovation cost, and own news net of losses from rivalry measures the leads that innovations create, which buyers later receive as lower prices. Own news is a cost because of free entry. A new product is worth its entry cost, so a sector with larger steps or slower diffusion has more takeovers, not more valuable ones, and an escape is worth the value of a lead, the marginal cost of escape research. Rivalry nets out what moves between firms. A takeover of a led product moves a lead from one firm to another, whereas a takeover or an escape on a neck-and-neck product creates a lead that no firm loses. Own gains therefore exceed losses from rivalry by the value of these leads, the first two terms of (25): profits that end when other producers learn the technology, and that then go to buyers as lower prices. The last term is the value of the fresh ideas that takeovers destroy, which the former holder loses and the innovator does not gain.

Technology news Technology news is the value of cheaper research, so it shows first in research spending and only later in sales and profits. Ideas give their recipient no product and no profit at once. They make its research cheaper, so it runs more of it, and by (26) technology news is the present value of the extra earnings of that research, ϕ per dollar of added research spending, for as long as the ideas would have stayed fresh. On a led product, the ideas help escapes only if the lead diffuses while they are fresh. Ideas land on products, so a firm with twice as many products receives twice as many ideas, and its technology news is, on average, the same share of its value.

Corollary 1. *On a steady state with positive entry, the research spending of a firm that takes a product of sector* s *rises by* $\zeta/(1 + \phi)$ *per dollar of its own news. The research spending of a firm*

whose neck-and-neck product of sector s receives ideas rises by $(\rho + h_s + a_s + \nu)/\phi$ per dollar of its technology news, which is more; when the product is led, it rises by less, because part of the news is the value of escapes that come only after the lead diffuses. An escape ends the escaping firm's escape research on the product, and a takeover ends the research of the firm that loses the product.

7.6 How entry responds to an innovation

Proposition 1 values each firm's news at the steady state's rates, which each firm takes as given. For the economy as a whole, an innovation also changes the shares of products a little, and the shares set how sales compare with output and how much of output goes to research and entry. While the shares return to their steady-state values, consumption grows at a different rate from sales, the discount rate (16) differs from ρ, and free entry (20) moves the takeover rate. An escape, for example, leaves fewer products neck and neck. A neck-and-neck product buys more inputs than a led one, because it earns no profit, and its holder pays for escape research, so consumption rises relative to sales. It falls back as other leads diffuse, and while it falls, values are discounted at less than ρ and free entry adds takeovers. Fresh ideas work the other way: firms' research takes products more cheaply than entrants do, so research that runs faster with fresh ideas lowers the spending that a given takeover rate requires. Ideas also spread these responses to the sectors that learn from the innovation.

Because one innovation happens on one product, it changes the shares, and through them the rates, only in proportion to the measure of the products that it touches. Its value to the household is therefore a derivative, which the first-order responses of the economy give exactly, and I linearize the equilibrium conditions around the steady state. Let Δ denote the deviation of a variable from its steady-state value. The takeover and escape rates of each sector then move in proportion to the deviations of the shares of all sectors, and the present values of their responses are linear in the deviations that the innovation causes.[24]

7.7 The value of innovation to consumers

An innovation's profits are temporary, but the lower price that it brings is permanent. Its profits end when other producers learn the technology, and its price stays low after that. The household owns all firms, so it gains the stock-market news of Proposition 1. Beyond that news, it gains two things that no firm's news contains: the lower price that remains after the lead ends, and the inputs that the innovation releases while the lead lasts. Both raise output, and with it the value of every firm a little, so they show in the market as a whole rather than in the news of the firms

[24]The shares are given at each date, whereas consumption and the values of a lead and of fresh ideas can change at once. As usual, I assume that from any small deviations of the shares exactly one path of the linearized system returns to the steady state. Appendix E writes the linear system and shows that the assumption holds with one sector and no ideas, where the takeover rate responds to the share of neck-and-neck products as $\Delta h_t = -\eta\, \Delta n_t$ for a constant $\eta \geq 0$.

that the innovation involves. Finally, the household gains or loses the innovations that entry and escape add or remove while the economy returns to its steady state.

Lower prices The lower price is the gain that lasts. A takeover of a led product lowers the product's price per unit of quality at once, because the fringe can now make the former holder's quality. An escape, or a takeover of a neck-and-neck product, lowers it when the new lead diffuses. Either way the price stays one step lower for good, because the product's later improvements happen as they would have and start one step higher. By the wage equation (15), the lower price raises the real wage in proportion to $\widetilde{\lambda}_s$, the sector's share in the cost of the final good. A lower price passes through the cost of every good that uses the product, directly or inside other goods, whatever the markups along the way, so $\widetilde{\lambda}_s$ adds up every chain of inputs, of any length, through which the sector's good reaches the final good. It measures the sector's centrality in the input-output network, and it counts more than the sector's direct sales: a sector that sells little to final demand is central if its good enters many other goods. In a symmetric network every sector has the same centrality, and the same fall in price is worth as much wherever it happens; otherwise it is worth more in a more central sector. A takeover of a led product without fresh ideas, for example, lowers the product's price per unit of quality by the factor γ for good, which is worth $\widetilde{\lambda}_s C \ln \gamma/\rho$ to the household.

Released inputs While a lead lasts, the innovation also releases inputs to the rest of the economy. An escape, or a takeover of a neck-and-neck product, raises the product's markup from one to γ without changing its price per unit of quality. The product therefore sells as much as before with fewer inputs: for each dollar of profit, it spends a dollar less on labor and on other sectors' goods. Its suppliers then sell less and buy less labor and fewer goods in turn, and so on up the supply chain. Along the chain, the dollar releases labor, except for the part that paid for the suppliers' profits, and it releases the research and entry spending that the suppliers' sales paid for. Let ℓ_s be the labor that a dollar of sector s's costs pays for, directly and through its inputs, and ψ_s the research and entry spending that it pays for in the sectors that supply it,

$$\ell_s = \alpha_s + \sum_{s'} \widetilde{\Omega}_{ss'} \ell_{s'} \int_0^1 \mu_\iota^{-1} \mathrm{d}\iota_{s'} \qquad\qquad \psi_s = \sum_{s'} \widetilde{\Omega}_{ss'} \Big(S_{s'} + \psi_{s'} \int_0^1 \mu_\iota^{-1} \mathrm{d}\iota_{s'} \Big)$$

where $S_{s'}$ is the share of sector s''s sales that is spent on external research, escape research, and entry. The released labor produces other goods, ℓ_s/Λ dollars of output per dollar of profit, of which the household consumes the share C/Y, and the household consumes the released research and entry spending as well. The stock-market news already counts the dollar of profit, so beyond that news the household gains $\ell_s C/(\Lambda Y) + \psi_s - 1$ per dollar of profit. This gain has either sign, because the released inputs can produce more or less consumption than the dollar that the market counts.

Two present values per product measure how much of each gain an innovation brings. Let B_1, B_0, B_1^f, and B_0^f be the present values of a product's term in the wage equation (15), $\ln(q_\iota/\mu_\iota)$, by whether the product is led and whether its research has fresh ideas, as for V, with quality measured from the product's best quality today. Let M_1, M_0, M_1^f, and M_0^f be the present values, in the same four states, of the product's profits per dollar of its sales until its next takeover. Both are at the steady state's rates, and their differences between a led and a neck-and-neck product solve

$$\begin{aligned}
(\rho + h_s + \delta + \zeta^o + a_s)(B_1 - B_0) &= -(1 + \zeta^o/\rho)\ln\gamma + a_s(B_1^f - B_0^f)\\
(\rho + h_s + \delta + \zeta^{of} + \nu)(B_1^f - B_0^f) &= -(1 + \zeta^{of}/\rho)\ln\gamma + \nu(B_1 - B_0)\\
(\rho + h_s + \delta + \zeta^o + a_s)(M_1 - M_0) &= 1 - 1/\gamma + a_s(M_1^f - M_0^f)\\
(\rho + h_s + \delta + \zeta^{of} + \nu)(M_1^f - M_0^f) &= 1 - 1/\gamma + \nu(M_1 - M_0)
\end{aligned}$$

In each line, the left side is the difference times ρ plus the rates of the events that end it or change it, and the right side is what the difference brings per unit of time plus what it becomes when fresh ideas arrive or become obsolete. Relative to a neck-and-neck product, a led product holds the wage down by its markup and earns profits of $1 - 1/\gamma$ per dollar of sales, until the lead diffuses, the neck-and-neck product escapes, or either product is taken, and fresh ideas change how fast the neck-and-neck product escapes while they last. The difference in B also counts the escape that the neck-and-neck product may make, which raises its quality for good. Without ideas, the first and third lines give $B_1 - B_0 = -(1+\zeta^o/\rho)\ln\gamma/(\rho+h_s+\delta+\zeta^o)$ and $M_1 - M_0 = (1-1/\gamma)/(\rho+h_s+\delta+\zeta^o)$. The equations are solved once, at the steady state, and the value of an innovation uses only the changes in B and M on the products that it touches.

An innovation touches several products. The product that it improves moves from its state ι to a led state ι', without fresh ideas after a takeover and with the fresh ideas that it had after an escape, and each product whose research receives its ideas moves to the same state with fresh ideas. With $B(\iota)$, $M(\iota)$, $B^f(\iota)$, and $M^f(\iota)$ defined as for V, let the changes in B and M on a product that the innovation touches be

$$(\Delta B_\iota, \Delta M_\iota) = \begin{cases} \big(\ln\gamma/\rho + B(\iota') - B(\iota),\ M(\iota') - M(\iota)\big) & \text{on the product improved} \\ \big(B^f(\iota) - B(\iota),\ M^f(\iota) - M(\iota)\big) & \text{on a product that receives its ideas} \end{cases}$$

An escape always happens on a neck-and-neck product. For an innovation on a product of sector s, let

$$H \equiv \underbrace{\xi^O - \xi^R + \textstyle\sum \xi^T}_{\text{stock-market news}} + \underbrace{\textstyle\sum_\iota \widetilde{\lambda}_{s(\iota)} C\,\Delta B_\iota}_{\text{lower prices}} + \underbrace{\textstyle\sum_\iota \Big(\frac{\ell_{s(\iota)} C}{\Lambda Y} + \psi_{s(\iota)} - 1\Big)\lambda_{s(\iota)} Y\,\Delta M_\iota}_{\text{released inputs}} \tag{27}$$

where $\sum \xi^T$ is the technology news of the firms that receive its ideas, the other two sums run over the products that the innovation touches, and $s(\iota)$ is the sector of product ι.

Let $\overline{H}_{s'}$ be the average of H over the takeovers of sector s', and $H^o_{s'}$ and $H^{of}_{s'}$ its values for an escape in sector s' on a product without and with fresh ideas. Per unit measure of innovations, an innovation changes the shares as follows: n_s falls by one if the product was neck and neck, n^f_s falls by one if it was neck and neck with fresh ideas, k_s falls by one if the product is taken and its research had fresh ideas, and its ideas raise $k_{s'}$ by $\kappa_{s's}(1-k_{s'})$ and $n^f_{s'}$ by $\kappa_{s's}(n_{s'}-n^f_{s'})$ in every sector s'. Let $\Delta h_{s',t}$, $\Delta\zeta^o_{s',t}$, and $\Delta\zeta^{of}_{s',t}$ be the first-order responses of the takeover and escape rates to these changes, from the linearized equilibrium conditions of Section 7.6.

Proposition 2. *Consider a steady state with positive entry and an innovation on a product of sector s.*

(i) If the takeover and escape rates kept their steady-state values, the innovation would be worth H to the household, in dollars of its date.

(ii) With the responses of entry and escape research, it is worth H plus the innovation added by entry and escape,

$$\sum_{s'}\Big[(\overline{H}_{s'}-\lambda_{s'}YF)\int_0^\infty e^{-\rho t}\Delta h_{s',t}\,\mathrm{d}t+\big(H^o_{s'}-\lambda_{s'}Y(V_1-V_0)\big)\int_0^\infty e^{-\rho t}(n_{s'}-n^f_{s'})\,\Delta\zeta^o_{s',t}\,\mathrm{d}t \\ +\big(H^{of}_{s'}-\lambda_{s'}Y(V^f_1-V^f_0)\big)\int_0^\infty e^{-\rho t}n^f_{s'}\,\Delta\zeta^{of}_{s',t}\,\mathrm{d}t\Big] \tag{28}$$

where F, V_1-V_0, and $V^f_1-V^f_0$ are those of sector s'.

The responses matter only through the gap between what an innovation is worth to the household and what it costs. Each integral in (28) counts one kind of innovation that the responses add in sector s': takeovers, escapes without fresh ideas, or escapes with them, discounted to the date of the innovation. Each is valued at its worth to the household, $\overline{H}_{s'}$, $H^o_{s'}$, or $H^{of}_{s'}$, less its marginal cost, which is the entry cost for a takeover and the value of a lead for an escape. If every innovation were worth exactly its marginal cost, the responses would add nothing, however large they were. The responses solve the linear system of Section 7.6, which links the shares of all sectors, so in general they have no closed form. With one sector and no ideas they do. An innovation that leaves one fewer product neck and neck then adds takeovers that die out as the share of neck-and-neck products returns, so (28) is the net value of a takeover, $\overline{H}-\lambda YF$, times the present value of those takeovers. A takeover of a led product changes no share and adds nothing (Appendix E).

7.8 Where to subsidize innovation

A single innovation moves the takeover and escape rates only while the shares that it changes return to the steady state. A lasting rise in one sector's innovations raises the arrival of ideas in

every sector for good, and more ideas bring more takeovers through free entry and more escapes on neck-and-neck products.

By free entry (24) and the steady-state shares, each sector's takeover rate and its innovations per product, $h_s + \zeta^o(n_s - n_s^f) + \zeta^{of} n_s^f$, are functions of the arrival rate of its ideas. Let $\partial h_s/\partial a_s$ be the derivative of the takeover rate, and $\mathcal{J}$ the matrix whose element $\mathcal{J}_{ss'}$ is $\kappa_{ss'}$ times the derivative of sector s's innovations per product with respect to a_s.

Proposition 3. *Consider a steady state with positive entry.*

(i) Each sector's takeover rate rises with the arrival rate of its ideas,

$$\frac{\partial h_s}{\partial a_s} = \frac{\partial v_s/\partial a_s}{-\partial v_s/\partial h_s} > 0 \tag{29}$$

where $v_s = V_1 + W_s$ is the value of a new product at the rates h_s and a_s.

(ii) Under the condition of Lemma 2, each sector's innovations per product rise with the arrival rate of its ideas, by less than in proportion, and the spectral radius of $\mathcal{J}$ is below one.

(iii) If the spectral radius of $\mathcal{J}$ is below one, a small permanent change that raises sector s's steady-state innovations per product by one unit at a given arrival of ideas raises the steady-state innovations per product of all sectors by the s-th column of $(I - \mathcal{J})^{-1}$ once ideas, entry, and escapes respond.

More frequent ideas make a product's research more valuable, through its external research and through the lead that it loses when the lead diffuses, so a new product is worth more than its entry cost until products are taken fast enough to restore free entry. At a given takeover rate, more frequent ideas also make neck-and-neck products escape sooner. Each sector's added innovations send ideas to the other sectors, whose added innovations send ideas back, and $(I - \mathcal{J})^{-1} = I + \mathcal{J} + \mathcal{J}^2 + \cdots$ adds up these rounds. The rounds shrink, because a sector's innovations rise less than in proportion with its ideas, so the spectral radius of $\mathcal{J}$ is below one. The s-th column of $(I-\mathcal{J})^{-1}$ thus measures sector s's centrality in the knowledge network, as $\widetilde{\lambda}_s$ measures its centrality in the input-output network: it adds up every chain through which the sector's innovations bring ideas, and those ideas bring innovations, in other sectors.

A subsidy to entry in one sector raises takeovers there for good and, through ideas, innovations in other sectors, and the values of Section 7.7 price each added takeover and each escape that it adds or crowds out. The subsidy raises sector s's takeover rate at a given arrival of ideas, which changes its innovations per product by one unit plus the response of its escapes. By part (iii) of Proposition 3, the innovations of every sector then change by that amount times the s-th column of $(I - \mathcal{J})^{-1}$, the arrival of ideas by κ times those changes, and each sector's takeover and escape rates by their responses to its ideas, and in sector s to the subsidy. Let $\Delta h_{s'}$, $\Delta\zeta^o_{s'}$, and $\Delta\zeta^{of}_{s'}$ be these

changes in sector s''s steady-state takeover rate and escape rates, without and with fresh ideas, per unit of the rise in sector s's takeover rate at a given arrival of ideas.

Corollary 2. *Consider a steady state with positive entry at which the spectral radius of $\mathcal{J}$ is below one.*

(i) Consider a small subsidy to entry in sector s, paid for by a lump-sum tax. Per unit of the rise in sector s's steady-state takeover rate that the subsidy brings at a given arrival of ideas, it raises the household's value, in dollars of the date it begins, by $1/\rho$ times

$$\sum_{s'}\Big[(\overline{H}_{s'}-\lambda_{s'}YF)\Delta h_{s'}+(H^{o}_{s'}-\lambda_{s'}Y(V_1-V_0))(n_{s'}-n^{f}_{s'})\,\Delta\zeta^{o}_{s'} + (H^{of}_{s'}-\lambda_{s'}Y(V^{f}_1-V^{f}_0))\,n^{f}_{s'}\,\Delta\zeta^{of}_{s'}\Big] \tag{30}$$

where F, V_1-V_0, and $V^f_1-V^f_0$ are those of sector s', plus (28) for the first-order responses, around the new steady state, to the deviations of the old steady state's shares from the new one's, per unit of that rise.

(ii) No firm improves a product that it leads, although such an improvement would lower the product's price per unit of quality by the factor γ for good, which is worth $\widetilde{\lambda}_s C\ln\gamma/\rho$ to the household, and would leave ideas like any other innovation, while the marginal cost of that research is zero at a zero rate.

In the long run, per unit of the takeovers that it adds directly, a small entry subsidy helps the household most in the sectors where (30) is largest: those whose innovations are worth most to the household net of their costs, which other things equal are the sectors most central in the input-output network, and those whose ideas raise innovations elsewhere the most, the sectors most central in the knowledge network. Faster takeovers also shorten leads, so a lead is worth less, and the holders of neck-and-neck products escape less, while the ideas that the added innovations leave make escapes cheaper. The escape terms of (30) value each escape added or forgone at its value to the household net of its cost, the value of a lead. Without ideas, $\mathcal{J}=0$, escapes respond only to the takeover rate, and the long-run effect of a small entry subsidy in sector s is positive exactly when (30) is positive for sector s alone, that is, when a takeover there is worth more to the household than it costs, net of the escapes that it crowds out. The transition adds to the long-run effect: the shares start where the old steady state left them, and while they move to their new values, the takeover and escape rates differ from those of the new steady state.

A subsidy to entry does not reach the research that leaders could do. A leader that improves its own product stays one step ahead, so the improvement is worth nothing to it. To the household, the same improvement on a led product without fresh ideas is worth exactly what a takeover of the product is worth: in both, the price falls by one step for good, the product stays led, and the innovation sends ideas to other products. The marginal cost of that research is zero at a zero

rate, so research on such products is too low whenever their takeovers are worth anything to the household. Without ideas they always are, by $\widetilde{\lambda}_s C \ln \gamma/\rho$.

8 Conclusion

This paper uses stock-market responses to patent announcements to measure the value that inventions create and destroy beyond the innovating firm. For every dollar of private value, other listed firms gain an additional $1.05 on net. This aggregate masks sizable differences across sectors in both the gains from shared technologies and the losses from competing inventions. Computer hardware and pharmaceuticals provide contrasting examples: hardware generates substantial net spillovers, whereas in pharmaceuticals steep rivalry losses offset almost all the technological gains. The benefits extending beyond an inventor therefore depend on how its discoveries enable further innovation and threaten existing businesses.

These financial measures contain information about subsequent firm performance and growth. Gains from technological spillovers anticipate further research and investment, while losses from competing inventions anticipate contraction. The measures also connect innovation at individual firms to broader changes in production: competitive losses predict higher sector productivity and lower output prices. Displacement can thus weaken the firms facing competition while improving production and lowering prices across their industry. Together, these findings contribute to the measurement of spillovers and the estimation of innovation's social value by connecting investors' assessments of inventions to subsequent investment, displacement, and productive growth.

The model explains why even these gains and losses leave part of innovation's value outside firms' profits. A better product can replace an incumbent's business, leaving the innovator's gain largely offset by the incumbent's loss, while buyers obtain higher quality. As the technology diffuses, competition erodes the profits but preserves the improvement. Discoveries also make subsequent research cheaper, creating opportunities whose eventual rewards accrue to firms that build on the original invention. The social value of research therefore depends both on improvements that outlast their private rewards and on discoveries that make further innovation possible. Measuring how an invention changes the prospects of other firms helps connect the inventor's incentive to undertake research with these wider benefits.

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A Details on data construction

A.1 Company, patent identifiers and sample construction

I combine Compustat GVKEY and CRSP PERMNO identifiers to match each dated security with its issuing company. I use grant-date ownership of patents to attribute each grant to a firm using Orbis IP, USPTO PatentsView, DISCERN, and the concordance between Orbis and Compustat/CRSP identifiers. I exclude utilities, defined by SIC codes 4900 to 4949, as both inventing firms and receivers in the sample. The return regression contains 11,679,420 company-grant-date observations, covering 23,697 companies and 2,295 dates. Eligible ordinary shares and American depositary receipts (ADRs) are included in the full dataset, but I explicitly discuss per section when they are included and excluded from analysis. The June comparison in Section 3 is a point-in-time census of ordinary common stocks for descriptive purposes, rather than a count of all companies observed during a year. Its patenting indicator records a matched grant during the preceding five completed calendar years.

TABLE A1: Our sample in selected years

Year	Firms	Firms granted at least one patent	Firm-dates	Patents
1981	4,634	1,073	222,638	22,903
1985	5,774	1,144	278,841	25,552
1990	6,070	1,225	294,074	28,892
1995	7,828	1,676	368,237	36,806
2000	7,913	2,132	373,473	63,820
2005	5,823	1,764	281,295	71,978
2010	4,884	1,614	237,236	97,674
2015	4,725	1,722	230,742	117,212
2020	4,847	1,716	229,099	130,012
2024	5,208	1,392	260,392	98,376

Notes: Annual nonutility accounting population, including ordinary shares and ADRs. Companies are distinct GVKEYs observed during the year. Firms granted at least one patent counts companies with a grant on a date when they enter the accounting population. The full 1981–2024 census contains 12,532,180 company-dates and 24,053 companies; the June common-stock census and regression sample use different observation rules.

TABLE A2: Patenting, market capitalization, sales, and earnings

Patents granted in preceding five years	1981	1990	2000	2010	2020	2024
Panel A: Share of listed companies (%)						
No patents	65.4	69.2	63.6	55.8	50.9	54.6
1 to 10	20.9	20.9	22.6	23.1	21.2	20.5
11 to 100	9.6	7.4	10.7	14.3	17.6	16.5
101 to 1,000	3.6	2.2	2.6	5.7	8.2	6.4
Above 1,000	0.5	0.4	0.5	1.1	2.0	2.0
Panel B: Share of market capitalization (%)						
No patents	26.1	30.8	27.6	21.9	15.4	15.2
1 to 10	14.9	16.4	16.0	18.6	9.6	6.1
11 to 100	15.5	12.9	12.3	14.1	10.4	10.6
101 to 1,000	25.6	24.7	21.0	20.3	24.8	21.5
Above 1,000	17.8	15.3	23.1	25.1	39.9	46.5
Panel C: Share of sales (%)						
No patents	24.5	31.6	38.2	24.9	28.4	28.4
1 to 10	15.4	15.9	19.9	23.4	13.7	11.5
11 to 100	15.5	13.5	11.2	16.2	12.2	14.9
101 to 1,000	26.8	22.3	13.2	18.4	21.5	20.3
Above 1,000	17.8	16.7	17.6	17.1	24.1	24.8
Panel D: Share of earnings (%)						
No patents	23.5	30.1	33.3	20.1	21.6	20.7
1 to 10	13.5	16.1	20.9	18.0	10.1	11.0
11 to 100	13.3	11.3	11.2	21.4	10.1	12.2
101 to 1,000	26.7	23.1	14.8	19.5	24.5	20.0
Above 1,000	23.0	19.4	19.9	21.0	33.7	36.0

Notes: Nonutility ordinary common-stock companies on the NYSE, AMEX, and Nasdaq at the last trading close of June. Groups count U.S. utility patents granted during the preceding five completed calendar years, attributed to historical corporate owners. Company shares divide by all linked nonutility June companies; capitalization shares divide by observed June market capitalization. Sales and earnings shares divide by their respective observed totals among these companies, using the latest twelve-month consolidated USD fiscal report ending in the indicated year. Earnings are operating income before depreciation (EBITDA); losses remain in the totals. Missing sales or earnings are excluded from the corresponding denominator, not assigned zero. Percentages within each panel and year sum to 100 before rounding.

TABLE A3: Patent activity, network coverage, and exposure

Panel A: Patent activity on firm-dates with a grant	Mean	SD	10th pct.	Median	90th pct.
Patents	4.29	9.70	1.00	1.00	9.00
Claims	72.46	166.06	7.00	26.00	155.00
Panel B: Exposure to other firms' patent grants	Observed (%)	Positive (%)	Peers granted, but not own (%)	Mean	SD
Technology	38.64	38.58	84.53	22.88	29.83
Rivalry	94.05	82.15	92.75	14.09	23.29
Suppliers (×1,000)	96.03	1.21	43.21	0.97	21.79
Customers (×1,000)	93.69	9.65	89.42	47.93	210.97

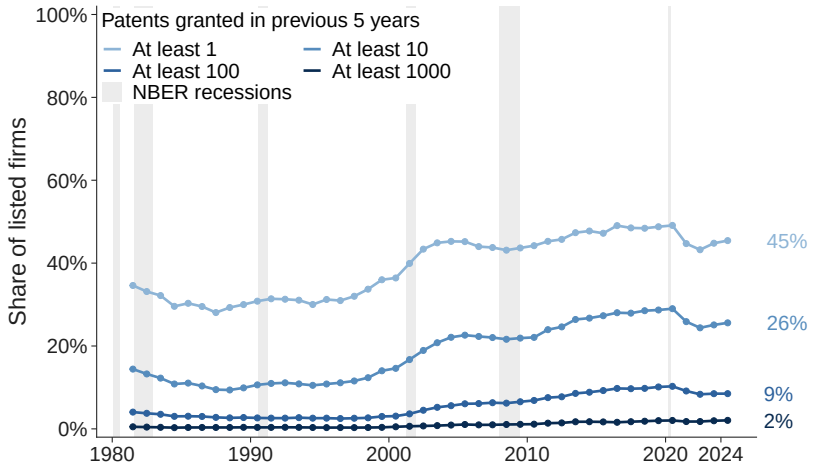
Notes: The nonutility estimation sample contains 11.6 million firm-dates over 1981–2024. Panel A describes the 0.7 million firm-dates with positive own grants (6 percent of the sample). Panel B uses patent exposures: sums of other firms' log one plus grants, weighted by predetermined links. Observed and positive exposures are percentages of all firm-dates; the third column is the fraction of positively exposed firm-dates without an own grant. Appendix A reports additional statistics and construction.

TABLE A4: Distributions of exposures to patent news

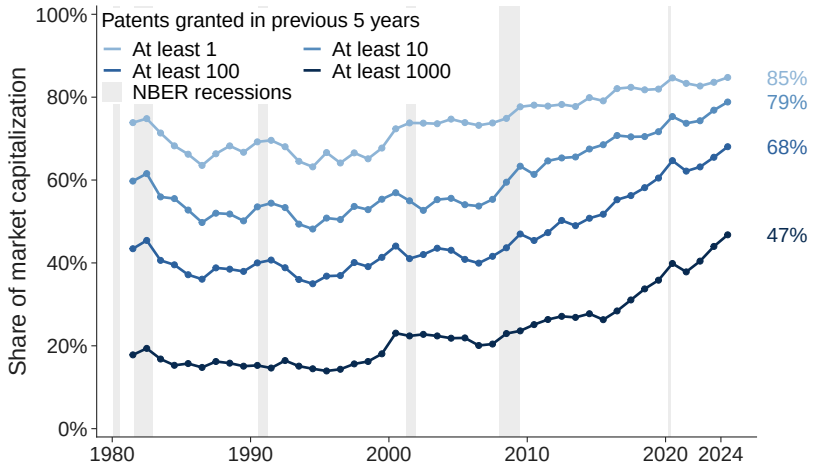
	Mean	SD	10th pct.	Median	90th pct.
Panel A: Patent-count regressors					
Own log activity	0.07	0.34	0.00	0.00	0.00
Technology	22.88	29.83	1.46	12.49	58.98
Rivalry	14.09	23.29	0.00	3.41	42.18
Suppliers (×1,000)	0.97	21.79	0.00	0.00	0.00
Customers (×1,000)	47.93	210.97	0.00	0.00	23.62
Panel B: Claim-count regressors					
Own log activity	0.21	0.88	0.00	0.00	0.00
Technology	62.22	77.92	4.08	34.85	157.60
Rivalry	40.49	65.34	0.00	10.07	127.02
Suppliers (×1,000)	2.57	52.90	0.00	0.00	0.00
Customers (×1,000)	108.18	452.87	0.00	0.00	62.13

Notes: Firm-date statistics on the common nonutility return-estimation sample, 1981–2024. Returns are three-day Fama-French abnormal returns, winsorized as in the main regressions, in basis points. Equity is nominal prior-close listed capitalization. Book-to-market excludes unavailable observations. Own activity is log one plus patents or claims; external exposures use equation (2). SDs are pooled descriptive standard deviations, distinct from the within-date scales used to report regression coefficients.

A.2 Patenting Participation and Grant Distributions



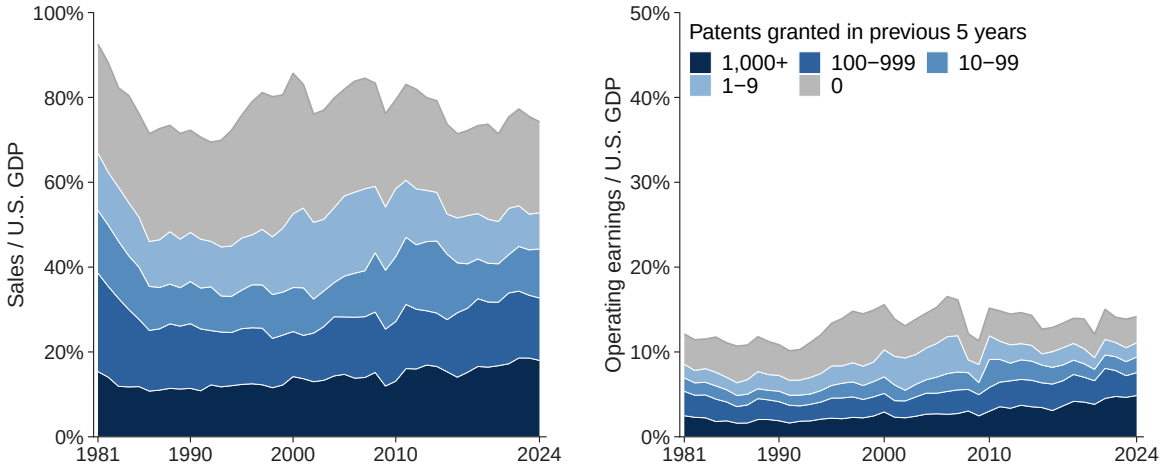
(a) Share of listed firms



(b) Share of market capitalization

FIGURE A1: Patenting participation and market capitalization

Notes: Annual June observations, 1981–2024, for ordinary common-stock companies on the NYSE, AMEX, and Nasdaq. The curves use nested thresholds for grants during the preceding five completed calendar years: at least 1, 10, 100, or 1,000 patents. They therefore differ from the mutually exclusive bands in Table 1. Each share divides by the corresponding total among linked June companies. Shading marks NBER recessions.

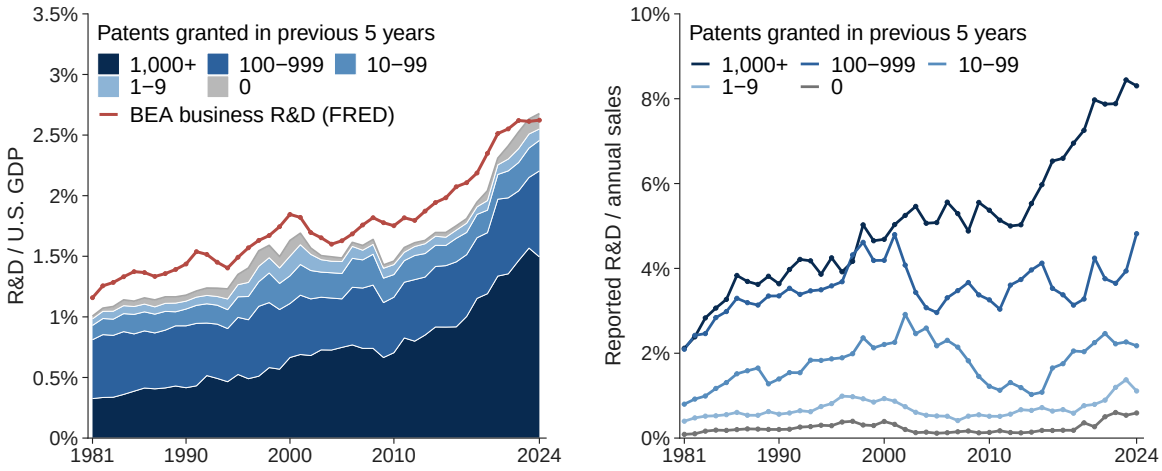


(a) Sales relative to GDP

(b) Operating earnings relative to GDP

FIGURE A2: Listed firms' sales and operating earnings relative to GDP

Notes: 1981–2024; listed ordinary-common-stock firms, excluding ADRs. Worldwide Compustat sales and EBITDA are scaled by U.S. GDP. Mutually exclusive bands use grants in the preceding five years. Financial firms and utilities are included.

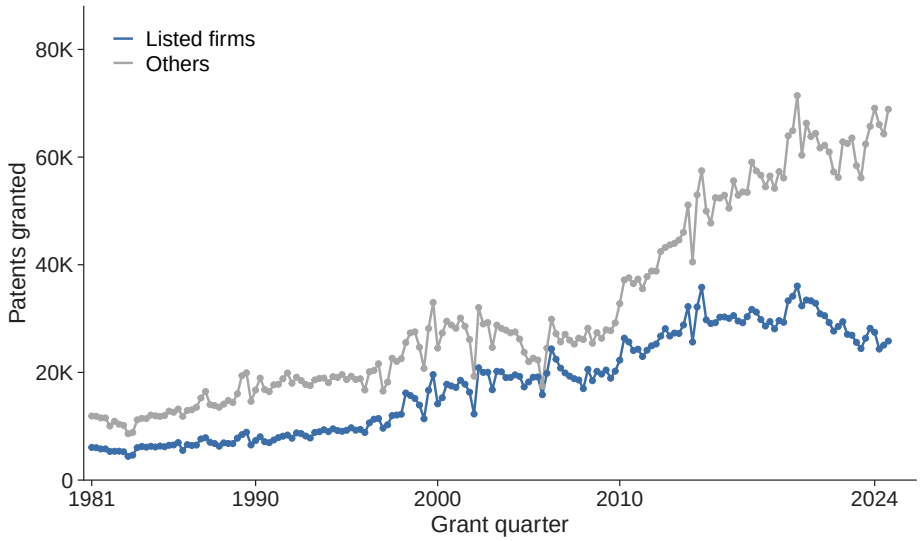


(a) R&D relative to GDP

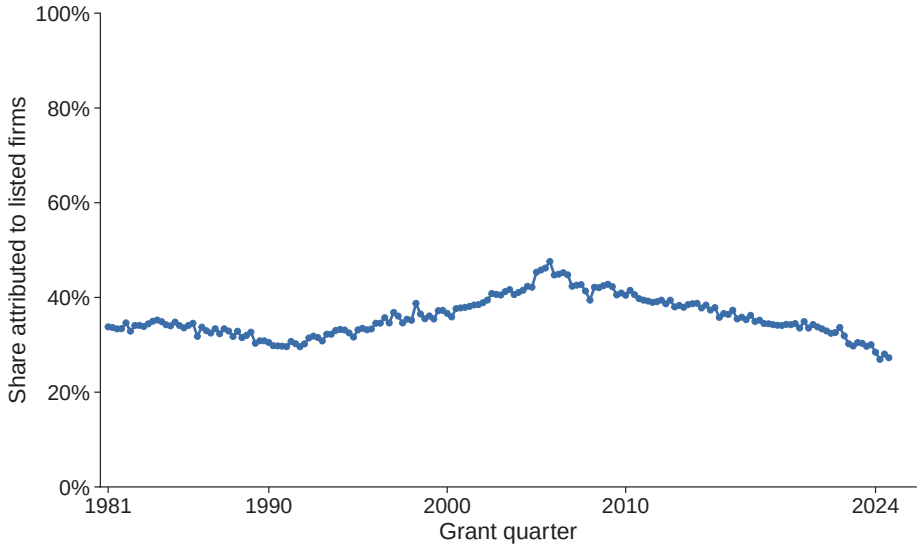
(b) R&D relative to sales

FIGURE A3: Reported R&D by patenting activity

Notes: Same firms and patent bands as Figure A2. Stacks show worldwide reported Compustat R&D; the red line shows BEA domestic business R&D investment (FRED). Panel (b) divides each band's reported R&D by its total observed sales; missing R&D is not imputed.



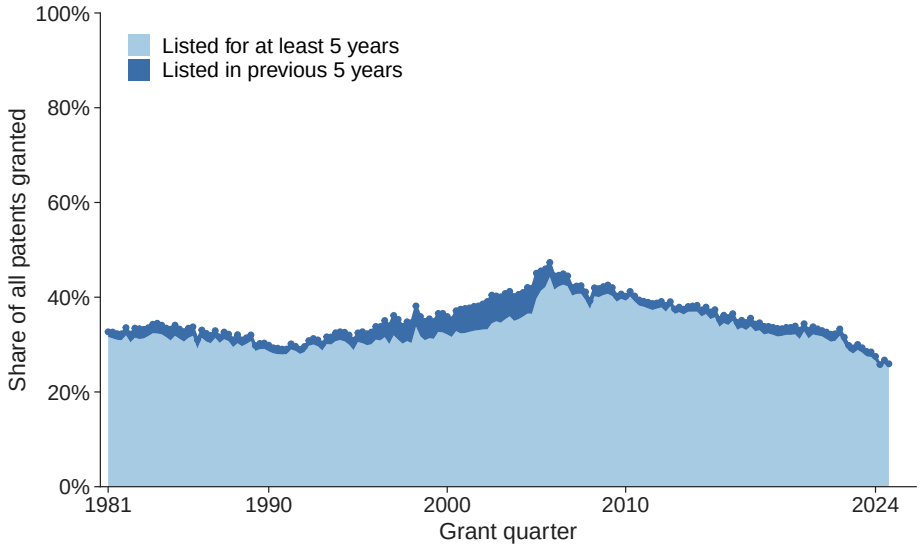
(a) Patent grants



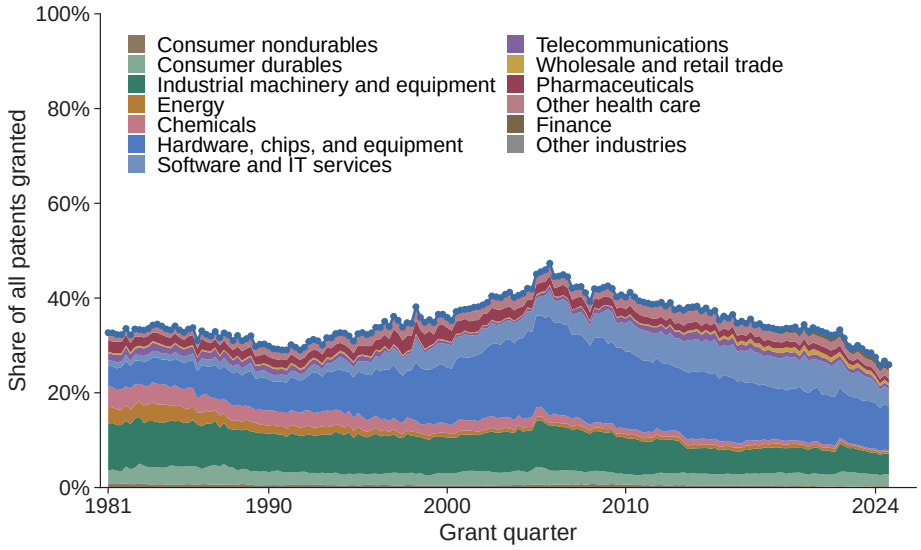
(b) Share of patents granted to listed firms

FIGURE A4: Patent grants and coverage of listed companies

Notes: Quarterly counts and shares of nonwithdrawn U.S. utility and design patent grants, 1981–2024. *Listed firms* denotes the nonutility listed corporate sample. Grants without an identified assignee remain in the total patent denominator and are attributed to *Others*.



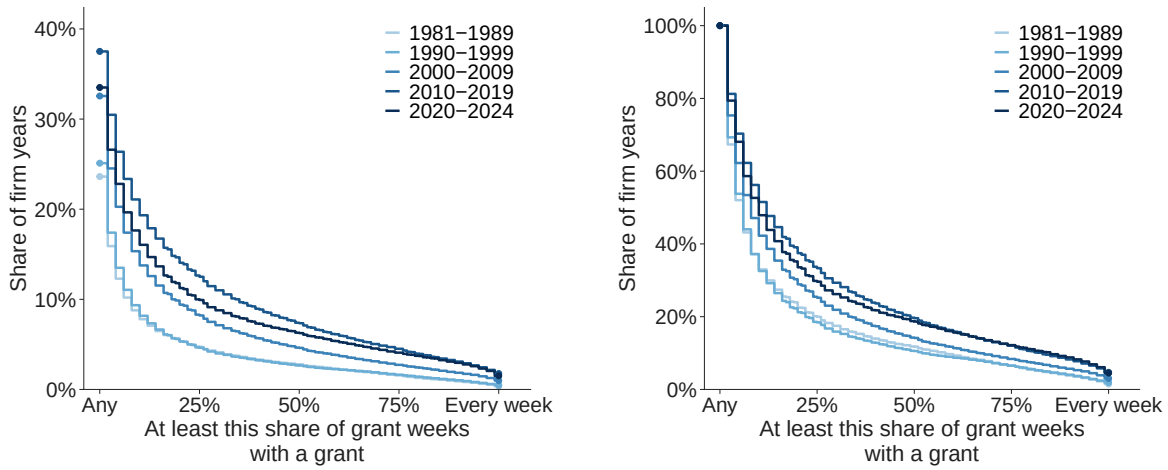
(a) By time since listing



(b) By industry

FIGURE A5: Listed companies' patent share by listing age and industry

Notes: Each area is a share of all patents granted in the quarter, 1981–2024. The areas sum to the share attributed to nonutility study companies listed on the NYSE, AMEX, or Nasdaq at the grant date. Panel (a) distinguishes companies listed within the previous five years from those listed for at least five years. Panel (b) uses the dated operating-industry classification and the common reporting groups in Appendix C.2, separating hardware from software and pharmaceuticals from other healthcare. Other contains residual and unavailable classifications; utilities are excluded.

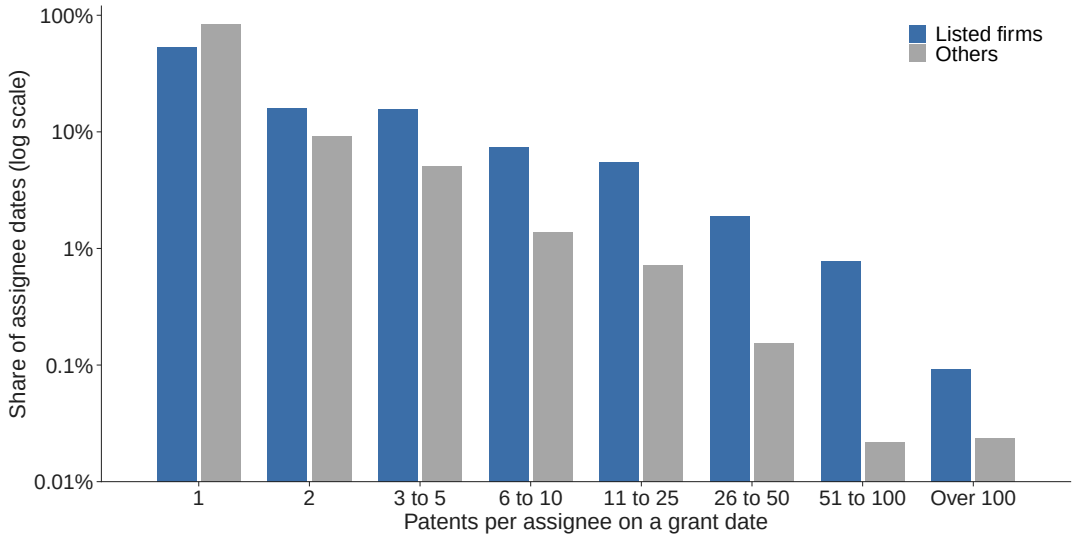


(a) All study-company firm-years

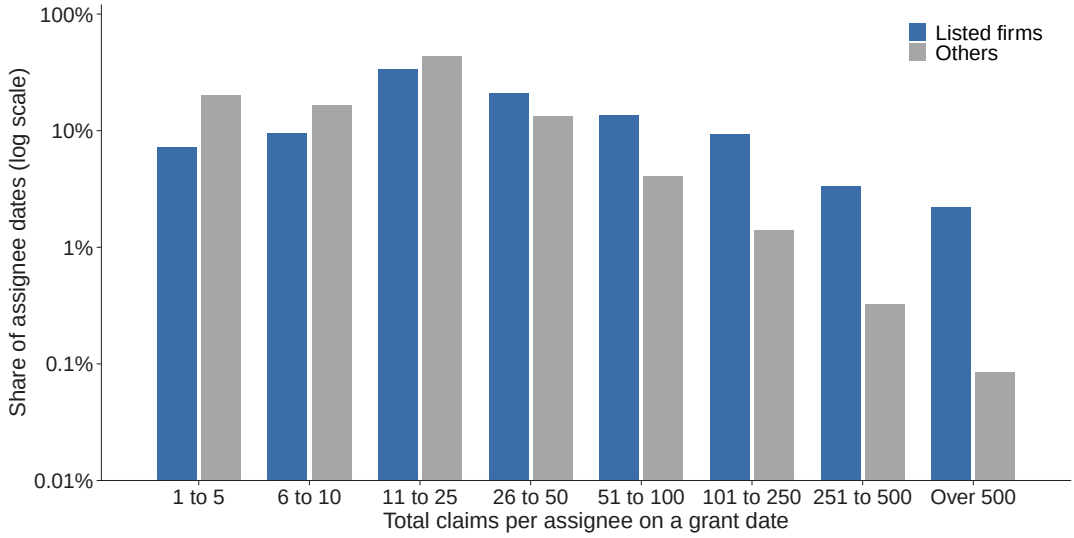
(b) Study-company firm-years with at least one grant

FIGURE A6: The frequency of patent grants across decades

Notes: The fixed union of study companies, retaining dated nonutility firm-years with complete 52- or 53-week coverage, 1981–2024; firm-years are equally weighted within each period. The horizontal axis provides the fraction of grant weeks with at least one patent; the vertical axis provides the share of firm-years meeting or exceeding that frequency. The left panel includes all complete study-company firm-years; the right conditions on at least one grant. The final period is 2020–2024. Grants on multiple dates in the same Monday–Sunday week are combined. These are repeated cross-sections, rather than a balanced panel of firms.



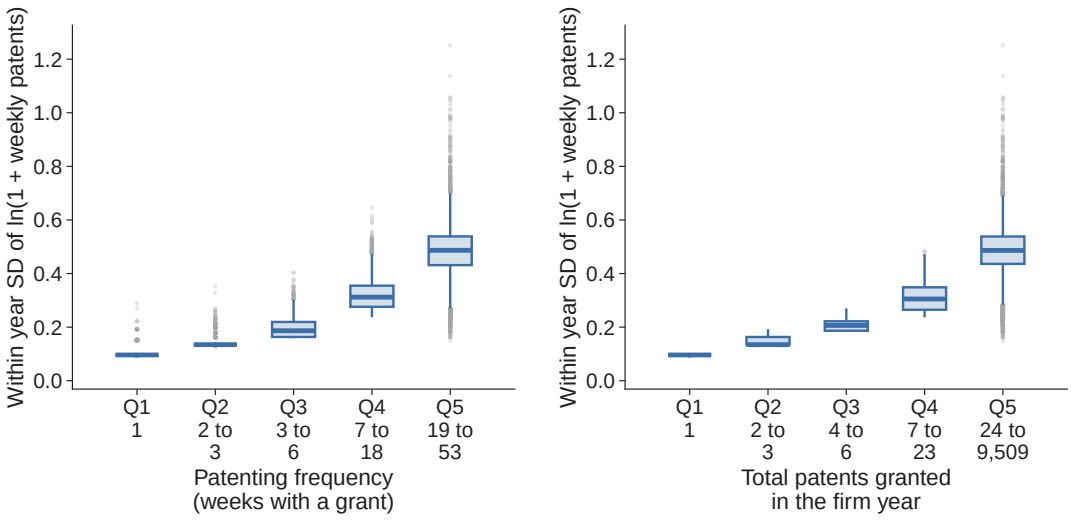
(a) Patents



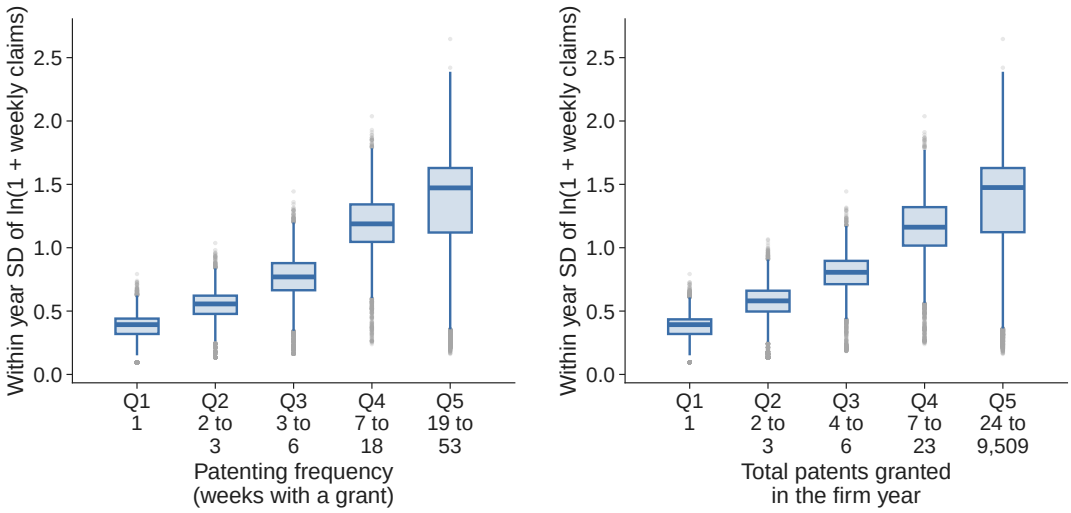
(b) Total claims

FIGURE A7: The distribution of grant-batch size

Notes: Pooled shares of identified firm- or assignee-date observations with positive patent grants, 1981–2024. Listed firms is the fixed reference-design company group; Others comprises the remaining identified holders. Each group's bars divide by its own pooled observation count, rather than averaging date-specific shares. The vertical axis is logic. Total claims sum the claims on all patents assigned to a holder on that grant date. Zero-grant dates are excluded; a jointly assigned patent can enter multiple holders' portfolios.



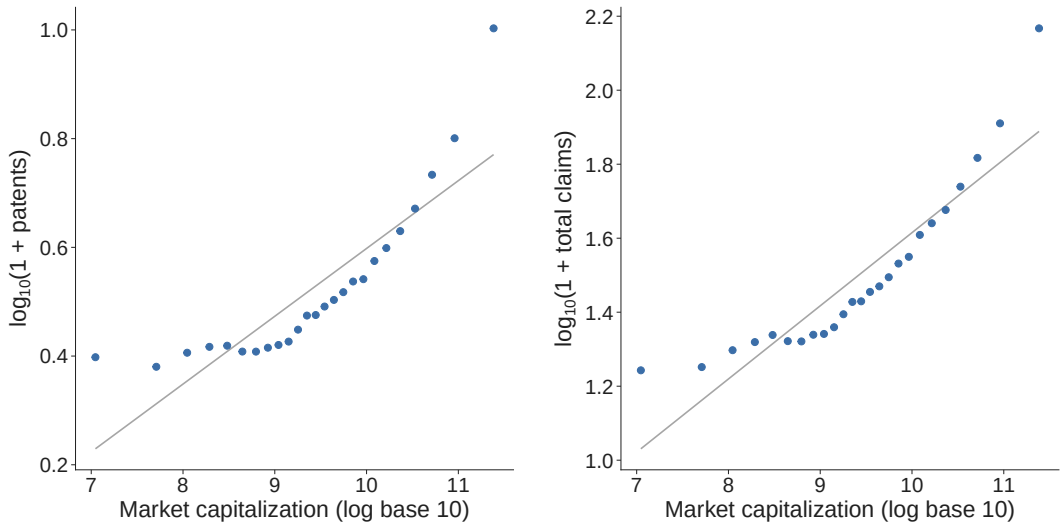
(a) Patents



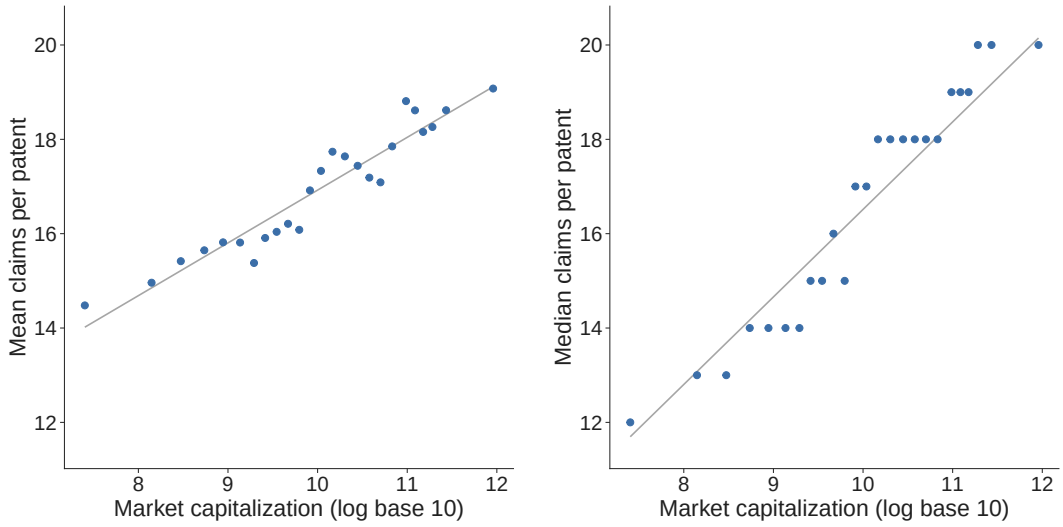
(b) Claims

FIGURE A8: Weekly activity dispersion by patenting frequency and annual patent volume

Notes: Each observation is a complete firm-year with at least one grant, 1981–2024. Dispersion is the within-year sample standard deviation of ln(1 + weekly activity), using all 52 or 53 weeks, including zero-grant weeks. Left panels group firm-years by pooled quintiles of the share of weeks with a grant; right panels use pooled quintiles of total annual patents. Ties stay together, and both patents and claims use the same groups. Boxes show the interquartile range and median; whiskers extend to the last observation within 1.5 interquartile ranges. Remaining observations appear as points. The frequency comparison does not hold annual volume fixed, nor does the volume comparison hold frequency fixed; neither removes common date effects.



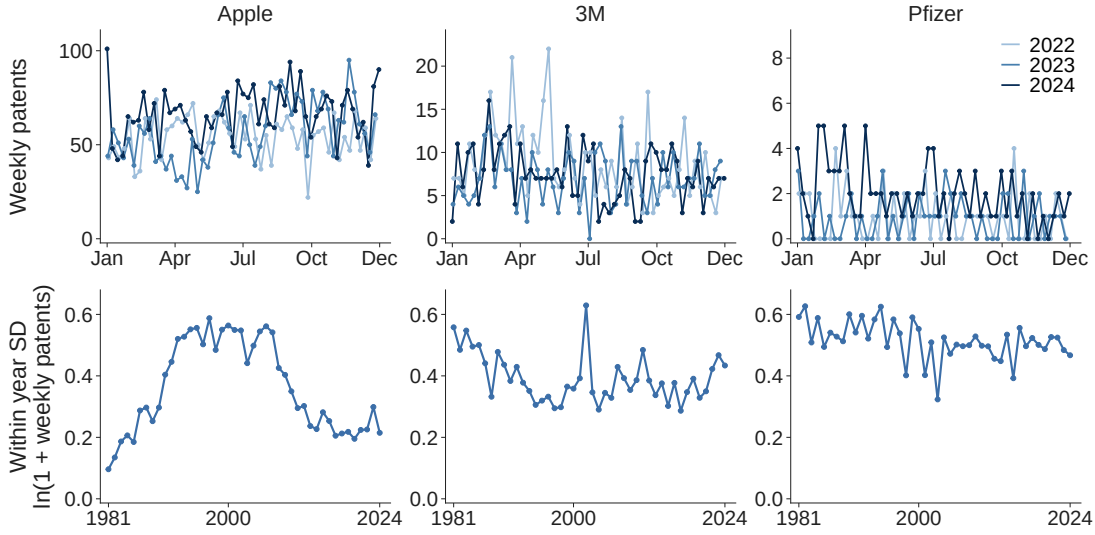
(a) Patent and claim activity on grant dates



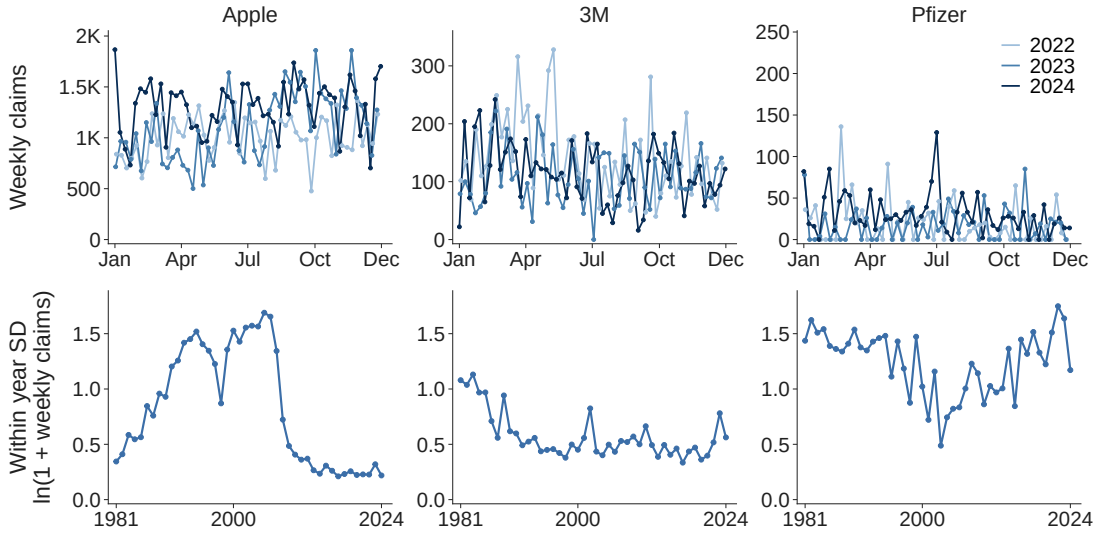
(b) Mean and median claims per patent

FIGURE A9: Patent activity, claims, and firm size

Notes: Listed reference-design firms with observed prior-close market capitalization, 1981–2024. Panel (a) provides means in 25 capitalization bins of positive-grant firm-dates, with OLS lines fitted to the individual observations. Panel (b) uses individual patents and 25 capitalization bins; the mean line is OLS and the median line is a linear median regression on individual patents. Capitalization is in nominal dollars on a base-10 logarithmic scale. Panel (a) also transforms patent and total claim counts using $\log_{10}(1+x)$; claims per patent in panel (b) remain in levels. No fixed effects are removed.



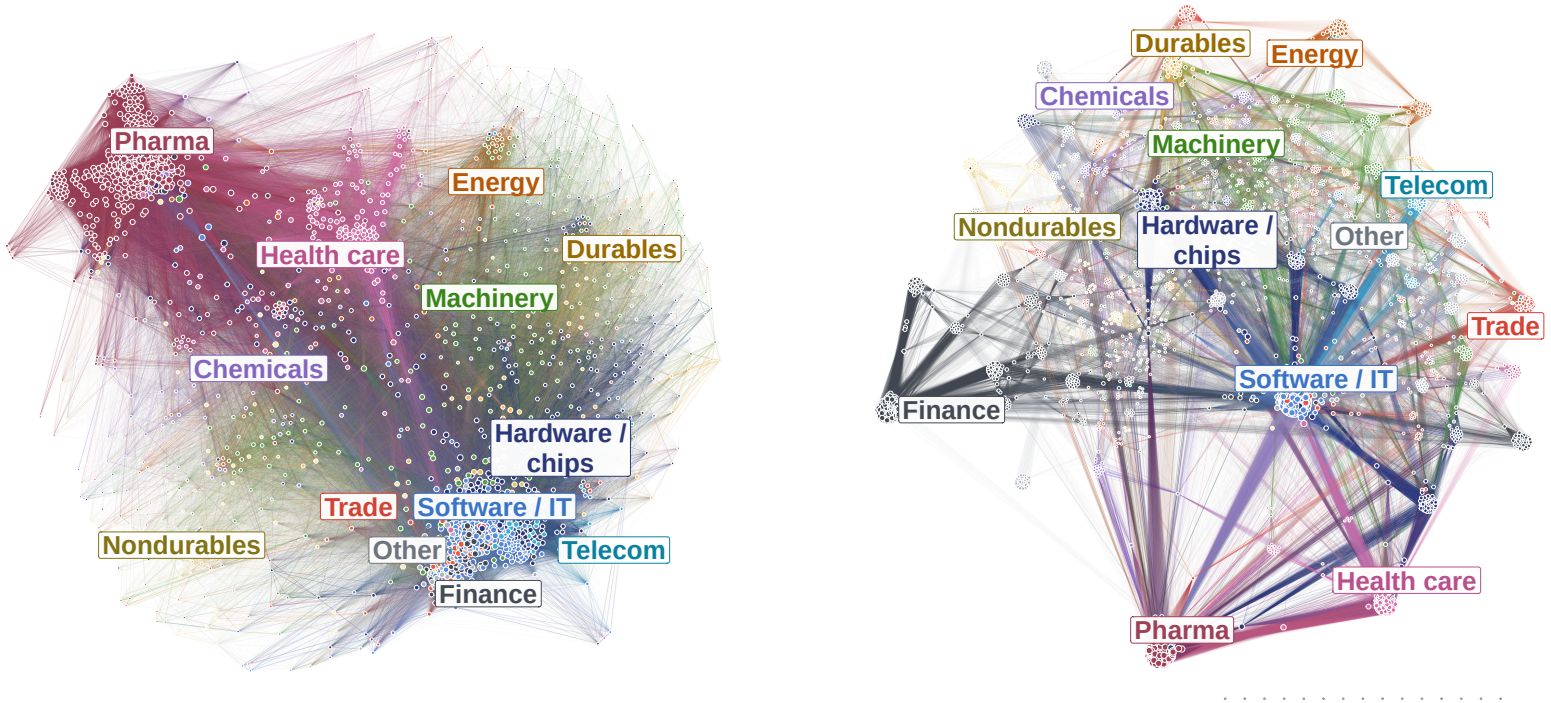
(a) Patents



(b) Claims

FIGURE A10: Weekly patent activity and within-year dispersion

Notes: Illustrations for Apple, 3M, and Pfizer. Upper panels overlay raw weekly counts in 2022, 2023, and 2024; the 53rd week of 2024 is retained, and vertical scales differ across firms. Lower panels report each firm's annual standard deviation of ln(1 + weekly activity), using all weeks of complete patenting firm-years, including zero-grant weeks. Years with no patents or incomplete coverage appear as gaps. These examples illustrate variation within firms and do not hold annual activity or common date effects fixed.

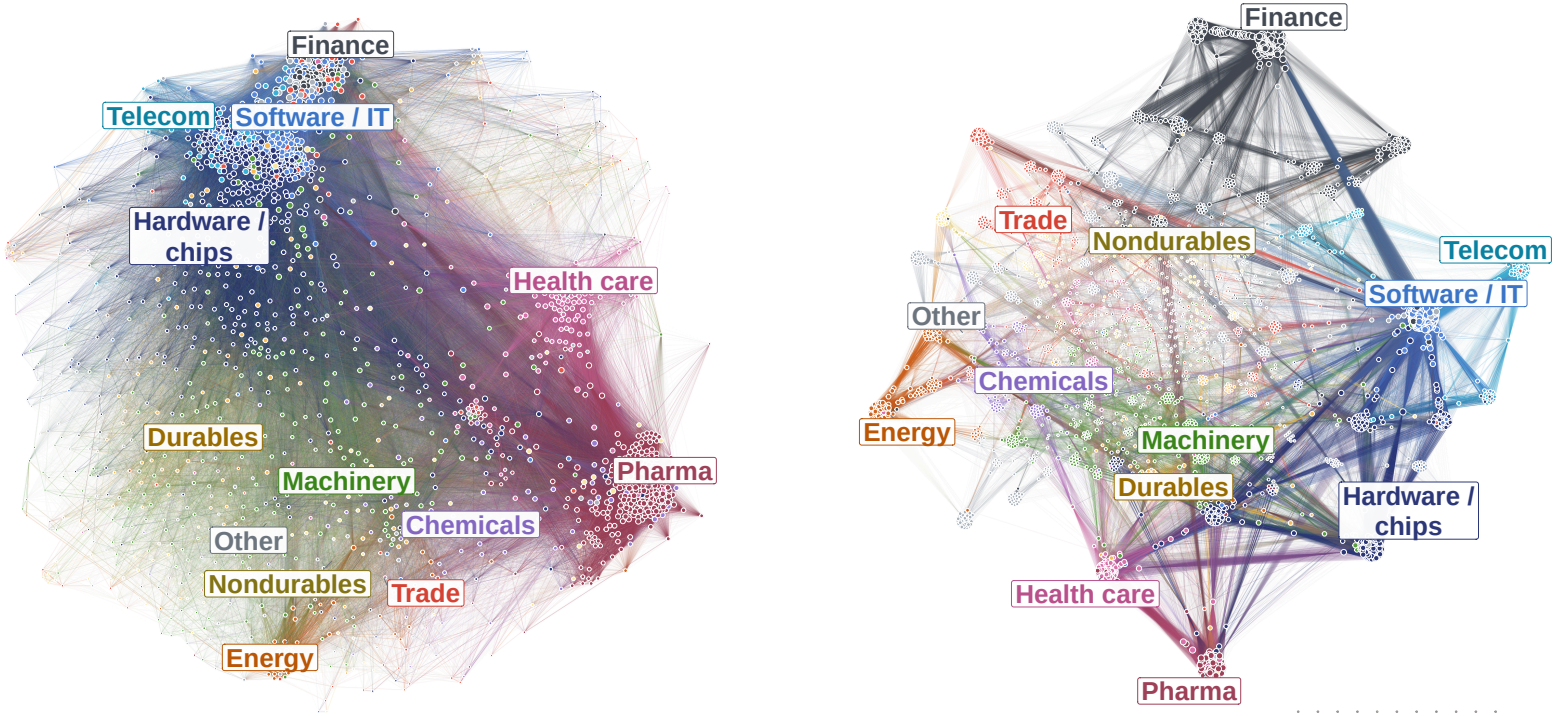


(a) Technology

(b) Product-market rivalry

FIGURE A11: Technology and product-market rivalry, 2024

Notes: Nonutility firms with observed five-year profiles. Rivalry uses each reported segment's primary SIC3, supplemented by company-industry allocations. Sector colors use current company classifications. All positive links are retained; edge opacity follows similarity and colors blend the endpoint sectors. Node area follows square-root weighted degree, with a visibility floor. Both networks and all years use identical layout settings without sector-based positioning. Unavailable profiles are omitted; observed isolates remain at the margin.

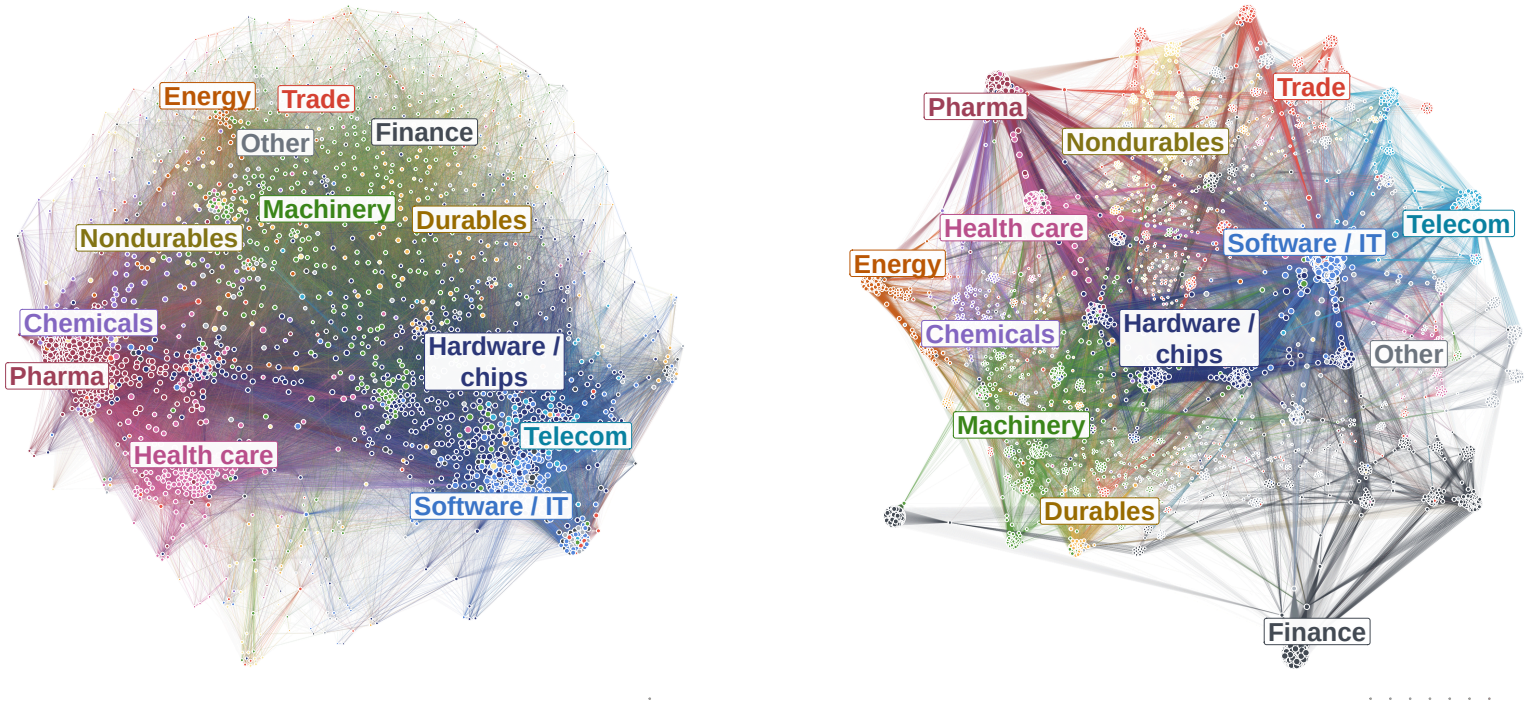


(a) Technology

(b) Product-market rivalry

FIGURE A12: Technology and product-market rivalry, 2014

Notes: Nonutility firms with observed five-year profiles. Rivalry uses each reported segment's primary SIC3, supplemented by company-industry allocations. Sector colors use current company classifications. All positive links are retained; edge opacity follows similarity and colors blend the endpoint sectors. Node area follows square-root weighted degree, with a visibility floor. Both networks and all years use identical layout settings without sector-based positioning. Unavailable profiles are omitted; observed isolates remain at the margin.

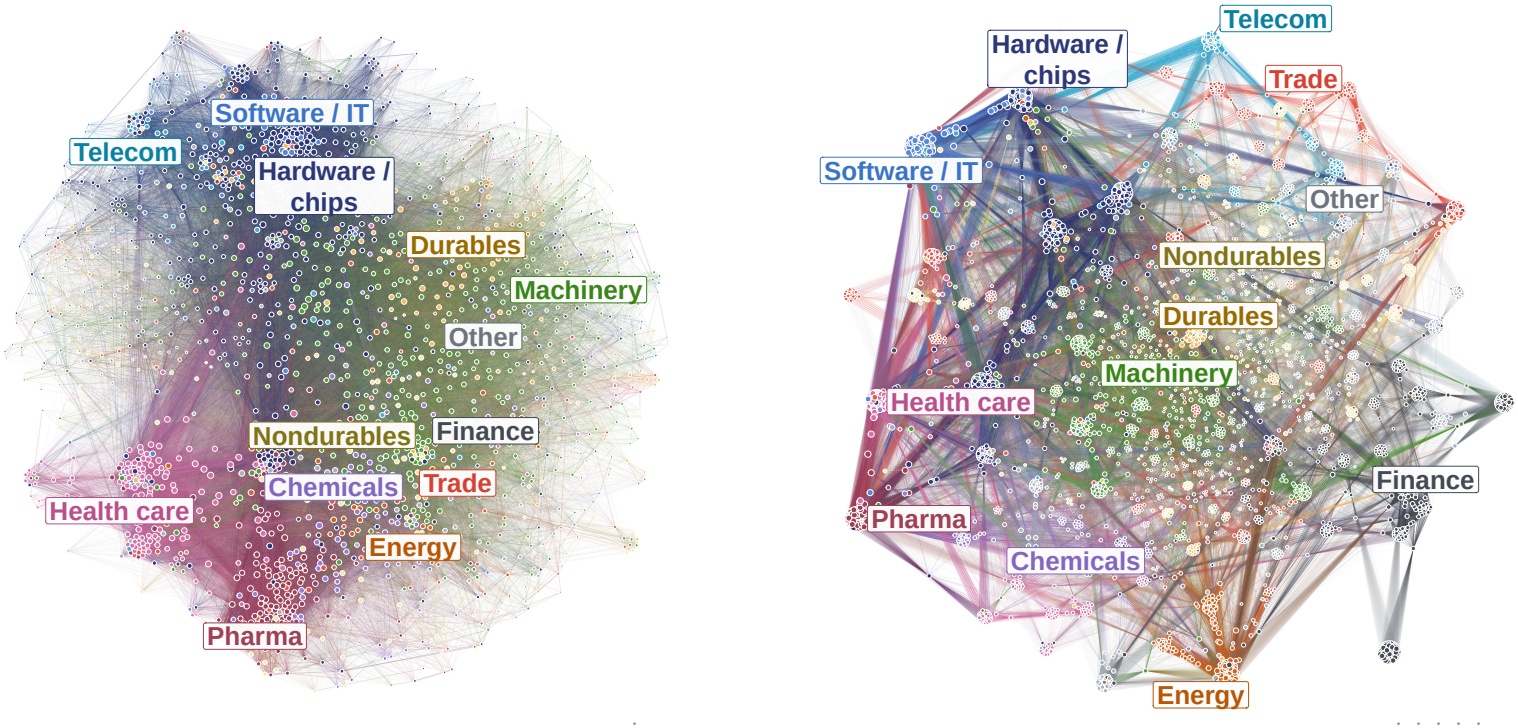


(a) Technology

(b) Product-market rivalry

FIGURE A13: Technology and product-market rivalry, 2004

Notes: Nonutility firms with observed five-year profiles. Rivalry uses each reported segment's primary SIC3, supplemented by company-industry allocations. Sector colors use current company classifications. All positive links are retained; edge opacity follows similarity and colors blend the endpoint sectors. Node area follows square-root weighted degree, with a visibility floor. Both networks and all years use identical layout settings without sector-based positioning. Unavailable profiles are omitted; observed isolates remain at the margin.

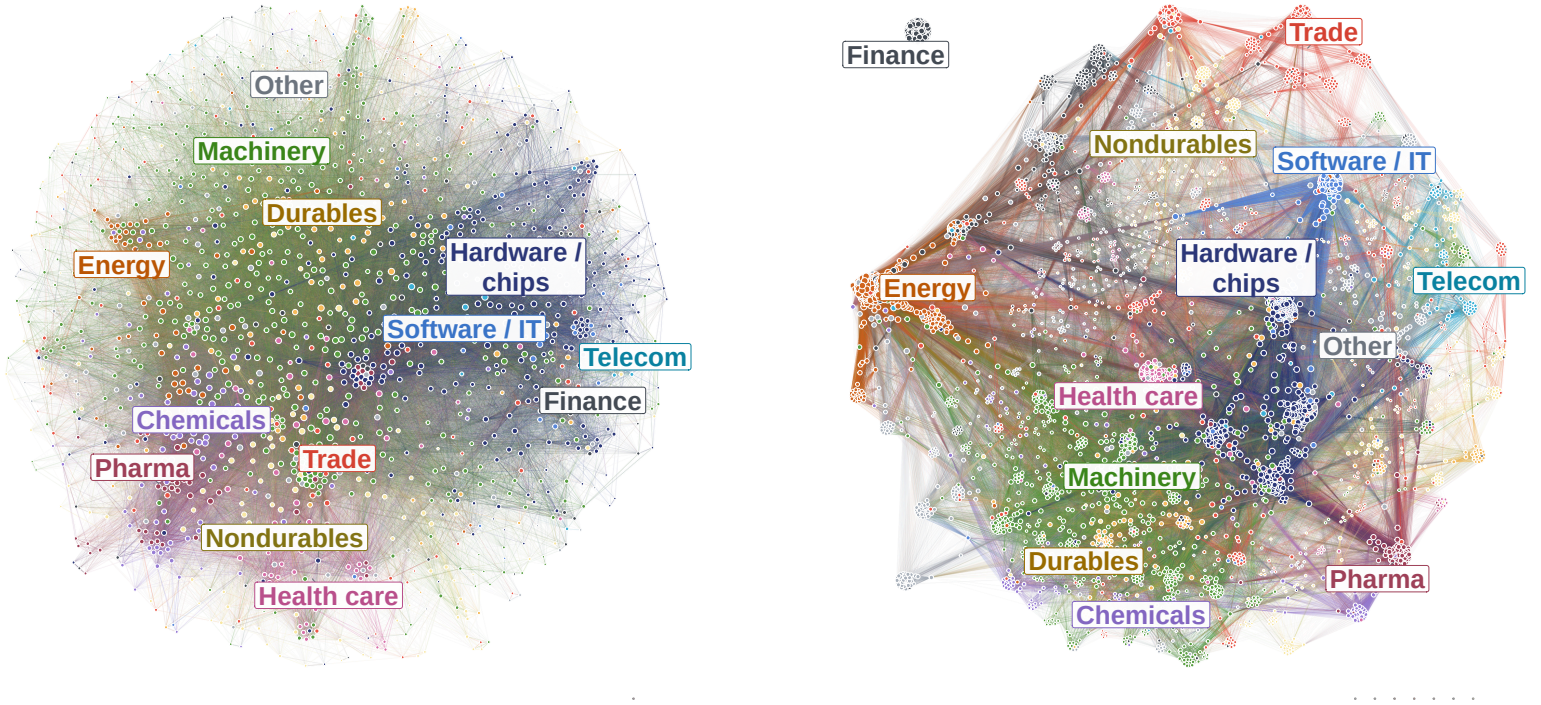


(a) Technology

(b) Product-market rivalry

FIGURE A14: Technology and product-market rivalry, 1994

Notes: Nonutility firms with observed five-year profiles. Rivalry uses each reported segment's primary SIC3, supplemented by company-industry allocations. Sector colors use current company classifications. All positive links are retained; edge opacity follows similarity and colors blend the endpoint sectors. Node area follows square-root weighted degree, with a visibility floor. Both networks and all years use identical layout settings without sector-based positioning. Unavailable profiles are omitted; observed isolates remain at the margin.



(a) Technology

(b) Product-market rivalry

FIGURE A15: Technology and product-market rivalry, 1984

Notes: Nonutility firms with observed five-year profiles. Rivalry uses each reported segment's primary SIC3, supplemented by company-industry allocations. Sector colors use current company classifications. All positive links are retained; edge opacity follows similarity and colors blend the endpoint sectors. Node area follows square-root weighted degree, with a visibility floor. Both networks and all years use identical layout settings without sector-based positioning. Unavailable profiles are omitted; observed isolates remain at the margin.

B Returns, estimation, and specification comparisons

I construct abnormal returns for each firm's dated primary return security using a 252-trading-day estimation window with at least 100 observations ending ten trading days before the grant date. The window rolls with each daily-return date, including the three dates in an event window. The ten-session gap excludes recent returns from the benchmark. Returns must be observed on all three trading days of the event window, and the window must end before the next Tuesday grant batch. I winsorize the three-day abnormal returns at the 0.5th and 99.5 percentiles of the eligible firm-date distribution in each grant year.

The baseline control vector contains log prior-close listed capitalization, log book-to-market and its missingness indicator, four own prior-return measures, and four analogous measures for each network channel. The lagged windows are trading days $[-5,-1]$, $[-10,-6]$, $[-30,-11]$, and $[-63,-31]$. Together they span the preceding quarter, allowing short-term return reversal over the most recent trading week to differ from broader momentum over the preceding three months. Peer prior-return controls weight peers' prior returns using their bilateral network weights.

For the industry return control, companies are assigned to their two-digit SIC groups, and the receiver's own company is excluded from the prior-capitalization-weighted portfolio. For the CPC technology-portfolio controls, I construct separate portfolio returns for granting and nongranting firms within each CPC subclass, weighting each source firm by the product of its CPC share and prior-close capitalization (excluding the receiver). Subclass returns are then aggregated using the receiver's own CPC shares, renormalized over observed class support, with separate indicators for unavailable granting and nongranting portfolios:

$$\text{CPC shares}_{it} \cdot \frac{\sum_{j \neq i} \text{CPC shares}_{jt} V_{jt^-} r_{j,[-5,-1]}}{\sum_{j \neq i} \text{CPC shares}_{jt} V_{jt^-}}$$

where CPC shares_{it} is the vector of shares of firm i's patents in each technology class over the five calendar years preceding the year of date t (renormalized over classes with observed portfolio returns), and V_{it^-} is firm i's market capitalization at the close of the trading day before date t. Here $r_{j,[-5,-1]}$ is the source firm's return over the five trading days before t. The second factor, computed class by class, is the capitalization-weighted prior return in each technology class, and the first factor is firm i's portfolio exposure to those classes. Computing this index separately for firms that receive patents on date t and for firms that do not allows prior technology-portfolio returns to differ between firms granting on date t and other firms.

TABLE B1: Sequential controls and an equal-weight network placebo

Dependent variable: three-day abnormal return

	(1) Basic	(2) Firm and prior	(3) Lagged portfolios	(4) Network controls	(5a) Equal weights	(5b) Equal weights	(6) Current returns
Panel A: Patents							
Own activity	0.82	2.44	2.43	2.25	3.11	3.18	2.30
	(0.25)	(0.26)	(0.26)	(0.26)	(0.27)	(0.35)	(0.24)
Technology	1.79	3.36	3.36	5.08	1.45	2.55	4.03
	(0.44)	(0.43)	(0.43)	(0.97)	(0.37)	(1.20)	(0.79)
Rivals	−0.85	−2.42	−2.42	−3.65	−1.49	−2.16	−3.23
	(0.70)	(0.65)	(0.65)	(0.97)	(0.60)	(0.95)	(0.83)
Suppliers	0.15	0.00	0.00	0.03	−0.07	−0.06	0.04
	(0.14)	(0.13)	(0.13)	(0.13)	(0.20)	(0.18)	(0.13)
Customers	−0.05	−0.09	−0.09	−0.10	−0.07	−0.08	−0.04
	(0.24)	(0.26)	(0.26)	(0.26)	(0.28)	(0.27)	(0.25)
R^2	0.01	0.01	0.01	0.02	0.01	0.02	0.02
Panel B: Claims							
Own activity	1.00	2.82	2.82	2.63	3.40	3.58	2.68
	(0.26)	(0.25)	(0.25)	(0.24)	(0.26)	(0.33)	(0.23)
Technology	1.75	3.35	3.35	5.47	1.68	3.71	4.33
	(0.44)	(0.42)	(0.42)	(1.07)	(0.36)	(1.32)	(0.86)
Rivals	−0.96	−2.62	−2.61	−4.23	−1.85	−3.03	−3.71
	(0.73)	(0.66)	(0.66)	(1.01)	(0.63)	(0.99)	(0.87)
Suppliers	0.20	0.04	0.04	0.06	−0.06	−0.04	0.08
	(0.15)	(0.14)	(0.14)	(0.14)	(0.22)	(0.21)	(0.14)
Customers	−0.09	−0.18	−0.17	−0.15	−0.16	−0.15	−0.08
	(0.25)	(0.27)	(0.27)	(0.27)	(0.28)	(0.28)	(0.26)
R^2	0.01	0.01	0.01	0.02	0.01	0.02	0.02
Date effects and coverage	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm and prior returns	No	Yes	Yes	Yes	Yes	Yes	Yes
Lagged industry/CPC	No	No	Yes	Yes	Yes	Yes	Yes
Network sums × date	No	No	No	Yes	No	Yes	Yes
Current industry/CPC	No	No	No	No	No	No	Yes
Firms	23,697	23,697	23,697	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295	2,295	2,295	2,295

Notes: Pooled estimates, 1981–2024, on identical sample. Firm controls include lagged size, book-to-market; prior own and peer returns span one quarter. Lagged industry/CPC returns use the preceding five trading days. Column (4) adds technology and rivalry network sums interacted with date. Columns (5a) and (5b) equalize connected-link weights, preserving each receiver's total weight. Column (6) adds contemporaneous leave-one-out industry and granting/nongranting CPC returns to column (4). Coefficients and two-way firm-and-date clustered SEs are basis points per within-date exposure SD from Table 2, column (3).

TABLE B2: Sequential channels and the technology–rivalry interaction

Dependent variable: three-day abnormal return

	(1) Own	(2) + Technology	(3) + Rivalry	(4) + Supply chain	(5) + Tech./rivalry	(6) Full	(7) + Interaction
Panel A: Patents							
Own activity	2.65 (0.28)	2.13 (0.25)	2.85 (0.27)	2.65 (0.28)	2.25 (0.26)	2.25 (0.26)	2.23 (0.26)
Technology	—	3.60 (1.06)	—	—	5.08 (0.97)	5.08 (0.97)	1.53 (0.95)
Rivals	—	—	−2.10 (1.03)	—	−3.66 (0.97)	−3.65 (0.97)	−4.40 (1.03)
Suppliers	—	—	—	0.04 (0.13)	—	0.03 (0.13)	0.02 (0.13)
Customers	—	—	—	−0.19 (0.27)	—	−0.10 (0.26)	−0.06 (0.26)
Tech. × rivalry	—	—	—	—	—	—	3.87 (0.88)
R^2	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Panel B: Claims							
Own activity	2.98 (0.27)	2.49 (0.24)	3.20 (0.26)	2.97 (0.27)	2.64 (0.24)	2.63 (0.24)	2.63 (0.24)
Technology	—	3.88 (1.13)	—	—	5.47 (1.07)	5.47 (1.07)	1.67 (1.03)
Rivals	—	—	−2.79 (1.05)	—	−4.24 (1.01)	−4.23 (1.01)	−4.90 (1.07)
Suppliers	—	—	—	0.07 (0.14)	—	0.06 (0.14)	0.06 (0.14)
Customers	—	—	—	−0.29 (0.27)	—	−0.15 (0.27)	−0.10 (0.27)
Tech. × rivalry	—	—	—	—	—	—	4.17 (0.96)
R^2	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Lagged return controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Network sums × date	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firms	23,697	23,697	23,697	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295	2,295	2,295	2,295

Notes: Pooled three-factor abnormal return estimates, 1981–2024, with the full lagged controls and network-by-date effects in Table B1, column (4). Columns (2)–(5) add the indicated channels to own activity; column (6) includes all five. Column (7) adds $\sum_{j \neq i} \text{Network}^{T}_{ijt} \times \text{Network}^{R}_{ijt} \times \text{Grants}_{jt}$ and its matching network sum interacted with date. Main-channel coefficients use the within-date SD from Table 2, column (3); the interaction uses its own SD. Parentheses report two-way firm-and-date clustered SEs.

B.1 Common ownership and return spillovers

Shared investors may incorporate news about connected firms before a patent is granted, or change how firms respond to one another's innovations. I measure these connections using institutional holdings reported in WRDS 13F data. For grants in year t, I use September holdings from $t-1$, selecting the latest WRDS file version dated no later than December of that year. The resulting ownership profiles remain fixed during year t. Holdings are matched to the same companies used for patent attribution through dated CRSP securities and CCM links. I align share quantities and prices for stock splits and sum a manager's matched common-share positions within each company. The denominator covers full company common equity, including nontraded common classes, rather than only the listed class used to measure returns. All matched reporting managers enter. I exclude ADRs as both sources and receivers to keep common comparison.

Common ownership measures the fraction of two companies' combined equity held by investors who hold both. Let $\text{Holdings}_{mi,t-1}$ denote manager m's dollar position in company i, and let $\mathcal{M}_{ij,t-1}$ contain managers with positive positions in both i and j. The pair weight is

$$\text{Ownership}_{ij,t} = \frac{\sum_{m \in \mathcal{M}_{ij,t-1}} (\text{Holdings}_{mi,t-1} + \text{Holdings}_{mj,t-1})}{\text{Common equity}_{i,t-1} + \text{Common equity}_{j,t-1}}.$$

For two observed profiles, the weight is zero when no manager holds both firms. Unavailable profiles are not interpreted as observed zero overlap. Ownership exposure combines these predetermined connections with grants at the connected firms:

$$\text{Ownership exposure}_{i\tau} = \sum_{j \neq i} \text{Ownership}_{ij,t} \log(1 + \text{Grants}_{j\tau}).$$

Grants denotes patents or their total claims on date τ in year t. The technology interaction replaces the pair weight in this sum with technology proximity times common ownership; the rivalry interaction uses rivalry times common ownership.

In Table B3, I separate ownership exposure from the economic networks on identical observations. The four columns include own activity with ownership, own activity with the four peer channels, both sets together, and their technology and rivalry interactions. Every column retains the lagged return controls, date effects, and the same coverage and network-by-date controls. Standard errors are clustered by company and date.

TABLE B3: Common ownership and return spillovers

Dependent variable: three-day abnormal return

	(1) Own + ownership	(2) Own + peers	(3) Own + peers + ownership	(4) All + interactions
Panel A: Patents				
Own activity	9.36	11.18	8.78	9.00
	(0.91)	(0.88)	(0.88)	(0.93)
Technology	—	0.27	0.27	0.49
		(0.06)	(0.06)	(0.10)
Rivalry	—	−0.22	−0.19	−0.41
		(0.06)	(0.06)	(0.09)
Common-owner exposure	1.25	—	1.25	1.24
	(0.06)		(0.06)	(0.06)
Technology × ownership	—	—	—	−0.81
				(0.27)
Rivalry × ownership	—	—	—	0.90
				(0.27)
Panel B: Claims				
Own activity	3.52	4.10	3.36	3.38
	(0.34)	(0.32)	(0.32)	(0.34)
Technology	—	0.11	0.11	0.18
		(0.02)	(0.02)	(0.04)
Rivalry	—	−0.09	−0.08	−0.15
		(0.02)	(0.02)	(0.03)
Common-owner exposure	0.47	—	0.47	0.47
	(0.02)		(0.02)	(0.02)
Technology × ownership	—	—	—	−0.28
				(0.11)
Rivalry × ownership	—	—	—	0.31
				(0.10)
Supplier/customer exposures	No	Yes	Yes	Yes
Lagged controls	Yes	Yes	Yes	Yes
Coverage and network-by-date controls	Yes	Yes	Yes	Yes
Firms	22,563	22,563	22,563	22,563
Dates	2,295	2,295	2,295	2,295

Notes: Pooled estimates, 1981–2024; ADRs excluded as sources and receivers. Coefficients are basis points per unit of log activity or network-weighted log activity. Peers comprise technology, rivalry, suppliers and customers. Ownership weights divide common 13F managers' combined dollar holdings in two firms by their combined full common-equity values. Prior-September holdings use WRDS file dates no later than the preceding December. Interactions multiply the ownership and economic-network weights before applying source grant activity. All columns use the same observations, lagged controls from Table 2, column (3), date effects, and ownership-coverage and network-by-date controls; unavailable profiles are flagged. Parentheses report standard errors clustered two ways, by firm and date.

B.2 Lagged return controls and alternative exposure measures

Dollar accounting uses the pooled headline coefficients in raw exposure units. Table B4 reports these coefficients, underlying columns (3) and (6) of Table 2, alongside the Fama-MacBeth estimates. Tables B6–B8 keep these lagged controls while varying source activity or network proximity. Utilities are excluded; financial firms remain included. Coefficients below are in basis points per unit of the stated exposure, rather than per standard deviation.

The Fama-MacBeth regressions fit a separate cross-section on each retained grant date and take the equal-weighted mean of the date-specific slopes. To identify coefficients, I require at least five distinct granting suppliers connected by positive measured links to receivers. This rule retains 2,295 dates over the sample period. Table B4 reports raw slopes, the exposure standard deviations used to standardize them, and Newey-West standard errors with 52 lags on the full weekly grant calendar.

TABLE B4: Unstandardized headline estimates and Fama–MacBeth comparison

Dependent variable: three-day abnormal return

	Patents		Claims	
	Pooled	Fama–MacBeth	Pooled	Fama–MacBeth
Own activity	6.579	5.820	3.028	2.581
	(0.754)	(1.107)	(0.280)	(0.437)
Technology	0.245	0.251	0.100	0.111
	(0.047)	(0.073)	(0.020)	(0.030)
Rivals	−0.171	−0.232	−0.071	−0.094
	(0.045)	(0.081)	(0.017)	(0.031)
Suppliers	1.406	8.142	1.217	2.161
	(6.083)	(15.384)	(2.697)	(6.336)
Customers	−0.465	−0.703	−0.353	−0.364
	(1.287)	(1.566)	(0.617)	(0.723)
R^2	0.02	—	0.02	—
Firms	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295

Notes: 1981–2024. Raw coefficients in basis points per unit of log activity or network-weighted log activity. All five channels enter jointly with the lagged return controls in Table 2, column (3). Pooled estimates include date effects and date-specific coefficients on technology and rivalry network sums and unavailable technology history; Fama–MacBeth uses their cross-sectional counterparts. Returns are capped at annual 0.5th/99.5th percentiles. Parentheses report two-way firm-and-date clustered SEs for pooled estimates and Newey–West SEs with 52 lags for Fama–MacBeth. Exposure SDs, in row order, are (0.342, 20.752, 21.392, 0.021, 0.204) for patents and (0.870, 54.670, 59.897, 0.052, 0.439) for claims. They pool deviations from grant-date means before residualizing on controls. Multiplying each coefficient and SE by its exposure SD gives the standardized estimates.

TABLE B5: Heterogeneity by receiver size

Dependent variable: three-day abnormal return

Receiver size	Bottom 50%	50–90%	90–98%	Top 2%
Panel A: Patents				
Own activity	9.627	9.190	5.210	1.926
	(2.350)	(1.278)	(1.019)	(0.978)
Technology	0.294	0.262	0.167	0.197
	(0.049)	(0.045)	(0.047)	(0.049)
Rivals	−0.145	−0.227	−0.236	−0.191
	(0.049)	(0.050)	(0.062)	(0.071)
Suppliers	35.845	10.833	−11.714	−0.776
	(32.803)	(8.195)	(9.954)	(12.097)
Customers	5.856	−6.626	−14.069	−0.146
	(1.839)	(1.822)	(4.993)	(8.660)
Panel B: Claims				
Own activity	4.021	3.780	2.052	0.849
	(0.781)	(0.387)	(0.401)	(0.483)
Technology	0.123	0.107	0.072	0.082
	(0.020)	(0.019)	(0.019)	(0.020)
Rivals	−0.060	−0.094	−0.094	−0.070
	(0.018)	(0.019)	(0.023)	(0.024)
Suppliers	11.771	3.930	−5.520	−0.407
	(9.058)	(3.253)	(4.689)	(5.413)
Customers	2.795	−3.565	−7.660	−1.155
	(0.855)	(0.863)	(2.495)	(4.092)
Firms in group	19,197	14,473	2,690	547
Firms in joint regression	23,697	23,697	23,697	23,697
Dates in joint regression	2,295	2,295	2,295	2,295

Panel C: Dollar accounting	Patents		Claims	
	Common slopes	Size-specific slopes	Common slopes	Size-specific slopes
Private value ($ trillion)	32.66	12.22	33.49	12.23
Technology value ($ trillion)	56.22	44.92	61.17	50.06
Net external value ($ trillion)	34.32	17.51	35.69	20.41
Net external/private	1.051	1.433	1.066	1.669
Technology retained (%)	100.0	79.9	100.0	81.8

Notes: Pooled three-factor abnormal returns, 1981–2024; unstandardized coefficients in basis points. Size groups use prior-close equity; firms may change groups. All five coefficients vary by size, with group-by-date effects and the controls and sample of Table 2, column (3). Dollar values, in 2025 dollars, use the corresponding size-group coefficients. Technology retained is a percentage of its value under common coefficients. Parentheses report two-way firm/date clustered SEs.

TABLE B6: Alternative measurements of patent news

Dependent variable: three-day abnormal return

	Log	Binary	Asinh	Counts
Panel A: Patents				
Own activity	6.5792	10.8372	5.4085	0.2535
	(0.7536)	(0.9858)	(0.5977)	(0.0908)
Technology	0.2450	0.4613	0.1969	0.0360
	(0.0469)	(0.0881)	(0.0377)	(0.0067)
Rivals	−0.1706	−0.3061	−0.1376	−0.0164
	(0.0454)	(0.0649)	(0.0361)	(0.0084)
Suppliers	1.4057	6.2666	1.3418	0.1953
	(6.0835)	(12.0444)	(4.8980)	(0.7960)
Customers	−0.4651	−3.1123	−0.4079	−0.0125
	(1.2870)	(2.7864)	(1.0516)	(0.1333)
R^2	0.02	0.02	0.02	0.02
Panel B: Claims				
Own activity	3.0277	10.8372	2.6061	0.0166
	(0.2805)	(0.9858)	(0.2392)	(0.0050)
Technology	0.1000	0.4613	0.0872	0.0020
	(0.0195)	(0.0881)	(0.0170)	(0.0004)
Rivals	−0.0706	−0.3061	−0.0614	−0.0009
	(0.0169)	(0.0649)	(0.0144)	(0.0005)
Suppliers	1.2166	6.2666	1.1306	0.0086
	(2.6970)	(12.0444)	(2.3555)	(0.0411)
Customers	−0.3530	−3.1123	−0.3344	0.0005
	(0.6174)	(2.7864)	(0.5406)	(0.0074)
R^2	0.02	0.02	0.02	0.02
Firms	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295

Notes: Pooled three-factor abnormal return estimates, 1981–2024, with the lagged controls in Table 2, column (3) and network-by-date effects. Apply each transformation before aggregation: in $X^c_{it} = \sum_{j \neq i} \text{Network}^c_{ijt} \times \text{Grants}_{jt}$, the column's transformation of firm j's activity G on date t replaces Grants_{jt}. Networks, observations and controls are identical across columns. Slopes and two-way firm-and-date clustered SEs are basis points per unit of transformed exposure. A zero-to-one own-activity change multiplies the coefficient by $\log 2$, 1, asinh(1) and 1, respectively. Patent and claim indicators coincide on this sample.

TABLE B7: Alternative technology and product-market proximity

Dependent variable: three-day abnormal return

	Technology comparison		Rivalry comparison	
	CPC cosine	Mahalanobis	Sales cosine	Structural
Panel A: Patents				
Own activity	5.675	5.643	6.462	6.888
	(0.742)	(0.743)	(0.750)	(0.753)
Technology	0.201	0.173	0.231	0.227
	(0.054)	(0.047)	(0.045)	(0.048)
Rivals	−0.174	−0.184	−0.136	−6.245
	(0.046)	(0.046)	(0.045)	(1.132)
Suppliers	2.530	2.251	0.743	1.213
	(6.104)	(6.052)	(6.118)	(5.842)
Customers	−0.589	−0.572	−0.421	−0.058
	(1.278)	(1.277)	(1.284)	(1.292)
R^2	0.02	0.02	0.02	0.02
Panel B: Claims				
Own activity	2.708	2.700	3.001	3.226
	(0.280)	(0.280)	(0.279)	(0.278)
Technology	0.083	0.071	0.095	0.090
	(0.023)	(0.020)	(0.019)	(0.020)
Rivals	−0.072	−0.075	−0.058	−3.670
	(0.017)	(0.017)	(0.017)	(0.549)
Suppliers	1.494	1.380	0.958	0.965
	(2.710)	(2.702)	(2.713)	(2.655)
Customers	−0.417	−0.382	−0.320	−0.150
	(0.611)	(0.610)	(0.617)	(0.621)
R^2	0.02	0.02	0.02	0.02
Firms	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295

Notes: Pooled three-factor abnormal return estimates, 1981–2024; raw coefficients in basis points. Within each pair, observations and controls are identical, including both networks' sums, coverage flags, and lagged peer returns. Mahalanobis similarity sums, over every pair of CPC fields, the product of the two firms' Euclidean-normalized shares in the two fields times the fields' co-occurrence. Structural rivalry sums, over three-digit SIC industries, the share of firm i's sales made in the industry times firm j's share of the industry's sales, using dated segment-sales allocations and the primary-industry fallback (Section 3.2). Baseline and structural rivalry both pool five years of sales reports available before the grant year; self-exposure is excluded. Network scales differ across columns. Parentheses report two-way firm-and-date clustered SEs.

TABLE B8: Patent citations replacing or supplementing technology similarity

Dependent variable: three-day abnormal return

	Baseline	Patent citations		Patents + applications	
	Baseline	Replace	Add	Replace	Add
Panel A: Patents					
Own activity	6.528	7.828	6.530	7.812	6.528
	(0.748)	(0.766)	(0.748)	(0.764)	(0.748)
Technology	0.220	—	0.219	—	0.221
	(0.047)		(0.046)		(0.046)
Citations	—	5.272	0.224	5.721	−0.191
		(2.326)	(1.963)	(2.657)	(2.300)
Rivals	−0.173	−0.134	−0.174	−0.134	−0.173
	(0.045)	(0.046)	(0.045)	(0.046)	(0.045)
Suppliers	1.658	2.311	1.641	2.269	1.672
	(5.976)	(5.629)	(5.972)	(5.632)	(5.976)
Customers	−0.532	−0.603	−0.533	−0.605	−0.530
	(1.286)	(1.290)	(1.287)	(1.290)	(1.287)
R^2	0.02	0.02	0.02	0.02	0.02
Panel B: Claims					
Own activity	2.985	3.453	2.985	3.449	2.985
	(0.279)	(0.290)	(0.279)	(0.290)	(0.279)
Technology	0.091	—	0.088	—	0.089
	(0.020)		(0.019)		(0.019)
Citations	—	3.415	0.742	3.606	0.522
		(1.338)	(1.143)	(1.497)	(1.304)
Rivals	−0.072	−0.058	−0.072	−0.058	−0.072
	(0.017)	(0.017)	(0.017)	(0.017)	(0.017)
Suppliers	1.327	1.603	1.295	1.588	1.303
	(2.663)	(2.583)	(2.660)	(2.584)	(2.661)
Customers	−0.385	−0.470	−0.386	−0.470	−0.386
	(0.616)	(0.620)	(0.616)	(0.619)	(0.616)
R^2	0.02	0.02	0.02	0.02	0.02
Firms	23,697	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295	2,295

Notes: Pooled three-factor abnormal return estimates, 1981–2024; raw coefficients in basis points. A receiver's prior citations to a source measure the knowledge link. Weights divide citations to that source by all eligible U.S.-document citations; self-exposure is excluded. The combined measure consolidates patent and application targets by application. All columns use identical observations, lagged controls in Table 2, column (3), and both citation definitions' network sums, coverage flags, and lagged peer returns. Replace substitutes citations for baseline technology exposure; Add includes both. Parentheses report two-way firm-and-date clustered SEs.

B.3 Supplementing Compustat with FactSet supply chain data

TABLE B9: Return spillovers with FactSet supply-chain links

Dependent variable: three-day abnormal return

	Pooled		Fama-MacBeth	
	Compustat	+ FactSet	Compustat	+ FactSet
Panel A: Patents				
Own activity	6.579	6.544	5.820	5.806
	(0.754)	(0.753)	(1.107)	(1.108)
Technology neighbors	0.245	0.245	0.251	0.252
	(0.047)	(0.047)	(0.073)	(0.073)
Rivals	−0.171	−0.170	−0.232	−0.232
	(0.045)	(0.045)	(0.081)	(0.081)
Suppliers	1.406	−0.095	8.142	9.506
	(6.083)	(5.557)	(15.384)	(15.350)
Customers	−0.465	−0.539	−0.703	−0.350
	(1.287)	(1.221)	(1.566)	(1.498)
Full controls	Yes	Yes	Yes	Yes
Panel B: Claims				
Own activity	3.028	3.015	2.581	2.578
	(0.280)	(0.280)	(0.437)	(0.437)
Technology neighbors	0.100	0.100	0.111	0.112
	(0.020)	(0.019)	(0.030)	(0.030)
Rivals	−0.071	−0.070	−0.094	−0.094
	(0.017)	(0.017)	(0.031)	(0.031)
Suppliers	1.217	0.013	2.161	2.861
	(2.697)	(2.504)	(6.336)	(6.290)
Customers	−0.353	−0.455	−0.364	−0.242
	(0.617)	(0.591)	(0.723)	(0.697)
Firms	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295

Notes: Three-factor abnormal return estimates, 1981–2024; raw coefficients in basis points. FactSet adds dated supplier and customer links and updates their prior-return controls. The receiver sample, annual return caps, own and horizontal exposures, and other controls are fixed. Return controls follow Table 2, column (3). All five channels enter jointly, with date effects and horizontal network sums interacted with date in pooled regressions, and corresponding network-sum controls within each Fama–MacBeth cross-section. Parentheses report two-way firm-and-date clustered SEs for pooled estimates and Newey–West SEs with 52 lags for Fama–MacBeth.

B.4 Factor returns comparisons

TABLE B10: Alternative return models

Dependent variable: three-day abnormal return

	Pooled			Fama-MacBeth		
	Market factor	3 factor	6 factor	Market factor	3 factor	6 factor
Panel A: Patents						
Own	2.16	2.25	2.36	1.75	1.99	2.09
	(0.29)	(0.26)	(0.25)	(0.35)	(0.38)	(0.36)
Technology	5.38	5.08	4.78	4.77	5.21	5.08
	(1.14)	(0.97)	(0.92)	(1.49)	(1.51)	(1.56)
Rivals	−3.25	−3.65	−3.79	−3.55	−4.97	−4.82
	(1.22)	(0.97)	(0.91)	(1.70)	(1.74)	(1.70)
Suppliers	0.06	0.03	0.00	0.12	0.17	0.17
	(0.13)	(0.13)	(0.13)	(0.29)	(0.33)	(0.34)
Customers	−0.02	−0.10	−0.10	−0.12	−0.14	−0.12
	(0.27)	(0.26)	(0.26)	(0.33)	(0.32)	(0.33)
Panel B: Claims						
Own	2.59	2.63	2.71	2.06	2.24	2.31
	(0.28)	(0.24)	(0.24)	(0.36)	(0.38)	(0.36)
Technology	5.80	5.47	5.17	5.46	6.08	6.07
	(1.24)	(1.07)	(1.01)	(1.61)	(1.62)	(1.67)
Rivals	−3.83	−4.23	−4.31	−4.16	−5.64	−5.59
	(1.30)	(1.01)	(0.94)	(1.79)	(1.83)	(1.77)
Suppliers	0.10	0.06	0.05	0.02	0.11	0.09
	(0.14)	(0.14)	(0.15)	(0.30)	(0.33)	(0.34)
Customers	−0.04	−0.15	−0.13	−0.11	−0.16	−0.15
	(0.28)	(0.27)	(0.27)	(0.33)	(0.32)	(0.33)
Firms	23,697	23,697	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295	2,295	2,295

Notes: Three-day abnormal returns, 1981–2024. The three-factor model adds size and value to the market factor; the six-factor model also adds profitability, investment, and momentum. All five channels and lagged controls from Table 2, column (3) enter throughout. Entries are basis points per within-date SD of the corresponding pooled sample. SEs are two-way clustered by firm and date (pooled) or Newey–West with 52 lags (Fama–MacBeth).

B.5 Alternative return windows

TABLE B11: Alternative return windows

Dependent variable: Three-factor abnormal return

	Pooled			Fama-MacBeth		
	1 day	3 days	To Monday	1 day	3 days	To Monday
Panel A: Patents						
Own activity	0.59	2.25	3.95	0.52	1.99	3.58
	(0.13)	(0.26)	(0.38)	(0.15)	(0.38)	(0.48)
Technology	1.22	5.08	6.48	1.49	5.21	5.66
	(0.54)	(0.97)	(1.26)	(0.72)	(1.51)	(1.82)
Rivals	−1.74	−3.65	−6.30	−2.22	−4.97	−8.44
	(0.50)	(0.97)	(1.28)	(0.66)	(1.74)	(2.13)
Suppliers	−0.13	0.03	0.02	−0.24	0.17	0.09
	(0.07)	(0.13)	(0.14)	(0.22)	(0.33)	(0.46)
Customers	−0.16	−0.10	−0.41	−0.19	−0.14	−0.43
	(0.16)	(0.26)	(0.31)	(0.19)	(0.32)	(0.40)
R^2	0.01	0.02	0.02	—	—	—
Firms	23,700	23,697	23,695	23,700	23,697	23,695
Dates	2,300	2,295	2,300	2,296	2,295	2,296
Panel B: Claims						
Own activity	0.66	2.63	4.39	0.53	2.24	3.86
	(0.13)	(0.24)	(0.34)	(0.15)	(0.38)	(0.47)
Technology	1.29	5.47	6.98	1.67	6.08	6.98
	(0.60)	(1.07)	(1.38)	(0.77)	(1.62)	(1.99)
Rivals	−2.01	−4.23	−7.13	−2.48	−5.64	−9.46
	(0.51)	(1.01)	(1.34)	(0.71)	(1.83)	(2.30)
Suppliers	−0.17	0.06	0.07	−0.19	0.11	0.28
	(0.10)	(0.14)	(0.17)	(0.21)	(0.33)	(0.45)
Customers	−0.19	−0.15	−0.60	−0.23	−0.16	−0.55
	(0.17)	(0.27)	(0.32)	(0.20)	(0.32)	(0.40)
R^2	0.01	0.02	0.02	—	—	—
Firms	23,700	23,697	23,695	23,700	23,697	23,695
Dates	2,300	2,295	2,300	2,296	2,295	2,296

Notes: Three-factor abnormal returns, 1981–2024, with all five channels and lagged controls from Table 2, column (3). The To Monday window ends before the next grant batch. Entries are basis points per within-date SD of the corresponding pooled sample. SEs are two-way clustered by firm and date (pooled) or Newey–West with 52 lags (Fama–MacBeth).

B.6 Geographic proximity

Nearby research locations may connect firms beyond their technological and product-market proximity. I measure these geographic connections using inventor addresses on patents granted in the five completed years before each news year. The construction adapts the distance weighting of Lychagin et al. (2016) to grant-date returns. Their application relates geographic exposure to R&D stocks and productivity; here the exposure is to current patent or claim activity.

Each historical patent contributes one unit, divided equally among its recorded inventor positions and assigned to the patent's matched company. If two of a patent's three inventors report one location, it receives two-thirds of the patent; the third inventor's location receives one-third. I add these fractional patent counts within each company and location. Dividing by the company's total historical patent count gives its location shares. Thus prolific inventors can contribute through several patents: the measure describes the geography of patented research, rather than the locations of distinct people or current employees. Profiles for news in year t use grants from $t-5$ through $t-1$ and remain fixed throughout year t.

Worldwide locations The first measure averages geographic proximity over the two firms' inventor locations:

$$\text{Worldwide proximity}_{ij,t} = \sum_{a,b} \text{Location share}_{ia,t}\, \text{Location share}_{jb,t}\, 2^{-\text{Distance}_{ab}/200} \tag{B1}$$

Distance is the great-circle distance in kilometres between the recorded coordinates of locations a and b. Proximity equals one at zero distance and halves every 200 kilometres; there is no distance cutoff. Unlocated inventor contributions remain in the share denominator, so observed shares can sum to less than one.

U.S. counties The second measure uses the same distance function between U.S. counties:

$$\text{County proximity}_{ij,t} = \sum_{a,b} \text{County share}_{ia,t}\, \text{County share}_{jb,t}\, 2^{-\text{County distance}_{ab}/200} \tag{B2}$$

Here a county's share is its fractional patent count divided by the firm's total fractional patent count assigned to U.S. inventors. U.S. locations without a matched county remain in this denominator. County identifiers are matched to the Census Bureau's 2020 county representative coordinates. Foreign locations do not enter this measure; the regressions separately control for the fraction of historical inventor contributions located outside the United States and for missing locations.

Normalized U.S. counties The third measure applies the county-share normalization in Lychagin et al. (2016):

$$\text{Normalized county proximity}_{ij,t} = \frac{\text{County proximity}_{ij,t}}{\sqrt{\sum_a \text{County share}_{ia,t}^2}\sqrt{\sum_b \text{County share}_{jb,t}^2}} \tag{B3}$$

The denominator adjusts for how concentrated each firm's research is across counties. With complete location coverage, a firm in one county has a divisor of one; a firm split equally across four counties has a divisor of one-half. The normalization therefore gives relatively more weight to connections between dispersed research portfolios. It changes relative pair weights as well as the unit of exposure, and the normalized measure need not lie below one. Fractional patent weights, rolling histories, and Census county coordinates are adaptations to the present data.

Exposure and controls Each measure enters as exposure to other firms' current grants:

$$\text{Geographic exposure}_{i\tau} = \sum_{j \neq i} \text{Geographic proximity}_{ij,t} \log(1 + \text{Grants}_{j\tau}) \tag{B4}$$

Grants are either the number of patents or their total claims granted to source firm j on date τ in year t. All self-links are excluded. Firms without a usable geographic profile are used in the sample with an explicit missing-profile control.

In the geographic specifications, the geographic network size receives the same treatment as technology and rivalry network size. For each measure I sum its weights over all eligible source firms other than the receiver, including sources without a grant that day. The fully controlled pooled regressions allow this sum, the technology sum, and the rivalry sum to have separate coefficients on every date. Their cross-sectional counterparts enter the Fama-MacBeth regressions.

Tables B12 and B13 separate geographic exposure from overlapping technology and rivalry exposure on the same headline sample. Column (1) includes own activity and geography. Column (2) adds rivalry, supplier and customer exposure; column (3) instead adds technology, supplier and customer exposure. Column (4) includes all five innovation channels and geography. Every column retains the same firm characteristics, prior own and peer returns, lagged industry and CPC returns, and technology, rivalry and geographic network-size and coverage controls. No contemporaneous industry or CPC return enters. Pooled standard errors are two-way clustered by firm and date; Fama-MacBeth standard errors use Newey–West with 52 lags.

In the full specification, technology exposure is positive and rivalry exposure is negative under each geographic measure. The geographic coefficient is imprecise in the pooled estimates under all three constructions. Worldwide geographic exposure is positive in the patent-based Fama-MacBeth estimates but imprecise in the pooled estimates. The comparisons show that the technology and rivalry associations persist after conditioning on research locations.

TABLE B12: Geographic proximity and patent-grant responses: Pooled estimates

Dependent variable: three-day abnormal return

	(1) Own + geography	(2) All except technology	(3) All except rivalry	(4) All + geography
Panel A: Worldwide inventor locations				
Own activity	7.56 (0.80)	8.08 (0.77)	6.17 (0.73)	6.52 (0.74)
Technology	—	—	0.17 (0.05)	0.24 (0.05)
Rivals	—	−0.10 (0.05)	—	−0.17 (0.05)
Suppliers	—	2.98 (5.81)	0.16 (6.29)	1.47 (6.15)
Customers	—	−0.38 (1.28)	−1.38 (1.30)	−0.49 (1.28)
Geography	0.11 (0.08)	0.15 (0.08)	0.02 (0.07)	0.04 (0.07)
Panel B: U.S. county locations				
Own activity	7.32 (0.79)	7.84 (0.76)	5.93 (0.72)	6.25 (0.74)
Technology	—	—	0.17 (0.05)	0.24 (0.05)
Rivals	—	−0.10 (0.05)	—	−0.17 (0.05)
Suppliers	—	2.23 (5.89)	−0.37 (6.36)	0.95 (6.19)
Customers	—	−0.38 (1.28)	−1.34 (1.30)	−0.47 (1.28)
Geography	0.07 (0.06)	0.11 (0.05)	−0.01 (0.05)	0.01 (0.05)
Panel C: Normalized U.S. county locations				
Own activity	6.58 (0.78)	7.09 (0.75)	5.15 (0.71)	5.46 (0.72)
Technology	—	—	0.18 (0.05)	0.25 (0.05)
Rivals	—	−0.10 (0.05)	—	−0.17 (0.05)
Suppliers	—	4.01 (5.84)	1.53 (6.21)	2.81 (6.06)
Customers	—	−0.34 (1.29)	−1.31 (1.31)	−0.42 (1.29)
Geography	0.01 (0.02)	0.02 (0.02)	−0.02 (0.02)	−0.01 (0.02)
Firms	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295

Notes: Patents, 1981–2024; unstandardized coefficients in basis points. Panels compare worldwide, county, and normalized county proximity (Appendix B.6). Each panel holds observations and controls fixed across columns. Controls follow Table 2, column (3), with geographic network-size and coverage controls added. Dashes denote excluded channels. Parentheses report two-way firm/date clustered SEs.

TABLE B13: Geographic proximity and patent-grant responses: Fama–MacBeth estimates

Dependent variable: three-day abnormal return

	(1) Own + geography	(2) All except technology	(3) All except rivalry	(4) All + geography
Panel A: Worldwide inventor locations				
Own activity	5.98 (1.03)	6.51 (1.08)	5.23 (1.00)	5.62 (1.05)
Technology	—	—	0.18 (0.07)	0.24 (0.07)
Rivals	—	−0.20 (0.08)	—	−0.23 (0.08)
Suppliers	—	6.78 (15.07)	6.08 (14.90)	7.87 (15.30)
Customers	—	−0.64 (1.56)	−1.57 (1.54)	−0.67 (1.57)
Geography	0.21 (0.11)	0.20 (0.10)	0.20 (0.11)	0.18 (0.10)
Panel B: U.S. county locations				
Own activity	5.94 (1.06)	6.42 (1.11)	5.23 (1.03)	5.58 (1.08)
Technology	—	—	0.18 (0.07)	0.24 (0.07)
Rivals	—	−0.21 (0.08)	—	−0.23 (0.08)
Suppliers	—	7.82 (14.79)	6.75 (14.65)	8.80 (15.03)
Customers	—	−0.66 (1.56)	−1.59 (1.53)	−0.69 (1.56)
Geography	0.18 (0.12)	0.19 (0.12)	0.19 (0.12)	0.19 (0.12)
Panel C: Normalized U.S. county locations				
Own activity	5.18 (1.02)	5.64 (1.07)	4.47 (0.99)	4.80 (1.04)
Technology	—	—	0.18 (0.07)	0.24 (0.07)
Rivals	—	−0.21 (0.08)	—	−0.24 (0.08)
Suppliers	—	9.98 (14.88)	9.09 (14.71)	11.15 (15.11)
Customers	—	−0.60 (1.55)	−1.54 (1.53)	−0.63 (1.56)
Geography	−0.04 (0.04)	−0.04 (0.04)	−0.05 (0.04)	−0.05 (0.04)
Firms	23,697	23,697	23,697	23,697
Dates	2,295	2,295	2,295	2,295

Notes: Patents, 1981–2024; unstandardized coefficients in basis points. Panels compare worldwide, county, and normalized county proximity (Appendix B.6). Each panel holds observations and controls fixed across columns. Controls follow Table 2, column (3), with geographic network-size and coverage controls added. Dashes denote excluded channels. Parentheses report Newey–West SEs with 52 lags.

C Dollar accounting and sector wise heterogeneity

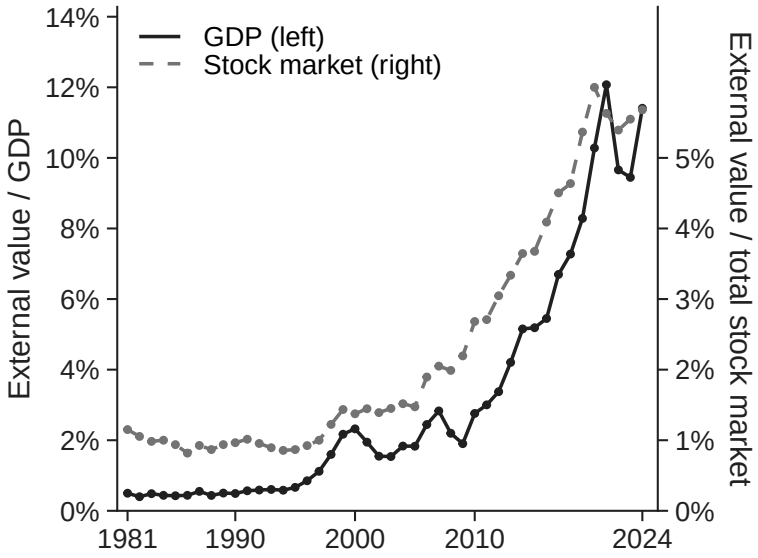


FIGURE C1: External innovation value relative to the U.S. economy

Notes: Patents, 1981–2024. Annual nominal net emitted external value divided by nominal GDP and daily-mean listed capitalization. The market denominator includes utilities and nonpatenting firms.

Table C1 reports cumulative dollars and external-to-private value ratios for patents and claims. I calculate nominal contributions from equation (4), convert each year's contributions to 2025 dollars using the calendar-year CPI deflator, and then sum over years. The CPI reference level is 321.961909. Ratios use these cumulative real-dollar sums. By contrast, the annual valuation-to-GDP ratios in Figures 3 and C1 divide nominal valuation news by nominal GDP in the same year.

TABLE C1: Private and external value: cumulative dollars and ratios

	Patents		Claims	
	Trillions of 2025 dollars	Per dollar of private value	Trillions of 2025 dollars	Per dollar of private value
Private value	32.66	1.000	33.49	1.000
	(3.74)		(3.10)	
Technology	56.22	1.721	61.17	1.827
	(10.75)	(0.397)	(11.95)	(0.399)
Rivalry	−21.92	−0.671	−25.56	−0.763
	(5.83)	(0.181)	(6.11)	(0.184)
Suppliers	0.09	0.003	0.20	0.006
	(0.40)	(0.012)	(0.44)	(0.013)
Customers	−0.07	−0.002	−0.12	−0.004
	(0.20)	(0.006)	(0.21)	(0.006)
Net external value	34.32	1.051	35.69	1.066
	(12.35)	(0.414)	(13.40)	(0.422)
Private plus net external value	66.99	2.051	69.18	2.066
	(12.34)	(0.414)	(13.45)	(0.422)

Notes: Cumulative values, 1981–2024, in trillions of 2025 dollars. Ratios divide each value by total private value. Estimates use the unstandardized coefficients in Table B4 and pre-grant equity. Net external value sums the four external channels. The sample includes 12,532,180 firm-dates and 24,053 companies, excluding utilities. Parentheses report SEs from the joint coefficient covariance, using the delta method for ratios.

C.1 Sensitivity of the external-to-private value ratio

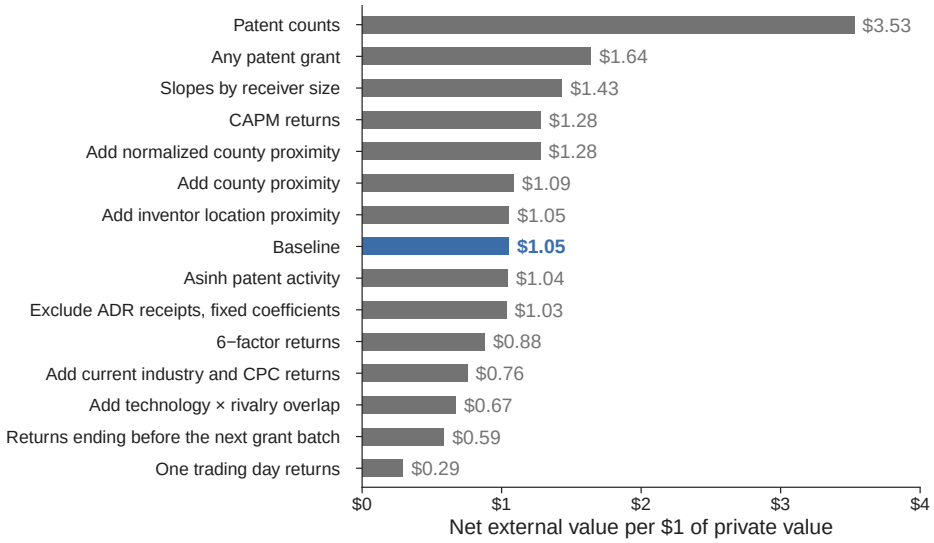


FIGURE C2: External value across specifications

Notes: Patents, 1981–2024; pooled estimates and 2025 dollars. Each bar changes the named feature of the baseline. Geography enters as a control, not an additional dollar channel.

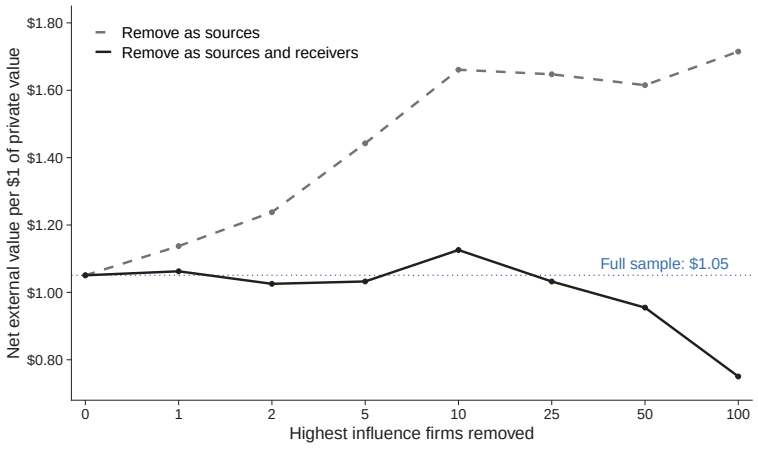


FIGURE C3: External value after removing influential firms

Notes: Patents, 1981–2024. Firms are ranked by the absolute change in the aggregate ratio when each is removed as a source. Both curves remove the same top-ranked firms.

C.2 Sector classification

Table C2 lists the reporting groups and their SIC codes. This grouping is common to Table 3, Figure 4, and Table C3. The sector-outcome exercises use BEA industry definitions, matching the level at which their outcome data are observed. Industry-specific external-to-own ratios always divide aggregate external dollars by aggregate own dollars in that industry. They are not averages of company ratios.

I allocate each firm's dollars across industries using its annual business-segment sales. A segment with two distinct reported industry codes is split equally between them. Unallocated sales and unusable segment reports use the company's current primary industry from Compustat-CCM-CRSP. In the incidence grid, each bilateral dollar is split using the product of the source and receiver shares; the allocations preserve aggregate private and external dollars.

Table C3 reports the disaggregated cumulative dollar accounts across the 13 displayed sector groups for both patents and claims. External accounts sum all four channels; Figure 4 separately displays the technology and rivalry components.

TABLE C2: Sector classification

Reporting group	SIC codes or coverage
Hardware, chips, and equipment	3570–3579, 3622, 3660–3692, 3694–3699, 3810–3839, 7391, 8730–8734
Software and IT services	7370–7379
Industrial machinery and equipment	2520–2589, 2600–2699, 2750–2769, 3000–3099, 3200–3569, 3580–3621, 3623–3629, 3700–3709, 3712–3713, 3715, 3717–3749, 3752–3791, 3793–3799, 3860–3899
Pharmaceuticals	2830–2839
Other health care	3693, 3840–3859, 8000–8099
Chemicals	2800–2829, 2840–2899
Energy	1200–1399, 2900–2999
Telecommunications	4800–4899
Utilities (excluded)	4900–4949
Finance	6000–6799
Wholesale and retail trade	5000–5999, 7200–7299, 7600–7699
Consumer durables	2500–2519, 2590–2599, 3630–3659, 3710–3711, 3714, 3716, 3750–3751, 3792, 3900–3939, 3990–3999
Consumer nondurables	0100–0999, 2000–2399, 2700–2749, 2770–2799, 3100–3199, 3940–3989
Other industries	Remaining classified industries, including construction, transportation, business services, and entertainment; firms without an available operating code are included for display

Notes: Allocation follows the description above. Utility segments of retained firms use the company's primary industry. Groups adapt Fama–French: Business Equipment is split into hardware and software, and Pharmaceuticals is separated from other Health care. Industrial machinery follows Fama–French Manuf., including fabricated materials and transport equipment. Other includes unavailable industry codes for display only; these remain separate in the underlying calculations. Rivalry uses five years of segment sales.

TABLE C3: Own, generated, and received value by sector: full accounts

Sector	Patents			Claims		
	Own	External generated	External received	Own	External generated	External received
Cumulative revaluation, 1981–2024, trillions of 2025 dollars						
Consumer nondurables	1.04	0.52	0.92	1.22	0.58	1.03
Consumer durables	0.94	1.57	0.54	0.97	1.43	0.58
Industrial machinery and equipment	3.21	2.88	1.81	3.29	3.02	1.95
Energy	1.68	0.39	0.99	2.06	0.43	1.12
Chemicals	1.37	0.96	0.69	1.44	1.07	0.79
Hardware, chips, and equipment	7.10	11.03	6.57	6.89	10.83	6.76
Software and IT services	9.48	8.08	8.93	8.64	8.40	8.62
Telecommunications	1.13	1.86	2.34	1.28	2.04	2.45
Wholesale and retail trade	1.13	1.30	2.44	1.16	1.48	2.63
Pharmaceuticals	2.11	0.37	0.51	2.43	0.39	0.49
Other health care	1.28	0.60	0.34	1.41	0.58	0.32
Finance	1.44	3.17	6.18	1.78	3.52	6.78
Other industries	0.75	1.58	2.06	0.92	1.90	2.17
Total	32.66	34.32	34.32	33.49	35.69	35.69

Notes: Trillions of 2025 dollars, 1981–2024; utilities excluded. Generated and received values assign the same external gains and losses to the innovator's and affected firm's sectors, respectively. Firms are allocated by segment sales, with primary-industry fallback. Sector definitions and allocation: Appendix C.2.

C.3 Comparison with Kogan et al. (2017) method

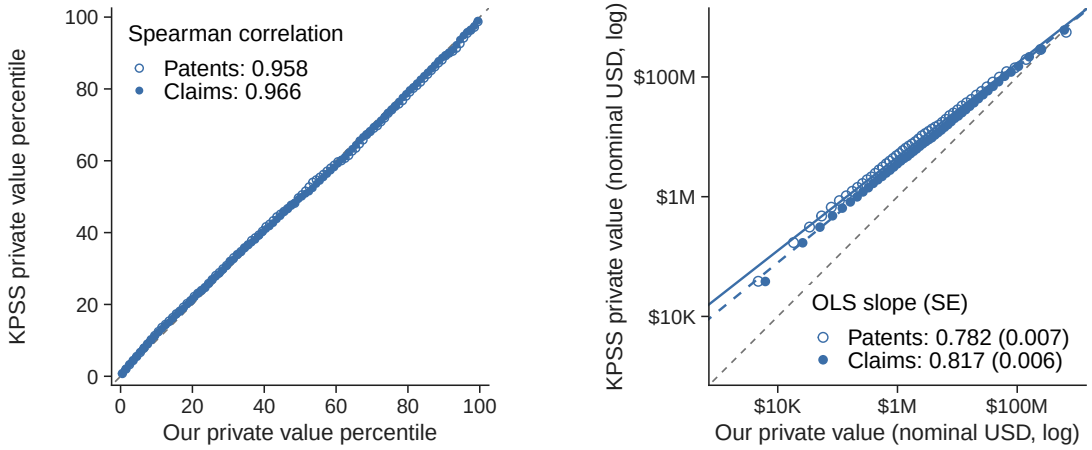
To provide an alternative validation for my implied dollar values of patents, I compare my grant activity based estimates with those I obtain from implementing the Kogan et al. (2017) method on my sample and abnormal returns. Their method estimates the dollar value of patent as follows. First, they assume that the observed return of a firm divides into a positive return attributable to innovation ($\upsilon > 0$), and the remainder as unrelated news (ε):

$$\underbrace{r_{it}}_{\text{Observed return}} = \underbrace{\upsilon_{it}}_{\text{Innovation}} + \underbrace{\varepsilon_{it}}_{\text{Unrelated news}}$$

Second, they back out the implied (filtered) return υ from observed return r using estimated changes in volatility of returns upon news of patent grants to obtain the signal to noise ratio attributable to patent news. To do so, their headline results assume that υ is half-normal and the noise component is normal. Using this filtered return, they then estimate the dollar value of patent news by multiplying it with the pre-event market capitalization of the firm (V_{it-}) and rescaling up by a constant factor of anticipation. Their surprise component of the dollar value of patent news is therefore given by:

$$\mathbb{E}[\upsilon \mid r_{it}] \times V_{it-}$$

In my comparison below, I use their headline distributional assumptions but apply them to the three factor abnormal returns. I find that the rank correlations between the two methods are 0.96 for patents and 0.97 for claims as my measures of grant activity.



(a) Rank-rank comparison

(b) Dollar value comparison

FIGURE C4: Comparison of private dollar value estimates with Kogan et al. (2017) method

Notes: Matched firm-grant dates, 1981–2024, excluding utilities.

D Firm growth, productivity and performance

D.1 Data and construction

For an external channel c, annual dollar news $\widehat{\Delta V}^{c}_{it}$ in equation (6) sums measured received dollars across all eligible grant dates in calendar year t; own innovation dollars $\widehat{\Delta V}^{O}_{it}$ are summed analogously. The denominator $\overline{V}_{it}$ in equation (6) is the mean of positive, finite prior-close market capitalization across eligible receiver dates in year t. Because capitalization varies across grant dates within a year, this ratio of annual dollar news to mean equity need not equal a simple sum of event-window returns. In the regressions, rivalry news News^{R}_{it} enters as a positive loss (minus the signed rivalry dollar inflow divided by $\overline{V}_{it}$), whereas the other channels retain their natural signs. Unavailable network information remains distinct from measured zero news. For each channel, a control records the fraction of eligible dates with usable capitalization on which channel information is unavailable, and an additional control records the fraction of eligible dates without usable capitalization. The annual dollar numerator sums only measured contributions rather than imputing missing contributions from other channels or dates.

The operating outcomes come from Compustat. Sales (SALE), operating earnings before depreciation (OIBDP), net income (NI), and research expenditure (XRD) are deflated by the CPI. Physical capital is gross property, plant, and equipment (PPEGT), deflated by the nonresidential investment price index, and employment is EMP. These six outcomes enter as $100 \log(\text{Outcome}_{i,t+h}/\text{Outcome}_{it})$ and require positive observed levels at both endpoints. Missing R&D is not set to zero, and nonpositive earnings do not enter the corresponding log-growth regression. R&D relative to assets is $100\,\text{XRD}/\text{AT}$ and enters as a percentage-point change.

Revenue productivity follows the Olley–Pakes approach (Olley and Pakes, 1996), implemented using the firm-data procedure of İmrohoroğlu and Tüzel (2014). Value added is the deflated sum of operating income and estimated labor expense; the procedure uses employment, investment, and vintage-adjusted capital to estimate a production residual. It absorbs three-digit industry–year effects, estimates on expanding samples, and accounts for exit selection. Capital-age lags remain within the same company. Industry classification uses the shared company reference at the fiscal endpoint: current Compustat company codes are attached to dated company identities, with dated primary-security CRSP codes where needed. Current company codes are applied retrospectively and are not claimed to have been historically available. The production-function training sample excludes utilities (SIC 4900–4949), financial firms with $6000 \leq \text{SIC} < 6999$, missing SIC codes, and industry–year cells with fewer than five observations. The other original financial and production-function restrictions are retained. The outcome is 100 times the change in the estimated log residual from year t to year $t + h$. Because the underlying output measure is revenue-based, this outcome measures TFPR rather than physical productivity.

The markup outcome uses the two-factor estimates constructed with the code of De Ridder et al. (2026). The estimate divides the output elasticity of variable inputs by their expenditure

share in sales; in this implementation, variable expenditure is cost of goods sold. The elasticity comes from a translog specification estimated by two-digit NAICS industry. I use the positive finite markup level and report its change multiplied by 100. The measure is inferred from financial data, so it should not be treated as a directly observed product price or marginal cost.

The firm-outcome sample requires a valid SIC code from the shared company reference and observed assets. It excludes utilities (SIC 4900–4949) and financial firms in SIC 6000–6799, and retains three-digit industries with positive own patent value somewhere in the matched annual sample. The financial match uses USD reports of twelve months, or reports with unavailable duration, with ambiguous company–year matches excluded. Outcome-specific positivity, coverage, and control requirements then determine the usable observations.

Before constructing growth, I winsorize the financial outcome levels, log capital, log employment, and log return volatility within year at the first and ninety-ninth percentiles. Annual news is winsorized at the same percentiles within activity measure and year. Every annual firm-outcome specification uses calendar-year $t-1$ news, ending before the actual fiscal close defining Y_{it}. The baseline regression includes initial log capital, log employment, log return volatility, the initial outcome, coverage controls for $t-1$ and t, three-digit industry effects, and year effects. The four network masses from news year $t-1$ enter with a separate slope in each base year. When capital or employment is the outcome, its initial log level is already among the controls and is not included twice. There are no firm fixed effects. The current-news columns in the explicit timing comparison retain the earlier timing for comparison.

Within each outcome, both activity measures and all three horizons use the same firm–base-year observations. A base observation must have usable outcomes at one, three, and five years, prior-year news and network masses, and baseline controls. Base years are 1981–2019, except for markups, which extend through 2020. Comparisons across horizons therefore hold the sample fixed, but describe firms with observed subsequent outcomes. They do not cover firms that leave the relevant data before a required endpoint. Tables D1–D2 report 54 regressions: nine outcomes, three horizons, and two activity measures.

All five news channels enter jointly. Firm/year clustered standard errors allow dependence within firms over time and across firms within years. They condition on the return coefficients used to construct news and, for markup and TFPR outcomes, on the estimated outcome measures. They do not propagate uncertainty from either preceding estimation step.

TABLE D1: Valuation news and subsequent firm outcomes: patents

Dependent variable: Cumulative change (units defined below)

Horizon	Sales	Earnings	Net income	Markup (×100)	TFPR	R&D	Capital	Employ-ment	R&D/ assets
Own									
1 year	0.21 (0.17)	2.07 (0.30)	3.37 (0.56)	0.83 (0.25)	1.07 (0.15)	0.25 (0.21)	0.23 (0.17)	0.19 (0.12)	0.33 (0.05)
3 years	0.90 (0.33)	3.38 (0.49)	5.09 (0.73)	1.57 (0.46)	1.87 (0.26)	0.47 (0.44)	0.89 (0.37)	1.07 (0.30)	0.47 (0.08)
5 years	1.35 (0.54)	3.54 (0.68)	4.96 (0.85)	2.03 (0.59)	2.01 (0.33)	0.28 (0.69)	1.41 (0.58)	1.83 (0.48)	0.46 (0.09)
Technology									
1 year	−0.15 (0.22)	−0.26 (0.33)	0.16 (0.45)	−0.30 (0.27)	0.00 (0.13)	0.44 (0.12)	0.35 (0.14)	0.03 (0.13)	0.14 (0.07)
3 years	−0.41 (0.50)	−0.14 (0.67)	0.57 (0.78)	−0.29 (0.64)	−0.04 (0.28)	1.15 (0.37)	0.71 (0.34)	0.27 (0.30)	0.16 (0.09)
5 years	−0.17 (0.78)	0.52 (0.88)	1.92 (1.18)	−0.03 (0.83)	−0.01 (0.38)	2.23 (0.58)	1.37 (0.52)	0.63 (0.47)	0.15 (0.13)
Rivalry loss									
1 year	−1.16 (0.35)	−2.07 (0.59)	−2.02 (0.95)	−0.52 (0.27)	−0.63 (0.20)	−0.93 (0.34)	−1.34 (0.23)	−0.52 (0.21)	−0.26 (0.10)
3 years	−3.42 (0.64)	−3.17 (1.00)	−4.16 (1.41)	−1.11 (0.57)	−1.08 (0.38)	−1.52 (0.69)	−3.49 (0.56)	−1.43 (0.47)	−0.17 (0.12)
5 years	−4.47 (0.90)	−4.44 (1.24)	−4.50 (1.65)	−1.24 (0.77)	−1.45 (0.47)	−2.33 (0.90)	−5.27 (0.81)	−2.27 (0.65)	−0.19 (0.19)
R^2									
1 year	0.09	0.12	0.18	0.08	0.13	0.06	0.07	0.04	0.18
3 years	0.11	0.15	0.23	0.15	0.22	0.08	0.11	0.07	0.25
5 years	0.10	0.14	0.22	0.17	0.26	0.09	0.11	0.07	0.24
Firms	9,692	6,821	5,166	7,092	6,048	5,152	9,862	9,724	6,249
Years	39	39	39	40	39	39	39	39	39

Notes: News is measured in calendar year $t-1$, ending before the baseline fiscal close; growth runs from t to $t+h$. Financial controls are measured in baseline year t. Technology, rivalry, supplier and customer network masses enter interacted with year. Each outcome and horizon is a separate regression. Sales, earnings, net income, capital, employment, and R&D use cumulative log changes ×100; TFPR uses the change in the estimated log-production residual ×100. Markup uses its level change ×100; R&D/assets uses percentage-point changes. Earnings are operating income before depreciation. Coefficients are reported per percentage point of valuation news relative to mean equity in news year $t-1$. News is annual own or received valuation dollars as a percentage of mean equity in news year $t-1$; loss from rivalry is positive for a loss. All five news measures enter jointly (supplier and customer coefficients are omitted), with initial capital, employment, return volatility, the initial outcome, and industry and year effects. Missing-data controls are the shares of dates with unavailable capitalization or channel information. Parentheses report standard errors two-way clustered by firm and year, conditional on the return coefficients. R^2 includes industry and year effects. Patent-count and claim-count measures and all horizons use the same observations within each outcome. Base years are 1981–2019, except markups (1981–2020). Appendix D provides construction and sample restrictions.

TABLE D2: Valuation news and subsequent firm outcomes: claims

Dependent variable: Cumulative change (units defined below)

Horizon	Sales	Earnings	Net income	Markup (×100)	TFPR	R&D	Capital	Employ-ment	R&D/ assets
Own									
1 year	0.25 (0.15)	2.06 (0.26)	3.48 (0.51)	0.87 (0.23)	1.04 (0.13)	0.29 (0.19)	0.24 (0.15)	0.20 (0.11)	0.32 (0.05)
3 years	1.00 (0.30)	3.42 (0.43)	5.13 (0.68)	1.69 (0.42)	1.85 (0.23)	0.56 (0.40)	0.92 (0.31)	1.04 (0.27)	0.45 (0.07)
5 years	1.50 (0.47)	3.71 (0.59)	5.24 (0.78)	2.16 (0.54)	2.05 (0.29)	0.51 (0.63)	1.45 (0.50)	1.82 (0.43)	0.44 (0.09)
Technology									
1 year	−0.20 (0.23)	−0.38 (0.33)	−0.04 (0.46)	−0.33 (0.28)	−0.03 (0.13)	0.42 (0.12)	0.32 (0.15)	0.03 (0.13)	0.11 (0.07)
3 years	−0.49 (0.51)	−0.31 (0.67)	0.32 (0.80)	−0.35 (0.65)	−0.09 (0.29)	1.15 (0.38)	0.65 (0.34)	0.27 (0.30)	0.13 (0.10)
5 years	−0.28 (0.79)	0.33 (0.88)	1.64 (1.23)	−0.13 (0.84)	−0.07 (0.38)	2.28 (0.59)	1.30 (0.53)	0.62 (0.47)	0.13 (0.13)
Rivalry loss									
1 year	−1.12 (0.31)	−1.86 (0.53)	−1.85 (0.85)	−0.49 (0.24)	−0.56 (0.18)	−0.85 (0.31)	−1.25 (0.21)	−0.50 (0.20)	−0.22 (0.10)
3 years	−3.19 (0.59)	−2.81 (0.93)	−3.90 (1.30)	−0.95 (0.52)	−0.97 (0.35)	−1.40 (0.61)	−3.18 (0.52)	−1.34 (0.43)	−0.14 (0.11)
5 years	−4.12 (0.82)	−3.96 (1.14)	−4.14 (1.50)	−1.01 (0.71)	−1.31 (0.43)	−2.32 (0.81)	−4.87 (0.74)	−2.18 (0.60)	−0.15 (0.17)
R^2									
1 year	0.09	0.12	0.19	0.08	0.13	0.06	0.07	0.04	0.18
3 years	0.11	0.15	0.23	0.15	0.22	0.08	0.11	0.07	0.25
5 years	0.10	0.14	0.22	0.17	0.26	0.09	0.11	0.07	0.24
Firms	9,692	6,821	5,166	7,092	6,048	5,152	9,862	9,724	6,249
Years	39	39	39	40	39	39	39	39	39

Notes: News is measured in calendar year $t-1$, ending before the baseline fiscal close; growth runs from t to $t+h$. Financial controls are measured in baseline year t. Technology, rivalry, supplier and customer network masses enter interacted with year. Each outcome and horizon is a separate regression. Sales, earnings, net income, capital, employment, and R&D use cumulative log changes ×100; TFPR uses the change in the estimated log-production residual ×100. Markup uses its level change ×100; R&D/assets uses percentage-point changes. Earnings are operating income before depreciation. Coefficients are reported per percentage point of valuation news relative to mean equity in news year $t-1$. News is annual own or received valuation dollars as a percentage of mean equity in news year $t-1$; loss from rivalry is positive for a loss. All five news measures enter jointly (supplier and customer coefficients are omitted), with initial capital, employment, return volatility, the initial outcome, and industry and year effects. Missing-data controls are the shares of dates with unavailable capitalization or channel information. Parentheses report standard errors two-way clustered by firm and year, conditional on the return coefficients. R^2 includes industry and year effects. Patent-count and claim-count measures and all horizons use the same observations within each outcome. Base years are 1981–2019, except markups (1981–2020). Appendix D provides construction and sample restrictions.

D.2 Capitalization at June and Year End

Panels A and B of Table D3 replace mean equity in the patent-news measures with equity at the last trading close of June or December of news year $t-1$. Annual dollar numerators remain unchanged. Both alternatives retain the common observed capitalization sample: equity must be positive at the preceding December close and at the June and December closes of the news year. Within each outcome, the same firm–base-year rows enter at all three horizons and under both denominators. Outcome construction, controls, fixed effects, clustering, and annual capping conventions remain unchanged; the news ratios are capped after applying each denominator.

June capitalization retains a negative rivalry–sales coefficient of −2.24 (SE 0.71); the rivalry coefficients for operating earnings and TFPR are also negative and significant at five percent. Year-end capitalization produces larger negative rivalry coefficients for employment and R&D, but less precise earnings and TFPR estimates. These are alternative normalizations of the same annual valuation dollars. Capitalization at either date can respond to news during the year, so the stronger year-end coefficients are not a separate causal estimate.

TABLE D3: Subsequent firm outcomes using June-end and year-end capitalization

Dependent variable: Cumulative change (units defined below)

Channel	Horizon	Sales	Earnings	Net income	Markup (×100)	TFPR	R&D	Capital	Employ-ment	R&D/ assets
Panel A: June-end capitalization										
Private value	1 year	0.06 (0.16)	1.85 (0.30)	3.20 (0.56)	0.71 (0.24)	1.03 (0.15)	0.21 (0.20)	0.10 (0.16)	0.10 (0.12)	0.29 (0.06)
	3 years	0.62 (0.32)	2.93 (0.46)	4.68 (0.73)	1.30 (0.43)	1.80 (0.25)	0.32 (0.43)	0.60 (0.35)	0.93 (0.29)	0.43 (0.07)
	5 years	0.91 (0.51)	3.01 (0.65)	4.53 (0.81)	1.76 (0.58)	1.93 (0.33)	0.10 (0.66)	1.05 (0.55)	1.54 (0.46)	0.42 (0.09)
Technology	1 year	−0.13 (0.21)	−0.03 (0.28)	0.44 (0.46)	−0.21 (0.28)	0.11 (0.13)	0.48 (0.14)	0.35 (0.14)	0.15 (0.14)	0.09 (0.07)
	3 years	−0.38 (0.46)	0.13 (0.61)	0.78 (0.74)	0.11 (0.55)	−0.07 (0.28)	1.31 (0.36)	0.82 (0.34)	0.43 (0.31)	0.11 (0.09)
	5 years	0.08 (0.67)	0.75 (0.84)	2.15 (1.13)	0.70 (0.75)	−0.02 (0.36)	2.47 (0.57)	1.53 (0.52)	0.92 (0.45)	0.08 (0.12)
Rivalry loss	1 year	−0.73 (0.34)	−1.25 (0.53)	−1.50 (0.84)	−0.12 (0.27)	−0.58 (0.17)	−0.16 (0.31)	−0.85 (0.21)	−0.25 (0.23)	−0.11 (0.09)
	3 years	−2.24 (0.71)	−2.24 (0.94)	−2.55 (1.33)	−0.23 (0.58)	−0.76 (0.36)	−0.52 (0.63)	−2.15 (0.55)	−0.80 (0.47)	−0.01 (0.12)
	5 years	−2.78 (1.00)	−3.57 (1.17)	−3.39 (1.59)	−0.81 (0.86)	−1.19 (0.48)	−0.83 (0.85)	−3.23 (0.78)	−1.00 (0.67)	−0.04 (0.19)
Panel B: Year-end capitalization										
Private value	1 year	0.25 (0.16)	1.91 (0.25)	3.35 (0.53)	0.62 (0.22)	0.98 (0.12)	0.43 (0.20)	0.24 (0.14)	0.23 (0.12)	0.25 (0.05)
	3 years	0.84 (0.30)	2.89 (0.48)	4.79 (0.73)	1.20 (0.39)	1.66 (0.25)	0.62 (0.41)	0.82 (0.35)	1.04 (0.28)	0.39 (0.07)
	5 years	1.24 (0.48)	3.04 (0.61)	4.43 (0.84)	1.75 (0.53)	1.78 (0.30)	0.42 (0.63)	1.26 (0.52)	1.69 (0.43)	0.35 (0.09)
Technology	1 year	−0.33 (0.15)	−0.07 (0.27)	−0.30 (0.44)	−0.29 (0.23)	0.06 (0.12)	0.10 (0.10)	−0.03 (0.17)	−0.08 (0.12)	0.06 (0.05)
	3 years	−0.69 (0.33)	0.09 (0.42)	0.32 (0.64)	−0.11 (0.50)	0.13 (0.21)	0.40 (0.27)	−0.15 (0.29)	−0.17 (0.27)	0.07 (0.07)
	5 years	−0.71 (0.50)	0.29 (0.56)	1.47 (1.01)	−0.42 (0.58)	0.21 (0.26)	1.14 (0.46)	0.06 (0.39)	−0.15 (0.38)	0.14 (0.09)
Rivalry loss	1 year	−0.90 (0.39)	−0.25 (0.76)	−1.09 (0.89)	0.01 (0.23)	0.10 (0.21)	−1.58 (0.40)	−1.23 (0.36)	−0.81 (0.24)	−0.01 (0.07)
	3 years	−2.16 (0.60)	−1.39 (0.78)	−2.90 (1.02)	−0.42 (0.39)	−0.22 (0.29)	−2.49 (0.59)	−2.65 (0.74)	−1.61 (0.46)	0.00 (0.06)
	5 years	−3.00 (0.95)	−2.30 (1.04)	−3.04 (1.33)	−0.95 (0.54)	−0.44 (0.35)	−3.17 (0.84)	−3.59 (0.98)	−2.15 (0.64)	0.10 (0.11)
Firms		9,719	6,815	5,128	7,147	6,084	5,168	9,902	9,760	6,270
Years		39	39	39	40	39	39	39	39	39

Notes: News is measured in calendar year $t-1$, ending before the baseline fiscal close; growth runs from t to $t+h$. Financial controls are measured in baseline year t. Technology, rivalry, supplier and customer network masses enter interacted with year. Each outcome and horizon is a separate regression. Annual own or received patent-innovation dollars are divided by equity at the last trading close of June (Panel A) or December (Panel B) in news year $t-1$ and multiplied by 100. Rivalry losses enter positively. All five channels enter jointly; supplier and customer coefficients are omitted. Sales, earnings (OIBDP), net income, R&D, capital, and employment use cumulative log changes ×100; TFPR uses the change in the log-production residual ×100; markup uses its level change ×100; R&D/assets uses percentage-point changes. Controls, industry and year effects, and annual first/ninety-ninth-percentile capping follow Table D1. Both panels and all horizons use the same firm–base-year observations within each outcome, requiring positive equity at December $t-2$, June $t-1$, and December $t-1$. Base years are 1981–2019, except markups (1981–2020). Parentheses report standard errors clustered by firm and year, conditional on the return coefficients.

D.3 Firm-outcome robustness

Table D5 separates the effect of requiring observed prior R&D from the effect of controlling for it. Own and leave-own-out industry-peer R&D/sales use the latest annual reporting period ending in calendar year $t-2$, before innovation news in $t-1$. The corresponding one- and five-year tables use the same design. The sample and tail comparisons vary endpoint availability or one capping convention at a time. All five innovation channels enter jointly throughout.

TABLE D4: Prior R&D controls: 1-year outcomes

	Patents						Claims					
Specification	Own	Technology	Rivalry loss	Firms	Years	R^2	Own	Technology	Rivalry loss	Firms	Years	R^2
Sales												
Baseline	0.21 (0.17)	−0.15 (0.22)	−1.16 (0.35)	9,692	39	0.09	0.25 (0.15)	−0.20 (0.23)	−1.12 (0.31)	9,692	39	0.09
R&D observed	−0.14 (0.18)	−0.10 (0.22)	−0.77 (0.40)	6,198	39	0.08	−0.04 (0.16)	−0.13 (0.23)	−0.76 (0.37)	6,198	39	0.08
Add prior R&D	−0.15 (0.18)	−0.07 (0.22)	−0.77 (0.40)	6,198	39	0.09	−0.05 (0.16)	−0.11 (0.23)	−0.75 (0.37)	6,198	39	0.09
Operating earnings												
Baseline	2.07 (0.30)	−0.26 (0.33)	−2.07 (0.59)	6,821	39	0.12	2.06 (0.26)	−0.38 (0.33)	−1.86 (0.53)	6,821	39	0.12
R&D observed	1.96 (0.32)	−0.32 (0.36)	−1.30 (0.69)	4,090	39	0.13	2.05 (0.29)	−0.43 (0.36)	−1.15 (0.62)	4,090	39	0.13
Add prior R&D	1.95 (0.32)	−0.28 (0.36)	−1.32 (0.69)	4,090	39	0.13	2.04 (0.29)	−0.40 (0.35)	−1.16 (0.63)	4,090	39	0.13
Net income												
Baseline	3.37 (0.56)	0.16 (0.45)	−2.02 (0.95)	5,166	39	0.18	3.48 (0.51)	−0.04 (0.46)	−1.85 (0.85)	5,166	39	0.19
R&D observed	3.32 (0.60)	0.46 (0.54)	−1.02 (1.15)	3,139	39	0.20	3.55 (0.58)	0.26 (0.56)	−0.89 (1.03)	3,139	39	0.20
Add prior R&D	3.28 (0.60)	0.52 (0.54)	−1.04 (1.15)	3,139	39	0.20	3.52 (0.58)	0.32 (0.56)	−0.91 (1.03)	3,139	39	0.20
Capital												
Baseline	0.23 (0.17)	0.35 (0.14)	−1.34 (0.23)	9,862	39	0.07	0.24 (0.15)	0.32 (0.15)	−1.25 (0.21)	9,862	39	0.07
R&D observed	−0.08 (0.18)	0.31 (0.14)	−0.95 (0.22)	6,243	39	0.08	−0.03 (0.16)	0.29 (0.15)	−0.86 (0.19)	6,243	39	0.08
Add prior R&D	−0.08 (0.18)	0.32 (0.15)	−0.96 (0.22)	6,243	39	0.08	−0.04 (0.16)	0.30 (0.15)	−0.86 (0.19)	6,243	39	0.08
Employment												
Baseline	0.19 (0.12)	0.03 (0.13)	−0.52 (0.21)	9,724	39	0.04	0.20 (0.11)	0.03 (0.13)	−0.50 (0.20)	9,724	39	0.04
R&D observed	−0.12 (0.12)	0.05 (0.15)	−0.39 (0.21)	6,173	39	0.05	−0.08 (0.11)	0.06 (0.15)	−0.36 (0.20)	6,173	39	0.05
Add prior R&D	−0.13 (0.12)	0.05 (0.15)	−0.39 (0.21)	6,173	39	0.05	−0.08 (0.11)	0.06 (0.15)	−0.37 (0.20)	6,173	39	0.05
Markups												
Baseline	0.83 (0.25)	−0.30 (0.27)	−0.52 (0.27)	7,092	40	0.08	0.87 (0.23)	−0.33 (0.28)	−0.49 (0.24)	7,092	40	0.08
R&D observed	0.52 (0.25)	−0.35 (0.26)	−0.63 (0.27)	4,797	40	0.08	0.62 (0.23)	−0.37 (0.27)	−0.60 (0.23)	4,797	40	0.08
Add prior R&D	0.53 (0.25)	−0.36 (0.27)	−0.63 (0.27)	4,797	40	0.08	0.63 (0.23)	−0.38 (0.27)	−0.60 (0.23)	4,797	40	0.08
TFPR												
Baseline	1.07 (0.15)	0.00 (0.13)	−0.63 (0.20)	6,048	39	0.13	1.04 (0.13)	−0.03 (0.13)	−0.56 (0.18)	6,048	39	0.13
R&D observed	1.02 (0.16)	0.10 (0.16)	−0.51 (0.24)	3,837	39	0.14	1.03 (0.15)	0.07 (0.16)	−0.45 (0.22)	3,837	39	0.14
Add prior R&D	1.02 (0.16)	0.10 (0.16)	−0.50 (0.24)	3,837	39	0.14	1.02 (0.15)	0.06 (0.16)	−0.45 (0.22)	3,837	39	0.14
R&D												
Baseline	0.25 (0.21)	0.44 (0.12)	−0.93 (0.34)	5,152	39	0.06	0.29 (0.19)	0.42 (0.12)	−0.85 (0.31)	5,152	39	0.06
R&D observed	0.15 (0.21)	0.49 (0.15)	−0.76 (0.37)	4,755	39	0.06	0.17 (0.19)	0.48 (0.15)	−0.69 (0.33)	4,755	39	0.06
Add prior R&D	0.15 (0.21)	0.49 (0.15)	−0.76 (0.37)	4,755	39	0.06	0.17 (0.19)	0.47 (0.15)	−0.69 (0.33)	4,755	39	0.06
R&D/assets												
Baseline	0.33 (0.05)	0.14 (0.07)	−0.26 (0.10)	6,249	39	0.18	0.32 (0.05)	0.11 (0.07)	−0.22 (0.10)	6,249	39	0.18
R&D observed	0.31 (0.05)	0.13 (0.07)	−0.24 (0.09)	5,721	39	0.16	0.30 (0.05)	0.11 (0.07)	−0.21 (0.09)	5,721	39	0.16
Add prior R&D	0.31 (0.05)	0.13 (0.07)	−0.24 (0.09)	5,721	39	0.16	0.30 (0.05)	0.11 (0.07)	−0.21 (0.09)	5,721	39	0.16

Notes: News is dated $t-1$; outcomes change from t to $t+h$. Outcome definitions, controls, units, and baseline samples follow Tables D1 and D2. R&D observed restricts the sample to observed own and industry-peer R&D. Add prior R&D uses that sample and adds own and peer R&D/sales and peer R&D coverage, measured in $t-2$. All five channels enter; supplier/customer coefficients are omitted. Rivalry denotes a loss. Parentheses report two-way firm/year clustered SEs.

TABLE D5: Prior R&D controls: 3-year outcomes

	Patents						Claims					
Specification	Own	Technology	Rivalry loss	Firms	Years	R^2	Own	Technology	Rivalry loss	Firms	Years	R^2
Sales												
Baseline	0.90 (0.33)	−0.41 (0.50)	−3.42 (0.64)	9,692	39	0.11	1.00 (0.30)	−0.49 (0.51)	−3.19 (0.59)	9,692	39	0.11
R&D observed	0.23 (0.37)	−0.46 (0.57)	−2.47 (0.68)	6,198	39	0.11	0.48 (0.35)	−0.52 (0.57)	−2.35 (0.62)	6,198	39	0.11
Add prior R&D	0.21 (0.37)	−0.41 (0.56)	−2.46 (0.68)	6,198	39	0.11	0.46 (0.35)	−0.46 (0.57)	−2.34 (0.61)	6,198	39	0.11
Operating earnings												
Baseline	3.38 (0.49)	−0.14 (0.67)	−3.17 (1.00)	6,821	39	0.15	3.42 (0.43)	−0.31 (0.67)	−2.81 (0.93)	6,821	39	0.15
R&D observed	2.82 (0.53)	−0.09 (0.72)	−2.01 (1.06)	4,090	39	0.16	3.05 (0.48)	−0.25 (0.71)	−1.77 (0.98)	4,090	39	0.16
Add prior R&D	2.80 (0.53)	−0.06 (0.72)	−2.03 (1.06)	4,090	39	0.16	3.04 (0.48)	−0.22 (0.71)	−1.79 (0.98)	4,090	39	0.16
Net income												
Baseline	5.09 (0.73)	0.57 (0.78)	−4.16 (1.41)	5,166	39	0.23	5.13 (0.68)	0.32 (0.80)	−3.90 (1.30)	5,166	39	0.23
R&D observed	4.68 (0.83)	0.90 (0.86)	−2.04 (1.53)	3,139	39	0.24	4.97 (0.80)	0.65 (0.88)	−1.90 (1.41)	3,139	39	0.24
Add prior R&D	4.64 (0.83)	0.92 (0.86)	−2.05 (1.53)	3,139	39	0.24	4.92 (0.79)	0.67 (0.88)	−1.92 (1.41)	3,139	39	0.24
Capital												
Baseline	0.89 (0.37)	0.71 (0.34)	−3.49 (0.56)	9,862	39	0.11	0.92 (0.31)	0.65 (0.34)	−3.18 (0.52)	9,862	39	0.11
R&D observed	0.23 (0.40)	0.61 (0.40)	−2.45 (0.60)	6,243	39	0.11	0.38 (0.36)	0.57 (0.40)	−2.22 (0.55)	6,243	39	0.11
Add prior R&D	0.22 (0.40)	0.62 (0.40)	−2.46 (0.60)	6,243	39	0.11	0.37 (0.36)	0.58 (0.40)	−2.22 (0.55)	6,243	39	0.11
Employment												
Baseline	1.07 (0.30)	0.27 (0.30)	−1.43 (0.47)	9,724	39	0.07	1.04 (0.27)	0.27 (0.30)	−1.34 (0.43)	9,724	39	0.07
R&D observed	0.41 (0.31)	0.32 (0.35)	−1.06 (0.51)	6,173	39	0.07	0.50 (0.29)	0.34 (0.35)	−1.01 (0.48)	6,173	39	0.07
Add prior R&D	0.40 (0.31)	0.32 (0.35)	−1.06 (0.51)	6,173	39	0.07	0.49 (0.29)	0.34 (0.35)	−1.01 (0.48)	6,173	39	0.07
Markups												
Baseline	1.57 (0.46)	−0.29 (0.64)	−1.11 (0.57)	7,092	40	0.15	1.69 (0.42)	−0.35 (0.65)	−0.95 (0.52)	7,092	40	0.15
R&D observed	1.05 (0.48)	−0.20 (0.80)	−1.38 (0.59)	4,797	40	0.14	1.24 (0.44)	−0.23 (0.81)	−1.23 (0.55)	4,797	40	0.14
Add prior R&D	1.05 (0.48)	−0.21 (0.81)	−1.38 (0.59)	4,797	40	0.14	1.25 (0.44)	−0.24 (0.81)	−1.24 (0.55)	4,797	40	0.14
TFPR												
Baseline	1.87 (0.26)	−0.04 (0.28)	−1.08 (0.38)	6,048	39	0.22	1.85 (0.23)	−0.09 (0.29)	−0.97 (0.35)	6,048	39	0.22
R&D observed	1.69 (0.30)	0.25 (0.31)	−0.81 (0.42)	3,837	39	0.24	1.76 (0.27)	0.19 (0.32)	−0.73 (0.38)	3,837	39	0.24
Add prior R&D	1.68 (0.30)	0.25 (0.31)	−0.81 (0.42)	3,837	39	0.24	1.75 (0.27)	0.19 (0.32)	−0.72 (0.38)	3,837	39	0.24
R&D												
Baseline	0.47 (0.44)	1.15 (0.37)	−1.52 (0.69)	5,152	39	0.08	0.56 (0.40)	1.15 (0.38)	−1.40 (0.61)	5,152	39	0.08
R&D observed	0.09 (0.43)	1.23 (0.42)	−1.30 (0.69)	4,755	39	0.08	0.19 (0.39)	1.26 (0.42)	−1.21 (0.61)	4,755	39	0.08
Add prior R&D	0.09 (0.43)	1.22 (0.42)	−1.30 (0.69)	4,755	39	0.08	0.19 (0.39)	1.24 (0.42)	−1.22 (0.61)	4,755	39	0.08
R&D/assets												
Baseline	0.47 (0.08)	0.16 (0.09)	−0.17 (0.12)	6,249	39	0.25	0.45 (0.07)	0.13 (0.10)	−0.14 (0.11)	6,249	39	0.25
R&D observed	0.42 (0.07)	0.15 (0.09)	−0.11 (0.12)	5,721	39	0.23	0.41 (0.07)	0.13 (0.09)	−0.10 (0.11)	5,721	39	0.23
Add prior R&D	0.42 (0.07)	0.15 (0.09)	−0.12 (0.12)	5,721	39	0.23	0.41 (0.07)	0.14 (0.09)	−0.10 (0.11)	5,721	39	0.23

Notes: News is dated $t-1$; outcomes change from t to $t+h$. Outcome definitions, controls, units, and baseline samples follow Tables D1 and D2. R&D observed restricts the sample to observed own and industry-peer R&D. Add prior R&D uses that sample and adds own and peer R&D/sales and peer R&D coverage, measured in $t-2$. All five channels enter; supplier/customer coefficients are omitted. Rivalry denotes a loss. Parentheses report two-way firm/year clustered SEs.

TABLE D6: Prior R&D controls: 5-year outcomes

	Patents						Claims					
Specification	Own	Technology	Rivalry loss	Firms	Years	R^2	Own	Technology	Rivalry loss	Firms	Years	R^2
Sales												
Baseline	1.35 (0.54)	−0.17 (0.78)	−4.47 (0.90)	9,692	39	0.10	1.50 (0.47)	−0.28 (0.79)	−4.12 (0.82)	9,692	39	0.10
R&D observed	0.53 (0.56)	−0.08 (0.87)	−3.40 (0.98)	6,198	39	0.11	0.91 (0.52)	−0.15 (0.88)	−3.23 (0.89)	6,198	39	0.11
Add prior R&D	0.49 (0.56)	0.02 (0.87)	−3.38 (0.97)	6,198	39	0.11	0.87 (0.52)	−0.05 (0.88)	−3.22 (0.89)	6,198	39	0.11
Operating earnings												
Baseline	3.54 (0.68)	0.52 (0.88)	−4.44 (1.24)	6,821	39	0.14	3.71 (0.59)	0.33 (0.88)	−3.96 (1.14)	6,821	39	0.14
R&D observed	2.53 (0.69)	0.70 (0.88)	−3.26 (1.35)	4,090	39	0.16	2.99 (0.63)	0.55 (0.87)	−2.94 (1.24)	4,090	39	0.16
Add prior R&D	2.50 (0.69)	0.74 (0.88)	−3.30 (1.35)	4,090	39	0.16	2.96 (0.63)	0.59 (0.87)	−2.97 (1.24)	4,090	39	0.16
Net income												
Baseline	4.96 (0.85)	1.92 (1.18)	−4.50 (1.65)	5,166	39	0.22	5.24 (0.78)	1.64 (1.23)	−4.14 (1.50)	5,166	39	0.22
R&D observed	4.09 (0.93)	2.33 (1.27)	−2.34 (1.67)	3,139	39	0.23	4.69 (0.87)	2.06 (1.30)	−2.18 (1.54)	3,139	39	0.23
Add prior R&D	4.03 (0.92)	2.35 (1.27)	−2.37 (1.67)	3,139	39	0.23	4.63 (0.86)	2.08 (1.30)	−2.20 (1.54)	3,139	39	0.23
Capital												
Baseline	1.41 (0.58)	1.37 (0.52)	−5.27 (0.81)	9,862	39	0.11	1.45 (0.50)	1.30 (0.53)	−4.87 (0.74)	9,862	39	0.11
R&D observed	0.48 (0.60)	1.38 (0.63)	−3.84 (0.87)	6,243	39	0.12	0.71 (0.53)	1.35 (0.65)	−3.58 (0.79)	6,243	39	0.12
Add prior R&D	0.48 (0.60)	1.38 (0.63)	−3.84 (0.87)	6,243	39	0.12	0.70 (0.53)	1.35 (0.65)	−3.58 (0.79)	6,243	39	0.12
Employment												
Baseline	1.83 (0.48)	0.63 (0.47)	−2.27 (0.65)	9,724	39	0.07	1.82 (0.43)	0.62 (0.47)	−2.18 (0.60)	9,724	39	0.07
R&D observed	0.87 (0.50)	0.96 (0.56)	−2.06 (0.73)	6,173	39	0.07	1.02 (0.46)	0.97 (0.57)	−2.05 (0.67)	6,173	39	0.07
Add prior R&D	0.86 (0.50)	0.96 (0.56)	−2.06 (0.73)	6,173	39	0.07	1.01 (0.46)	0.97 (0.57)	−2.05 (0.67)	6,173	39	0.07
Markups												
Baseline	2.03 (0.59)	−0.03 (0.83)	−1.24 (0.77)	7,092	40	0.17	2.16 (0.54)	−0.13 (0.84)	−1.01 (0.71)	7,092	40	0.17
R&D observed	1.43 (0.63)	0.03 (0.95)	−1.62 (0.89)	4,797	40	0.17	1.64 (0.58)	−0.03 (0.97)	−1.40 (0.82)	4,797	40	0.17
Add prior R&D	1.43 (0.63)	0.02 (0.96)	−1.62 (0.89)	4,797	40	0.17	1.64 (0.58)	−0.04 (0.97)	−1.40 (0.81)	4,797	40	0.17
TFPR												
Baseline	2.01 (0.33)	−0.01 (0.38)	−1.45 (0.47)	6,048	39	0.26	2.05 (0.29)	−0.07 (0.38)	−1.31 (0.43)	6,048	39	0.26
R&D observed	1.81 (0.36)	0.26 (0.42)	−1.16 (0.54)	3,837	39	0.27	1.97 (0.32)	0.20 (0.43)	−1.06 (0.50)	3,837	39	0.27
Add prior R&D	1.79 (0.36)	0.25 (0.42)	−1.15 (0.54)	3,837	39	0.27	1.94 (0.32)	0.19 (0.42)	−1.05 (0.49)	3,837	39	0.27
R&D												
Baseline	0.28 (0.69)	2.23 (0.58)	−2.33 (0.90)	5,152	39	0.09	0.51 (0.63)	2.28 (0.59)	−2.32 (0.81)	5,152	39	0.09
R&D observed	−0.11 (0.68)	2.48 (0.64)	−2.13 (0.91)	4,755	39	0.09	0.13 (0.63)	2.55 (0.65)	−2.13 (0.82)	4,755	39	0.09
Add prior R&D	−0.11 (0.68)	2.46 (0.64)	−2.12 (0.91)	4,755	39	0.09	0.12 (0.63)	2.53 (0.65)	−2.12 (0.82)	4,755	39	0.09
R&D/assets												
Baseline	0.46 (0.09)	0.15 (0.13)	−0.19 (0.19)	6,249	39	0.24	0.44 (0.09)	0.13 (0.13)	−0.15 (0.17)	6,249	39	0.24
R&D observed	0.46 (0.08)	0.14 (0.12)	−0.16 (0.19)	5,721	39	0.23	0.43 (0.08)	0.13 (0.12)	−0.12 (0.18)	5,721	39	0.23
Add prior R&D	0.46 (0.08)	0.15 (0.12)	−0.16 (0.19)	5,721	39	0.23	0.43 (0.08)	0.13 (0.12)	−0.12 (0.18)	5,721	39	0.23

Notes: News is dated $t-1$; outcomes change from t to $t+h$. Outcome definitions, controls, units, and baseline samples follow Tables D1 and D2. R&D observed restricts the sample to observed own and industry-peer R&D. Add prior R&D uses that sample and adds own and peer R&D/sales and peer R&D coverage, measured in $t-2$. All five channels enter; supplier/customer coefficients are omitted. Rivalry denotes a loss. Parentheses report two-way firm/year clustered SEs.

TABLE D7: Endpoint availability and outliers: 1-year outcomes

	Patents						Claims					
Specification	Own	Technology	Rivalry loss	Firms	Years	R^2	Own	Technology	Rivalry loss	Firms	Years	R^2
Sales: scale												
Baseline	0.21 (0.17)	−0.15 (0.22)	−1.16 (0.35)	9,692	39	0.09	0.25 (0.15)	−0.20 (0.23)	−1.12 (0.31)	9,692	39	0.09
Available endpoints	−0.22 (0.16)	0.20 (0.17)	−0.61 (0.41)	15,183	43	0.08	−0.14 (0.15)	0.19 (0.17)	−0.62 (0.38)	15,183	43	0.08
Uncapped news	0.17 (0.13)	−0.16 (0.22)	−1.15 (0.34)	9,692	39	0.09	0.24 (0.14)	−0.21 (0.22)	−1.11 (0.31)	9,692	39	0.09
Uncapped outcome	0.16 (0.16)	−0.14 (0.23)	−1.14 (0.35)	9,692	39	0.09	0.21 (0.15)	−0.19 (0.23)	−1.11 (0.31)	9,692	39	0.09
Operating earnings												
Baseline	2.07 (0.30)	−0.26 (0.33)	−2.07 (0.59)	6,821	39	0.12	2.06 (0.26)	−0.38 (0.33)	−1.86 (0.53)	6,821	39	0.12
Available endpoints	1.94 (0.25)	−0.14 (0.24)	−2.06 (0.55)	11,122	43	0.12	1.98 (0.23)	−0.24 (0.24)	−1.85 (0.51)	11,122	43	0.12
Uncapped news	1.44 (0.23)	−0.27 (0.33)	−1.99 (0.60)	6,821	39	0.12	1.81 (0.23)	−0.43 (0.33)	−1.80 (0.54)	6,821	39	0.12
Uncapped outcome	2.11 (0.30)	−0.23 (0.33)	−2.10 (0.60)	6,821	39	0.12	2.10 (0.27)	−0.35 (0.34)	−1.88 (0.53)	6,821	39	0.12
TFPR: productivity												
Baseline	1.07 (0.15)	0.00 (0.13)	−0.63 (0.20)	6,048	39	0.13	1.04 (0.13)	−0.03 (0.13)	−0.56 (0.18)	6,048	39	0.13
Available endpoints	1.13 (0.16)	−0.13 (0.14)	−0.40 (0.19)	10,101	43	0.13	1.07 (0.14)	−0.15 (0.14)	−0.33 (0.18)	10,101	43	0.13
Uncapped news	0.76 (0.11)	0.01 (0.14)	−0.63 (0.20)	6,048	39	0.13	0.91 (0.11)	−0.04 (0.14)	−0.57 (0.18)	6,048	39	0.13
Uncapped outcome	1.13 (0.16)	−0.02 (0.15)	−0.66 (0.21)	6,048	39	0.13	1.10 (0.14)	−0.06 (0.15)	−0.59 (0.19)	6,048	39	0.13
Markups: margins												
Baseline	0.83 (0.25)	−0.30 (0.27)	−0.52 (0.27)	7,092	40	0.08	0.87 (0.23)	−0.33 (0.28)	−0.49 (0.24)	7,092	40	0.08
Available endpoints	0.83 (0.23)	−0.14 (0.32)	−0.47 (0.26)	10,494	44	0.09	0.89 (0.20)	−0.18 (0.32)	−0.43 (0.24)	10,494	44	0.09
Uncapped news	0.43 (0.23)	−0.30 (0.26)	−0.48 (0.27)	7,092	40	0.08	0.67 (0.22)	−0.36 (0.27)	−0.45 (0.24)	7,092	40	0.08
Uncapped outcome	2.73 (0.90)	−1.02 (—)	−1.98 (1.04)	7,092	40	0.01	2.80 (0.87)	−1.30 (—)	−1.68 (1.16)	7,092	40	0.01

Notes: News is dated $t-1$; outcomes change from t to $t+h$. Outcome definitions, controls, units, and baseline samples follow Tables D1 and D2. Available endpoints requires only the displayed horizon; Baseline requires all three. Uncapped news and Uncapped outcome omit the respective annual 1st/99th-percentile winsorization on the baseline sample. All five channels enter; supplier/customer coefficients are omitted. Rivalry denotes a loss. Parentheses report two-way firm/year clustered SEs. A dash denotes an unavailable SE from a negative clustered variance estimate.

TABLE D8: Endpoint availability and outliers: 3-year outcomes

	Patents						Claims					
Specification	Own	Technology	Rivalry loss	Firms	Years	R^2	Own	Technology	Rivalry loss	Firms	Years	R^2
Sales: scale												
Baseline	0.90 (0.33)	−0.41 (0.50)	−3.42 (0.64)	9,692	39	0.11	1.00 (0.30)	−0.49 (0.51)	−3.19 (0.59)	9,692	39	0.11
Available endpoints	0.49 (0.35)	0.20 (0.44)	−2.57 (0.69)	12,070	41	0.10	0.60 (0.33)	0.14 (0.45)	−2.42 (0.63)	12,070	41	0.10
Uncapped news	0.73 (0.27)	−0.42 (0.50)	−3.38 (0.64)	9,692	39	0.11	0.93 (0.28)	−0.50 (0.51)	−3.17 (0.58)	9,692	39	0.11
Uncapped outcome	0.71 (0.34)	−0.39 (0.51)	−3.41 (0.65)	9,692	39	0.11	0.83 (0.31)	−0.47 (0.52)	−3.19 (0.59)	9,692	39	0.11
Operating earnings												
Baseline	3.38 (0.49)	−0.14 (0.67)	−3.17 (1.00)	6,821	39	0.15	3.42 (0.43)	−0.31 (0.67)	−2.81 (0.93)	6,821	39	0.15
Available endpoints	3.07 (0.47)	0.14 (0.56)	−3.30 (0.91)	9,016	41	0.14	3.20 (0.41)	−0.04 (0.56)	−2.94 (0.84)	9,016	41	0.14
Uncapped news	2.35 (0.40)	−0.18 (0.68)	−3.00 (0.98)	6,821	39	0.15	3.01 (0.39)	−0.43 (0.68)	−2.68 (0.92)	6,821	39	0.15
Uncapped outcome	3.30 (0.49)	−0.09 (0.67)	−3.16 (1.01)	6,821	39	0.15	3.33 (0.44)	−0.25 (0.67)	−2.80 (0.94)	6,821	39	0.15
TFPR: productivity												
Baseline	1.87 (0.26)	−0.04 (0.28)	−1.08 (0.38)	6,048	39	0.22	1.85 (0.23)	−0.09 (0.29)	−0.97 (0.35)	6,048	39	0.22
Available endpoints	1.87 (0.26)	−0.17 (0.24)	−1.04 (0.36)	7,953	41	0.22	1.84 (0.23)	−0.21 (0.24)	−0.91 (0.32)	7,953	41	0.23
Uncapped news	1.28 (0.23)	−0.00 (0.29)	−1.03 (0.38)	6,048	39	0.22	1.61 (0.21)	−0.09 (0.29)	−0.94 (0.35)	6,048	39	0.22
Uncapped outcome	1.93 (0.28)	−0.03 (0.29)	−1.17 (0.40)	6,048	39	0.22	1.93 (0.24)	−0.10 (0.30)	−1.05 (0.36)	6,048	39	0.22
Markups: margins												
Baseline	1.57 (0.46)	−0.29 (0.64)	−1.11 (0.57)	7,092	40	0.15	1.69 (0.42)	−0.35 (0.65)	−0.95 (0.52)	7,092	40	0.15
Available endpoints	1.57 (0.46)	−0.43 (0.57)	−0.89 (0.55)	8,635	42	0.15	1.73 (0.41)	−0.50 (0.58)	−0.76 (0.50)	8,635	42	0.15
Uncapped news	0.74 (0.43)	−0.29 (0.63)	−1.02 (0.57)	7,092	40	0.15	1.24 (0.40)	−0.40 (0.64)	−0.87 (0.53)	7,092	40	0.15
Uncapped outcome	5.07 (1.59)	−2.46 (2.43)	−3.74 (2.10)	7,092	40	0.01	5.36 (1.55)	−3.03 (2.49)	−2.97 (2.08)	7,092	40	0.01

Notes: News is dated $t-1$; outcomes change from t to $t+h$. Outcome definitions, controls, units, and baseline samples follow Tables D1 and D2. Available endpoints requires only the displayed horizon; Baseline requires all three. Uncapped news and Uncapped outcome omit the respective annual 1st/99th-percentile winsorization on the baseline sample. All five channels enter; supplier/customer coefficients are omitted. Rivalry denotes a loss. Parentheses report two-way firm/year clustered SEs.

TABLE D9: Endpoint availability and outliers: 5-year outcomes

	Patents						Claims					
Specification	Own	Technology	Rivalry loss	Firms	Years	R^2	Own	Technology	Rivalry loss	Firms	Years	R^2
Sales: scale												
Baseline	1.35 (0.54)	−0.17 (0.78)	−4.47 (0.90)	9,692	39	0.10	1.50 (0.47)	−0.28 (0.79)	−4.12 (0.82)	9,692	39	0.10
Available endpoints	1.46 (0.54)	−0.11 (0.78)	−4.55 (0.87)	9,794	39	0.11	1.58 (0.48)	−0.22 (0.79)	−4.16 (0.80)	9,794	39	0.11
Uncapped news	1.09 (0.44)	−0.19 (0.77)	−4.42 (0.89)	9,692	39	0.10	1.40 (0.44)	−0.30 (0.79)	−4.09 (0.82)	9,692	39	0.10
Uncapped outcome	0.98 (0.54)	−0.15 (0.79)	−4.50 (0.91)	9,692	39	0.10	1.17 (0.48)	−0.26 (0.81)	−4.14 (0.84)	9,692	39	0.10
Operating earnings												
Baseline	3.54 (0.68)	0.52 (0.88)	−4.44 (1.24)	6,821	39	0.14	3.71 (0.59)	0.33 (0.88)	−3.96 (1.14)	6,821	39	0.14
Available endpoints	3.58 (0.69)	0.49 (0.84)	−5.09 (1.17)	7,516	39	0.14	3.78 (0.60)	0.26 (0.85)	−4.53 (1.07)	7,516	39	0.14
Uncapped news	2.44 (0.55)	0.42 (0.90)	−4.28 (1.23)	6,821	39	0.14	3.26 (0.54)	0.13 (0.90)	−3.85 (1.13)	6,821	39	0.14
Uncapped outcome	3.40 (0.68)	0.55 (0.88)	−4.36 (1.25)	6,821	39	0.14	3.55 (0.60)	0.37 (0.88)	−3.86 (1.15)	6,821	39	0.14
TFPR: productivity												
Baseline	2.01 (0.33)	−0.01 (0.38)	−1.45 (0.47)	6,048	39	0.26	2.05 (0.29)	−0.07 (0.38)	−1.31 (0.43)	6,048	39	0.26
Available endpoints	2.08 (0.35)	0.02 (0.36)	−1.36 (0.45)	6,451	39	0.26	2.12 (0.30)	−0.04 (0.36)	−1.23 (0.42)	6,451	39	0.26
Uncapped news	1.34 (0.29)	0.04 (0.38)	−1.36 (0.47)	6,048	39	0.25	1.76 (0.27)	−0.07 (0.38)	−1.25 (0.43)	6,048	39	0.26
Uncapped outcome	2.08 (0.34)	−0.02 (0.40)	−1.53 (0.48)	6,048	39	0.25	2.15 (0.30)	−0.09 (0.40)	−1.39 (0.44)	6,048	39	0.25
Markups: margins												
Baseline	2.03 (0.59)	−0.03 (0.83)	−1.24 (0.77)	7,092	40	0.17	2.16 (0.54)	−0.13 (0.84)	−1.01 (0.71)	7,092	40	0.17
Available endpoints	2.09 (0.60)	−0.18 (0.84)	−1.36 (0.78)	7,179	40	0.17	2.22 (0.55)	−0.29 (0.85)	−1.10 (0.72)	7,179	40	0.18
Uncapped news	0.96 (0.54)	−0.04 (0.83)	−1.12 (0.77)	7,092	40	0.17	1.59 (0.52)	−0.22 (0.84)	−0.91 (0.71)	7,092	40	0.17
Uncapped outcome	3.57 (2.32)	−0.41 (3.05)	−3.81 (3.18)	7,092	40	0.02	3.54 (2.23)	−0.84 (3.18)	−2.96 (3.13)	7,092	40	0.02

Notes: News is dated $t-1$; outcomes change from t to $t+h$. Outcome definitions, controls, units, and baseline samples follow Tables D1 and D2. Available endpoints requires only the displayed horizon; Baseline requires all three. Uncapped news and Uncapped outcome omit the respective annual 1st/99th-percentile winsorization on the baseline sample. All five channels enter; supplier/customer coefficients are omitted. Rivalry denotes a loss. Parentheses report two-way firm/year clustered SEs.

TABLE D10: Innovation news before the baseline fiscal close

News timing	Sales			Operating earnings			TFPR		
	Year t Full sample	Year t Common sample	Year $t-1$ Common sample	Year t Full sample	Year t Common sample	Year $t-1$ Common sample	Year t Full sample	Year t Common sample	Year $t-1$ Common sample
Panel A: Patents									
Own	1.13 (0.33)	0.93 (0.32)	0.90 (0.33)	3.61 (0.49)	3.50 (0.49)	3.38 (0.49)	2.00 (0.25)	2.00 (0.25)	1.87 (0.26)
Technology	−0.10 (0.49)	−0.12 (0.49)	−0.41 (0.50)	0.21 (0.58)	0.23 (0.58)	−0.14 (0.67)	−0.04 (0.27)	−0.05 (0.27)	−0.04 (0.28)
Rivalry loss	−2.96 (0.77)	−2.92 (0.76)	−3.42 (0.64)	−3.21 (1.02)	−3.25 (1.02)	−3.17 (1.00)	−1.25 (0.38)	−1.24 (0.38)	−1.08 (0.38)
Firms	9,742	9,692	9,692	6,854	6,821	6,821	6,056	6,048	6,048
Years	39	39	39	39	39	39	39	39	39
R^2	0.10	0.11	0.11	0.15	0.15	0.15	0.22	0.22	0.22
Panel B: Claims									
Own	1.21 (0.30)	1.02 (0.29)	1.00 (0.30)	3.69 (0.43)	3.58 (0.43)	3.42 (0.43)	1.98 (0.22)	1.98 (0.22)	1.85 (0.23)
Technology	−0.18 (0.50)	−0.19 (0.50)	−0.49 (0.51)	0.04 (0.58)	0.05 (0.58)	−0.31 (0.67)	−0.10 (0.27)	−0.10 (0.27)	−0.09 (0.29)
Rivalry loss	−2.72 (0.73)	−2.67 (0.71)	−3.19 (0.59)	−2.82 (0.96)	−2.86 (0.96)	−2.81 (0.93)	−1.14 (0.35)	−1.13 (0.35)	−0.97 (0.35)
Firms	9,742	9,692	9,692	6,854	6,821	6,821	6,056	6,048	6,048
Years	39	39	39	39	39	39	39	39	39
R^2	0.10	0.11	0.11	0.15	0.15	0.15	0.22	0.22	0.22

Notes: Outcomes are three-year log changes ×100. Within each outcome, the first column uses year-t news on the full sample; the next two compare year-t and year-$t-1$ news on identical observations. News is divided by mean equity in its year. All five channels, financial controls, coverage indicators, and industry and year effects enter; network masses follow the news year and interact with year. Supplier/customer coefficients are omitted. Parentheses report two-way firm/year clustered SEs.

TABLE D11: Fitted innovation contributions to sales, employment and earnings growth

	Sales			Employment			Operating earnings			Net income		
Fitted terms omitted	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years	1 year	3 years	5 years
Panel A: Patents												
Own	0.45	0.67	0.62	0.29	0.56	0.57	4.59	2.59	1.68	7.62	4.12	2.57
Technology	−0.46	−0.44	−0.11	0.08	0.22	0.32	−0.88	−0.16	0.37	0.52	0.68	1.40
Rivalry	−1.19	−1.27	−1.05	−0.52	−0.48	−0.47	−2.49	−1.37	−1.22	−2.68	−2.14	−1.50
Suppliers	0.02	0.09	0.02	−0.06	0.01	−0.02	−0.02	0.04	−0.04	−0.13	−0.21	−0.26
Customers	−0.07	−0.04	−0.02	0.01	0.02	0.04	−0.23	−0.12	−0.09	−0.28	−0.12	−0.11
All external, jointly	−1.71	−1.71	−1.18	−0.48	−0.23	−0.11	−3.68	−1.64	−0.94	−2.56	−1.72	−0.26
All five, jointly	−1.24	−0.98	−0.50	−0.18	0.34	0.47	1.22	1.17	0.87	5.42	2.76	2.36
Observed growth	2.79	3.12	3.07	2.13	2.18	2.03	3.88	4.21	4.08	5.80	6.40	6.29
Panel B: Claims												
Own	0.64	0.88	0.82	0.37	0.65	0.68	5.42	3.09	2.09	9.15	4.81	3.16
Technology	−0.65	−0.58	−0.20	0.09	0.25	0.34	−1.39	−0.40	0.26	−0.15	0.42	1.32
Rivalry	−1.33	−1.38	−1.11	−0.57	−0.52	−0.52	−2.59	−1.41	−1.27	−2.87	−2.35	−1.62
Suppliers	0.04	0.09	0.02	−0.06	0.01	−0.01	0.02	0.06	−0.03	−0.04	−0.14	−0.22
Customers	−0.09	−0.05	−0.02	0.00	0.01	0.04	−0.25	−0.13	−0.09	−0.29	−0.14	−0.12
All external, jointly	−2.04	−1.96	−1.34	−0.54	−0.24	−0.13	−4.30	−1.92	−1.12	−3.38	−2.17	−0.44
All five, jointly	−1.38	−1.00	−0.44	−0.16	0.42	0.55	1.51	1.45	1.14	6.29	3.12	2.81
Observed growth	2.79	3.12	3.07	2.13	2.18	2.03	3.88	4.21	4.08	5.80	6.40	6.29
Firms	9,692	9,692	9,692	9,724	9,724	9,724	6,821	6,821	6,821	5,166	5,166	5,166
Years	39	39	39	39	39	39	39	39	39	39	39	39

Notes: News is measured in calendar year $t-1$, ending before the baseline fiscal close; growth runs from t to $t+h$. Financial controls remain at the baseline. Technology, rivalry, supplier and customer network masses enter interacted with year. Entries are annualized percentage points. Each row reports the change in fitted growth when the indicated channel terms are omitted from each firm's prediction, holding all other terms fixed. Each fitted term is the estimate of δ_h^c in equation (7) times the channel's news as a fraction of equity. The firm-level difference is the initial outcome times the exponential of fitted growth before the removal, less the initial outcome times the exponential of fitted growth after it. Sum differences within base year, divide by initial aggregate outcome and the horizon, multiply by 100, and average over 1981–2019. Endpoints extend through 2024. Each outcome uses the same observations across horizons and activities. Individual removals need not sum to joint removals because the mapping to levels is nonlinear. Rivalry retains its fitted sign. Operating earnings are OIBDP. Earnings samples require positive observed earnings at the baseline and one-, three- and five-year endpoints; they exclude loss-makers. All values are conditional fitted contributions among covered surviving firms, not causal GDP, welfare or total corporate-profit shares.

D.4 Price-to-earnings ratios, subsequent earnings, and the content of innovation

D.4.1 Timing, sample, and controls

The one- and five-year regressions extend equation (8), using its earnings definition, fiscal-close valuation, controls, and inference. Samples require the relevant future earnings endpoint, rather than observations at all three horizons. Utilities and financial firms are excluded. News is summed between consecutive fiscal closes. Reported growth is annualized by h; changes in fiscal year-end can make elapsed time differ from h calendar years.

Coverage controls span the preceding one and five fiscal years. Following David et al. (2022), the discount rate adds to the risk-free rate the expected excess return implied by Fama–French exposures estimated over 40 consecutive quarters. Post-2019 exposures use the earlier estimated prices of risk.

TABLE D12: Sequential P/E decomposition and 1-year earnings growth

Dependent variable: Annualized log growth in street earnings

	(1) P/E	(2) Prior/change	(3) Own split	(4) External split	(5) Full split
Log P/E	0.51				
	(0.02)				
Prior equity		0.50	0.50	0.51	0.51
		(0.02)	(0.02)	(0.02)	(0.02)
Total change in equity		0.52			
		(0.02)			
Own innovation			0.46		0.65
			(0.13)		(0.12)
Technology				0.51	0.49
				(0.05)	(0.05)
Rivalry				−0.94	−0.95
				(0.11)	(0.11)
Remaining change in equity			0.52	0.53	0.53
			(0.02)	(0.02)	(0.02)
Supplier/customer terms	No	No	No	Yes	Yes
Firms	3,247	3,247	3,247	3,247	3,247
Years	43	43	43	43	43
R^2	0.25	0.25	0.25	0.25	0.25

Notes: Patents; annualized one-year street-earnings growth. Column definitions, valuation components, controls, and inference follow Table 5; only the horizon and its eligible sample change. All columns use the same firm-years. Rivalry enters as a positive loss. Supplier and customer components enter columns (4) and (5), but their coefficients are not displayed. Parentheses report two-way firm/fiscal-year clustered standard errors.

TABLE D13: Sequential P/E decomposition and 5-year earnings growth

Dependent variable: Annualized log growth in street earnings

	(1) P/E	(2) Prior/change	(3) Own split	(4) External split	(5) Full split
Log P/E	0.14				
	(0.00)				
Prior equity		0.15	0.15	0.15	0.15
		(0.00)	(0.00)	(0.00)	(0.00)
Total change in equity		0.14			
		(0.01)			
Own innovation			0.21		0.24
			(0.04)		(0.04)
Technology				0.18	0.16
				(0.03)	(0.03)
Rivalry				−0.27	−0.27
				(0.04)	(0.04)
Remaining change in equity			0.14	0.14	0.14
			(0.01)	(0.00)	(0.00)
Supplier/customer terms	No	No	No	Yes	Yes
Firms	2,415	2,415	2,415	2,415	2,415
Years	39	39	39	39	39
R^2	0.24	0.24	0.24	0.24	0.24

Notes: Patents; annualized five-year street-earnings growth. Column definitions, valuation components, controls, and inference follow Table 5; only the horizon and its eligible sample change. All columns use the same firm-years. Rivalry enters as a positive loss. Supplier and customer components enter columns (4) and (5), but their coefficients are not displayed. Parentheses report two-way firm/fiscal-year clustered standard errors.

D.4.2 Average fitted contributions

The contribution of each innovation channel is calculated from the full valuation-share specification in equation (8). With signed components, its equal-weight mean is

$$\overline{C}_h^c = \frac{100}{N_h} \sum_{(i,t)\in\mathcal{S}_h} \widehat{\beta}_h^c A_{it}^c, \qquad \overline{C}_h^{\text{all}} = \sum_c \overline{C}_h^c. \tag{D1}$$

Here $\mathcal{S}_h$ is the estimation sample and N_h its number of firm-years. A common slope produces different contributions because firms have different valuation components. The table averages those products equally across firm-years and reports percentage points of annual log earnings growth. The total includes all five innovation channels and excludes prior equity, remaining change, controls, and fixed effects. It is a component of predicted growth, not total predicted growth or a causal effect of deleting innovation. No adjusted-P/E slope is subtracted.

TABLE D14: Fitted earnings-growth contributions from the sequential P/E decomposition

Percentage points of annual log earnings growth

	(1) 1 year	(2) 3 years	(3) 5 years
Own innovation	1.35	0.82	0.55
	(0.25)	(0.13)	(0.09)
Technology	2.87	1.39	0.89
	(0.31)	(0.18)	(0.14)
Rivalry	−4.00	−1.62	−1.05
	(0.45)	(0.20)	(0.16)
Suppliers	0.04	0.01	0.01
	(0.03)	(0.02)	(0.01)
Customers	0.11	0.04	0.01
	(0.09)	(0.06)	(0.05)
All innovation channels	0.37	0.64	0.41
	(0.57)	(0.29)	(0.22)
Firms	3,247	2,746	2,415
Years	43	41	39

Notes: Patents. Entries average each channel's coefficient times its valuation-share component across estimation firm-years, using column (5) of Tables D12, 5, and D13. Signed contributions sum across channels. Parentheses report SEs from the joint coefficient covariance, conditional on component means and estimated patent values. These are fitted earnings-growth contributions.

D.4.3 Alternative log-P/E allocation

An alternative allocation measures the log-valuation difference associated with removing the signed sum of recorded innovation dollars from fiscal-close equity. Define

$$I_{it} = \sum_c \widehat{\Delta V}^c_{it} \qquad V^0_{it} = V_{it} - I_{it} \qquad Z^c_{it} = \widehat{\Delta V}^c_{it} \frac{\log(V_{it}/V^0_{it})}{I_{it}} \tag{D2}$$

At $I_{it} = 0$, the continuous limit is $Z^c_{it} = \widehat{\Delta V}^c_{it}/V_{it}$. For $V^0_{it} > 0$, the identity is

$$\log(V_{it}/E_{it}) = \log(V^0_{it}/E_{it}) + \sum_c Z^c_{it} \tag{D3}$$

Table D15 compares ordinary P/E with a regression containing adjusted log P/E and all five Z^c components jointly. It retains the same fiscal windows, samples, and controls as the sequential exercise. It changes the component definitions, so its coefficients and contributions are not interchangeable with the valuation-share decomposition in the previous tables.

TABLE D15: Alternative log-P/E decomposition: patents

Dependent variable: Annualized log growth in street earnings

	1 year		3 years		5 years	
	(1)	(2)	(3)	(4)	(5)	(6)
	P/E	Log allocation	P/E	Log allocation	P/E	Log allocation
Log P/E	0.506		0.223		0.144	
	(0.016)		(0.007)		(0.005)	
Adjusted log P/E		0.508		0.224		0.144
		(0.016)		(0.007)		(0.005)
Own innovation		0.855		0.649		0.435
		(0.316)		(0.134)		(0.092)
Technology		0.536		0.296		0.205
		(0.143)		(0.076)		(0.063)
Rivalry		−1.849		−0.622		−0.438
		(0.350)		(0.149)		(0.116)
Firms	3,247	3,247	2,746	2,746	2,415	2,415
Years	43	43	41	41	39	39
R^2	0.25	0.25	0.26	0.26	0.24	0.24

Notes: Even-numbered columns use adjusted log P/E and the five Z^c components defined above, rather than the valuation shares in Table 5. Samples and controls are identical within each horizon. Outcomes are annualized log growth in positive IBES street earnings. Rivalry enters as a positive loss; supplier/customer coefficients are omitted. Parentheses report two-way firm/fiscal-year clustered standard errors, conditional on estimated news and discount rates.

D.4.4 Comparison with the ordinary P/E benchmark

Ordinary P/E predicts earnings growth with magnitudes close to those reported by Boppart et al. (2026). Table D16 compares the annualized slopes with their Appendix Table A2. The samples and controls differ, so the comparison establishes similarity in scale rather than replication.

TABLE D16: Price-to-earnings ratios and annualized earnings growth

Dependent variable: annualized log growth in street earnings

Horizon	BKLL	This paper
1 year	0.447	0.506
	(0.006)	(0.016)
3 years	0.197	0.223
	(0.003)	(0.007)
5 years	0.129	0.144
	(0.002)	(0.005)

Notes: Coefficients on log P/E; standard errors in parentheses. The BKLL column reports estimates from Boppart et al. (2026), Appendix Table A2, for all industries. Both specifications include calendar-year and fiscal-end-month effects and a discount-rate cubic. This paper excludes financial and utility firms and adds financial and coverage controls described in Appendix D.4; its standard errors are two-way clustered by firm and fiscal year. Coefficients and standard errors are annualized at every horizon.

D.5 From micro to macro: Prices, output, and productivity

The sector results extend equation (10) to one-, three-, and five-year horizons and both patent and claim measures. BEA GDP by Industry Tables 18, 23, 16, and 8 supply gross-output and intermediate-input prices, real gross output, and real value added, respectively (October 2026 release). TFP comes from the April 2026 BEA-BLS industry production account. BEA outcomes end in 2025 and TFP in 2024. Rebasing the published 2017 indices to 1997 leaves growth rates and innovation slopes unchanged under sector effects.

Prices, output, and value added cover 57 private-sector industries at one and three years and 56 at five years, excluding utilities, finance, insurance, and real estate. TFP covers 51 and 50 industries, respectively. Exact TFP matches exclude finer retail, hospital, and nursing-care groups available only as combined series. These industries differ from the broad groups used to report corporate valuations.

Equation (9) uses dated operating SIC codes for eligibility and segment sales for industry allocation, with company classification for missing segments and unallocated sales. Official NAICS concordances resolve remaining codes only when they identify one BEA sector. Sales use the latest eligible twelve-month statement ending in the news year. Firms without sales are excluded; missing capitalization or channel information does not remove other measured contributions or trigger weight renormalization.

Tables D17 and D18 use identical sector–years within each outcome and horizon. Prices, output, and value added share observations; TFP has separate coverage. Pre-news controls require base years from 2000, and matched comparisons exclude rows without prior-year indices. Longer horizons end earlier; firms contributing news need not survive to the outcome endpoint. All equations include five channels, sector and year effects, equal sector–year weights, and four sales-weighted network controls with slopes common across years. Two-way cluster-jackknife inference adds sector and year covariances and subtracts their intersection, conditional on return coefficients, networks, and sales allocation.

Table D20 compares news and control timing on identical observations. Current outcome levels at t can already reflect news from $t-1$; the main specification uses levels at $t-2$. Table D19 isolates adding that pre-news outcome level. Without it, output and TFP coefficients remain positive, but only TFP is distinguishable from zero at five percent for patents; prices and value added are also imprecise.

TABLE D17: Prior innovation news and subsequent sector outcomes: patents

Dependent variable: Cumulative log growth ×100

Horizon	Output prices	Real gross output	Real value added	TFP
Own				
1 year	−0.08 (0.18)	−0.08 (0.35)	0.43 (0.33)	0.09 (0.15)
3 years	−0.32 (0.47)	−0.68 (0.90)	0.87 (0.71)	0.30 (0.41)
5 years	−0.05 (0.79)	−0.59 (1.27)	0.71 (1.09)	0.34 (0.66)
Technology				
1 year	0.10 (0.53)	−0.18 (0.31)	−0.83 (0.41)	−0.38 (0.11)
3 years	−0.34 (1.04)	−0.74 (0.89)	−1.80 (0.90)	−0.75 (0.45)
5 years	−2.01 (1.28)	−1.89 (1.43)	−2.46 (1.35)	−1.16 (0.91)
Rivalry loss				
1 year	−0.91 (0.40)	2.27 (0.76)	2.57 (0.83)	1.01 (0.24)
3 years	−2.06 (1.07)	5.66 (1.59)	6.07 (1.95)	2.52 (0.76)
5 years	−3.54 (1.70)	10.00 (2.68)	10.72 (2.89)	4.50 (1.21)
R^2				
1 year	0.26	0.39	0.24	0.20
3 years	0.48	0.54	0.42	0.45
5 years	0.64	0.68	0.61	0.62
Years				
1 year	25	25	25	24
3 years	23	23	23	22
5 years	21	21	21	20
Industries				
1 year	57	57	57	51
3 years	57	57	57	51
5 years	56	56	56	50
Base years				
1 year	2000–2024	2000–2024	2000–2024	2000–2023
3 years	2000–2022	2000–2022	2000–2022	2000–2021
5 years	2000–2020	2000–2020	2000–2020	2000–2019

Notes: The four sales-weighted network masses enter as controls. News is dated $t-1$; outcomes are cumulative log changes ×100 from t to $t+h$. All five indices enter jointly; supplier and customer coefficients are omitted. Controls include growth ending in $t-2$, sales concentration in $t-2$, each outcome's own log level in $t-2$, as in equation (10). All regressions include sector and year effects. Coefficients are per percentage point of the sales-weighted news index. Parentheses report ordinary two-way sector/year cluster-jackknife standard errors, conditional on the return coefficients. R^2 includes fixed effects.

TABLE D18: Prior innovation news and subsequent sector outcomes: claims

Dependent variable: Cumulative log growth ×100

Horizon	Output prices	Real gross output	Real value added	TFP
Own				
1 year	0.04 (0.30)	0.04 (0.32)	0.44 (0.46)	0.04 (0.20)
3 years	−0.20 (0.55)	−0.76 (0.86)	0.60 (0.77)	0.07 (0.44)
5 years	0.28 (0.82)	−0.45 (1.21)	0.43 (1.18)	0.10 (0.77)
Technology				
1 year	0.10 (0.55)	−0.18 (0.29)	−0.78 (0.43)	−0.34 (0.12)
3 years	−0.38 (1.09)	−0.74 (0.85)	−1.68 (0.92)	−0.62 (0.44)
5 years	−2.17 (1.32)	−2.06 (1.38)	−2.48 (1.34)	−1.07 (0.92)
Rivalry loss				
1 year	−0.87 (0.33)	2.06 (0.67)	2.38 (0.74)	0.91 (0.20)
3 years	−1.87 (0.96)	5.19 (1.37)	5.72 (1.74)	2.31 (0.64)
5 years	−3.08 (1.57)	9.22 (2.29)	10.00 (2.47)	4.12 (1.06)
R^2				
1 year	0.26	0.40	0.24	0.20
3 years	0.48	0.54	0.42	0.45
5 years	0.64	0.68	0.61	0.62
Years				
1 year	25	25	25	24
3 years	23	23	23	22
5 years	21	21	21	20
Industries				
1 year	57	57	57	51
3 years	57	57	57	51
5 years	56	56	56	50
Base years				
1 year	2000–2024	2000–2024	2000–2024	2000–2023
3 years	2000–2022	2000–2022	2000–2022	2000–2021
5 years	2000–2020	2000–2020	2000–2020	2000–2019

Notes: The four sales-weighted network masses enter as controls. News is dated $t-1$; outcomes are cumulative log changes ×100 from t to $t+h$. All five indices enter jointly; supplier and customer coefficients are omitted. Controls include growth ending in $t-2$, sales concentration in $t-2$, each outcome's own log level in $t-2$, as in equation (10). All regressions include sector and year effects. Coefficients are per percentage point of the sales-weighted news index. Parentheses report ordinary two-way sector/year cluster-jackknife standard errors, conditional on the return coefficients. R^2 includes fixed effects.

TABLE D19: Pre-news level controls and three-year sector outcomes

Dependent variable: 3-year cumulative log growth ×100

	Output prices		Real gross output		Real value added		TFP	
Level controls	Without	With	Without	With	Without	With	Without	With
Panel A: Patents								
Own	−0.00 (0.65)	−0.32 (0.47)	−0.25 (1.29)	−0.68 (0.90)	0.91 (0.94)	0.87 (0.71)	0.45 (0.45)	0.30 (0.41)
Technology	0.84 (0.93)	−0.34 (1.04)	−1.29 (1.14)	−0.74 (0.89)	−3.07 (1.37)	−1.80 (0.90)	−1.60 (0.74)	−0.75 (0.45)
Rivalry loss	−0.86 (1.05)	−2.06 (1.07)	2.92 (1.43)	5.66 (1.59)	3.49 (1.78)	6.07 (1.95)	2.28 (0.86)	2.52 (0.76)
Own-outcome level, $t-2$	—	−0.32 (0.10)	—	−0.22 (0.06)	—	−0.21 (0.07)	—	−0.20 (0.05)
R^2	0.40	0.48	0.49	0.54	0.38	0.42	0.40	0.45
Panel B: Claims								
Own	0.05 (0.81)	−0.20 (0.55)	−0.29 (1.20)	−0.76 (0.86)	0.74 (1.01)	0.60 (0.77)	0.36 (0.50)	0.07 (0.44)
Technology	0.91 (0.98)	−0.38 (1.09)	−1.30 (1.07)	−0.74 (0.85)	−3.05 (1.39)	−1.68 (0.92)	−1.56 (0.78)	−0.62 (0.44)
Rivalry loss	−0.81 (0.99)	−1.87 (0.96)	2.83 (1.25)	5.19 (1.37)	3.48 (1.64)	5.72 (1.74)	2.15 (0.79)	2.31 (0.64)
Own-outcome level, $t-2$	—	−0.31 (0.10)	—	−0.22 (0.06)	—	−0.21 (0.07)	—	−0.20 (0.05)
R^2	0.40	0.48	0.49	0.54	0.38	0.42	0.40	0.45
Industries	57	57	57	57	57	57	51	51
Years	23	23	23	23	23	23	22	22
Base years	2000–2022	2000–2022	2000–2022	2000–2022	2000–2022	2000–2022	2000–2021	2000–2021

Notes: The four sales-weighted network masses enter as controls (Section 6). News is dated $t-1$; growth runs from t to $t+3$. The two columns within each outcome use identical sector–years and all five news indices, with growth controls ending in $t-2$, sales concentration in $t-2$, and sector and year effects. Supplier and customer coefficients are omitted. With-level columns add only $100 \log Y_{s,t-2}$ for the outcome in that equation. Dashes indicate excluded controls. Parentheses report two-way sector/year cluster-jackknife standard errors, conditional on the return coefficients.

TABLE D20: News timing and outcome-level controls: three-year sector outcomes

Dependent variable: 3-year cumulative log growth ×100

	Output prices	Real gross output	Real value added	TFP
Panel A: Rivalry loss, patents				
Current news, no levels	−1.31 (1.10)	3.29 (1.32)	4.46 (1.63)	2.63 (0.82)
Prior news, no levels	−1.13 (1.09)	3.11 (1.49)	3.80 (1.80)	2.37 (0.86)
Current news, outcome level	−3.26 (1.44)	7.45 (1.84)	9.42 (2.00)	3.39 (1.11)
Prior news, outcome level	−3.25 (1.43)	7.76 (1.99)	9.48 (2.10)	3.22 (1.16)
Prior news, pre-news controls	−0.86 (1.05)	2.92 (1.43)	3.49 (1.78)	2.28 (0.86)
Prior news, pre-news controls + outcome level	−2.06 (1.07)	5.66 (1.59)	6.07 (1.95)	2.52 (0.76)
Panel B: Rivalry loss, claims				
Current news, no levels	−1.34 (1.02)	3.16 (1.12)	4.34 (1.51)	2.43 (0.75)
Prior news, no levels	−1.09 (1.03)	3.00 (1.31)	3.80 (1.68)	2.24 (0.80)
Current news, outcome level	−3.15 (1.29)	6.80 (1.65)	8.76 (1.85)	3.09 (0.94)
Prior news, outcome level	−3.04 (1.30)	7.06 (1.73)	8.85 (1.90)	2.95 (0.97)
Prior news, pre-news controls	−0.81 (0.99)	2.83 (1.25)	3.48 (1.64)	2.15 (0.79)
Prior news, pre-news controls + outcome level	−1.87 (0.96)	5.19 (1.37)	5.72 (1.74)	2.31 (0.64)
Industries	57	57	57	51
Years	23	23	23	22
Base years	2000–2022	2000–2022	2000–2022	2000–2021

Notes: The four sales-weighted network masses enter as controls (Section 6). Each cell reports the rivalry-loss coefficient; all five indices enter jointly with sector and year effects. Rows use identical sector–years within each outcome. Current and prior news refer to t and $t-1$. The first four rows use growth controls ending in $t-1$ and sales concentration in $t-1$; outcome level is the equation's log outcome in t. The final two rows move growth controls and sales concentration back one year to $t-2$; the final row adds only the outcome's own log level in $t-2$. Log levels are multiplied by 100. Parentheses report ordinary two-way sector/year cluster-jackknife standard errors, conditional on the return coefficients.

Alternative capitalization denominators Tables D21 and D22 compare June-end and year-end equity using prior-year patent news, pre-news growth controls and the outcome's own pre-news level, and sales-weighted network masses. Within this comparison, annual dollar numerators, original segment-sales weights, sector–year rows, controls, and inference remain fixed. Contributing firms must have positive equity at the December close preceding the news year and at its June and December closes under both alternatives; sales weights are not renormalized. The comparison retains the former observed sector–years where prior-year news and pre-news controls are available. Rivalry retains positive coefficients for real output, value added, and TFP. Year-end normalization makes the three-year output and value-added estimates less precise. Mean equity remains the main denominator.

TABLE D21: June-end capitalization and subsequent sector outcomes: patents

Dependent variable: Cumulative log growth ×100

Horizon	Output prices	Real gross output	Real value added	TFP
Own				
1 year	−0.03 (0.17)	−0.14 (0.30)	0.24 (0.32)	0.06 (0.15)
3 years	−0.25 (0.44)	−0.85 (0.87)	0.44 (0.65)	0.20 (0.33)
5 years	0.01 (0.78)	−0.76 (1.28)	0.33 (1.07)	0.21 (0.55)
Technology				
1 year	−0.02 (0.52)	−0.14 (0.31)	−0.50 (0.39)	−0.27 (0.16)
3 years	−0.30 (0.91)	−0.76 (0.79)	−1.74 (0.75)	−0.76 (0.37)
5 years	−1.88 (1.25)	−1.90 (1.35)	−2.39 (1.20)	−0.96 (0.83)
Loss from rivalry				
1 year	−0.86 (0.37)	2.16 (0.71)	2.37 (0.76)	0.94 (0.25)
3 years	−2.12 (1.03)	5.38 (1.49)	5.71 (1.92)	2.45 (0.73)
5 years	−3.56 (1.69)	9.69 (2.30)	10.45 (2.59)	4.27 (1.27)
Years				
1 year	25	25	25	24
3 years	23	23	23	22
5 years	21	21	21	20
Industries				
1 year	57	57	57	51
3 years	57	57	57	51
5 years	56	56	56	50
Base years				
1 year	2000–2024	2000–2024	2000–2024	2000–2023
3 years	2000–2022	2000–2022	2000–2022	2000–2021
5 years	2000–2020	2000–2020	2000–2020	2000–2019

Notes: The four sales-weighted network masses enter as controls (Section 6). Each outcome and horizon is a separate regression. Annual own or received patent-innovation dollars are divided by equity at the last trading close of June in news year $t-1$ and multiplied by 100. Loss from rivalry is positive for a loss. All five channels enter jointly; supplier and customer coefficients are omitted. Firm news is aggregated with the news-year ($t-1$) segment-sales weights. The June and December alternatives (this table and Table D22) require positive capitalization at December $t-2$, June $t-1$, and December $t-1$; sales weights are not renormalized. News is dated $t-1$ and growth runs from t to $t+h$. Growth controls end in $t-2$; sales concentration and the outcome's own log level are dated $t-2$. Value-added and TFP equations include their own prior growth. Sector and year effects are included. Parentheses report ordinary two-way sector/year cluster-jackknife standard errors, conditional on the return coefficients.

TABLE D22: Year-end capitalization and subsequent sector outcomes: patents

Dependent variable: Cumulative log growth ×100

Horizon	Output prices	Real gross output	Real value added	TFP
Own				
1 year	0.09 (0.15)	−0.28 (0.48)	0.35 (0.60)	0.08 (0.14)
3 years	−0.08 (0.51)	−0.29 (0.88)	1.45 (1.07)	0.31 (0.31)
5 years	0.48 (0.73)	0.01 (1.09)	1.42 (1.53)	0.44 (0.48)
Technology				
1 year	−0.00 (0.25)	−0.13 (0.30)	−0.44 (0.40)	−0.27 (0.11)
3 years	−0.28 (0.46)	−0.47 (0.76)	−1.34 (0.86)	−0.73 (0.37)
5 years	−0.94 (0.67)	−1.90 (1.08)	−2.52 (1.39)	−0.97 (0.77)
Loss from rivalry				
1 year	−0.27 (0.60)	1.39 (1.02)	1.48 (1.14)	0.74 (0.42)
3 years	−1.18 (1.72)	3.39 (2.08)	3.70 (2.38)	2.38 (0.67)
5 years	−3.49 (1.71)	7.89 (2.23)	8.27 (2.51)	3.26 (1.09)
Years				
1 year	25	25	25	24
3 years	23	23	23	22
5 years	21	21	21	20
Industries				
1 year	57	57	57	51
3 years	57	57	57	51
5 years	56	56	56	50
Base years				
1 year	2000–2024	2000–2024	2000–2024	2000–2023
3 years	2000–2022	2000–2022	2000–2022	2000–2021
5 years	2000–2020	2000–2020	2000–2020	2000–2019

Notes: The four sales-weighted network masses enter as controls (Section 6). Each outcome and horizon is a separate regression. Annual own or received patent-innovation dollars are divided by equity at the last trading close of December in news year $t-1$ and multiplied by 100. Loss from rivalry is positive for a loss. All five channels enter jointly; supplier and customer coefficients are omitted. Firm news is aggregated with the news-year ($t-1$) segment-sales weights. The June and December alternatives (this table and Table D21) require positive capitalization at December $t-2$, June $t-1$, and December $t-1$; sales weights are not renormalized. News is dated $t-1$ and growth runs from t to $t+h$. Growth controls end in $t-2$; sales concentration and the outcome's own log level are dated $t-2$. Value-added and TFP equations include their own prior growth. Sector and year effects are included. Parentheses report ordinary two-way sector/year cluster-jackknife standard errors, conditional on the return coefficients.

TABLE D23: Sector outcomes with sequential innovation channels

Dependent variable: 3-year cumulative log growth ×100

	(1) Own	(2) Own + Technology	(3) Own + Rivalry	(4) Own + Supply chain	(5) Own + Technology + Rivalry	(6) All five
Panel A: Output prices						
Own	−0.95 (0.54)	−0.43 (0.44)	−0.37 (0.42)	−0.98 (0.55)	−0.29 (0.44)	−0.32 (0.47)
Technology	—	−1.23 (1.02)	—	—	−0.36 (1.05)	−0.34 (1.04)
Rivalry loss	—	—	−2.33 (1.19)	—	−2.05 (1.10)	−2.06 (1.07)
R^2	0.47	0.48	0.48	0.47	0.48	0.48
Panel B: Real gross output						
Own	0.44 (0.73)	−0.25 (0.89)	−0.92 (0.75)	0.47 (0.70)	−0.73 (0.90)	−0.68 (0.90)
Technology	—	1.47 (0.99)	—	—	−0.74 (0.89)	−0.74 (0.89)
Rivalry loss	—	—	5.02 (1.45)	—	5.62 (1.60)	5.66 (1.59)
R^2	0.52	0.52	0.54	0.52	0.54	0.54
Panel C: Real value added						
Own	1.45 (0.62)	1.24 (0.67)	0.32 (0.49)	1.51 (0.59)	0.78 (0.64)	0.87 (0.71)
Technology	—	0.49 (1.18)	—	—	−1.91 (0.93)	−1.80 (0.90)
Rivalry loss	—	—	4.87 (1.89)	—	6.30 (1.91)	6.07 (1.95)
R^2	0.40	0.40	0.42	0.41	0.42	0.42
Panel D: TFP						
Own	0.58 (0.32)	0.41 (0.42)	0.11 (0.36)	0.61 (0.32)	0.27 (0.40)	0.30 (0.41)
Technology	—	0.41 (0.45)	—	—	−0.73 (0.42)	−0.75 (0.45)
Rivalry loss	—	—	1.95 (0.70)	—	2.52 (0.73)	2.52 (0.76)
R^2	0.43	0.43	0.45	0.43	0.45	0.45
Supplier and customer controls	No	No	No	Yes	No	Yes
Industries (A–C / D)	57 / 51	57 / 51	57 / 51	57 / 51	57 / 51	57 / 51
Years (A–C / D)	23 / 22	23 / 22	23 / 22	23 / 22	23 / 22	23 / 22

Notes: The four sales-weighted network masses enter as controls. Patents. News is dated $t-1$; growth runs from t to $t+3$. Each panel holds observations, pre-news growth and concentration controls, each outcome's own pre-news level, and sector and year effects fixed across columns. Supplier and customer exposures enter in columns (4) and (6); their coefficients are omitted. Coefficients are per percentage point of the sales-weighted news index; rivalry is positive for a loss. Parentheses report ordinary two-way sector/year cluster-jackknife SEs, conditional on return coefficients. Base years are 2000–2022 in Panels A–C and 2000–2021 in Panel D. Column (6) reproduces Table 6.

E The model: proofs

E.1 Firm value and the steady state

Proof of Lemma 1. Values are measured per dollar of the sales of a product of sector s, $\lambda_s Y$, which on a steady state grow with output, so they are discounted at ρ. A firm's state is the list of the products that it holds, each led or neck and neck and each with or without fresh ideas. Each product brings the firm its own events. Another firm or an entrant takes it at the rate h_s; a lead diffuses at the rate δ; the holder of a neck-and-neck product escapes at the rate ζ^o or ζ^{of} that it chooses, by whether the product's research has fresh ideas, and keeps them after the escape; the research on the product receives fresh ideas at the rate a_s and loses them at the rate ν; and the firm's external research on the product succeeds at the rate ζ that it chooses, adding a led product whose research has no fresh ideas. A leader runs no internal research, which would leave its lead at one step and earn nothing.

Conjecture that the firm's value is the sum, over the products that it holds, of $V(\iota) + W(\iota)$, as in (21). Under the conjecture each event changes the firm's value by the change in the term of one product: a takeover by $-[V(\iota) + W(\iota)]$, diffusion by $-(V_1 - V_0)$ or $-(V_1^f - V_0^f)$, an escape by $V_1 - V_0$ or $V_1^f - V_0^f$, the arrival of fresh ideas by $V^f(\iota) - V(\iota) + W_s^f - W_s$, their obsolescence by the opposite change, and a success of external research by $v_s = V_1 + W_s$. Substituting these changes into the firm's Bellman equation makes it a sum over the firm's products of the same terms, so it holds for every list of products if and only if the values of each product solve (17) and (18). Each bracket in these equations is strictly concave, so the maximizing rates are (19), and at these rates the brackets equal

$$\frac{\phi}{1+\phi}\,\chi^{-1/\phi}(V_1 - V_0)^{(1+\phi)/\phi} = \frac{\phi(V_1 - V_0)\zeta^o}{1+\phi} \qquad \frac{\phi(V_1^f - V_0^f)\zeta^{of}}{1+\phi} \qquad \frac{\phi v_s \zeta_s}{1+\phi} \qquad \frac{\phi v_s \zeta_s^f}{1+\phi} \tag{E1}$$

where the second equals $\phi(\chi^f)^{-1/\phi}(V_1^f - V_0^f)^{(1+\phi)/\phi}/(1+\phi)$. On a steady state the values are constant. Subtracting the second line of (17) from the first, and the fourth from the third, and substituting (E1) gives (22).

The left side of the first line of (22) rises from zero without bound in $V_1 - V_0$, at a rate above $\rho + h_s + \delta + a_s$, so the line makes $V_1 - V_0$ an increasing function of $V_1^f - V_0^f$ that rises at a rate below $a_s/(\rho + h_s + \delta + a_s)$. In the same way the second line makes $V_1^f - V_0^f$ an increasing function of $V_1 - V_0$ that rises at a rate below $\nu/(\rho + h_s + \delta + \nu)$. Composed, the two functions map $V_1 - V_0$ to a value that is positive at zero and rises at a rate below one, so they have exactly one fixed point, and (22) has exactly one positive solution. If $V_1^f - V_0^f$ were at least $V_1 - V_0$, the second and the

first line would give

$$(\rho + h_s + \delta)(V_1^f - V_0^f) + \frac{\phi}{1+\phi}(\chi^f)^{-1/\phi}(V_1^f - V_0^f)^{(1+\phi)/\phi} \le 1 - 1/\gamma$$
$$1 - 1/\gamma \le (\rho + h_s + \delta)(V_1 - V_0) + \frac{\phi}{1+\phi}\chi^{-1/\phi}(V_1 - V_0)^{(1+\phi)/\phi}$$

which is impossible, because the left side of the first inequality has the larger value of a lead and the smaller cost scale $\chi^f < \chi$, so it exceeds the right side of the second. Hence $V_1^f - V_0^f < V_1 - V_0$. Subtracting the second line of (22) from the first gives

$$(\rho + h_s + \delta + a_s + \nu)\big[(V_1 - V_0) - (V_1^f - V_0^f)\big] = \frac{\phi}{1+\phi}\big[(V_1^f - V_0^f)\zeta^{of} - (V_1 - V_0)\zeta^o\big] \tag{E2}$$

so $(V_1^f - V_0^f)\zeta^{of} > (V_1 - V_0)\zeta^o$, and since $V_1^f - V_0^f < V_1 - V_0$, $\zeta^{of} > \zeta^o$.

The first two lines of (17) then give

$$V_1 = \frac{1 - 1/\gamma - \delta(V_1 - V_0) + a_s(V_1^f - V_1)}{\rho + h_s} \tag{E3}$$

and

$$V_0 = \frac{\phi\,\chi^{-1/\phi}(V_1 - V_0)^{(1+\phi)/\phi}/(1+\phi) + a_s(V_0^f - V_0)}{\rho + h_s} \tag{E4}$$

Subtracting the second line of (17) from the fourth and substituting (E1) gives the value of fresh ideas to escape research in (23). Subtracting the first line from the third, and using $(V_1^f - V_0^f) - (V_1 - V_0) = (V_1^f - V_1) - (V_0^f - V_0)$, gives

$$(\rho + h_s + a_s + \nu)(V_1^f - V_1) = \delta\big[(V_0^f - V_0) - (V_1^f - V_1)\big] = \delta\big[(V_1 - V_0) - (V_1^f - V_0^f)\big] \tag{E5}$$

Solving the first equality for $V_1^f - V_1$ gives $\delta(V_0^f - V_0)/(\rho + h_s + \delta + a_s + \nu)$, the value of fresh ideas to a led product. Subtracting the first line of (18) from the second gives

$$(\rho + h_s + a_s + \nu)(W_s^f - W_s) = \frac{\phi\,\upsilon_s(\zeta_s^f - \zeta_s)}{1+\phi}$$

which is the rest of (23).

It remains to show that the conjecture is the value of the firm's problem. The value of a new product, $\upsilon_s = V_1 + W_s$, appears on both sides of (18). The right side of $\upsilon_s = V_1 + W_s$ is convex in υ_s, equals $V_1 > 0$ at $\upsilon_s = 0$, and rises with υ_s at the rate $\partial W_s/\partial \upsilon_s$, an average of ζ_s and ζ_s^f divided by $\rho + h_s$, which is below one when $\zeta_s^f < \rho + h_s$. The equation therefore has a smallest solution, the one that iterating the Bellman equation from zero reaches. At this solution the firm's expected number of products grows at most at the rate $\zeta_s^f - h_s < \rho$, so the present value of the products

that the firm expects to hold at distant dates tends to zero. Hence the conjecture is the value of the firm's problem. □

Proof of Lemma 2. Assume for now that entry is positive in every sector, which I verify below. Then $v_s = F$, the maximized brackets of (18) are Π_s and Π_s^f, and (18) solves to

$$W_s = \frac{\Pi_s}{\rho + h_s} + \frac{a_s}{\rho + h_s + a_s + \nu} \cdot \frac{\Pi_s^f - \Pi_s}{\rho + h_s} \tag{E6}$$

For given a_s, both terms fall as h_s rises, and W_s rises with a_s, from $\Pi_s/(\rho + h_s)$ at $a_s = 0$ toward $\Pi_s^f/(\rho + h_s)$, which it never reaches. To shorten the expressions, write D and D^f for the two values of a lead, $V_1 - V_0$ and $V_1^f - V_0^f$, at the rates h_s and a_s, and D_0 for the value of a lead when no ideas arrive, the solution of (22) at $a_s = 0$. By (E5), $a_s(V_1^f - V_1) = \delta a_s(D - D^f)/(\rho + h_s + a_s + \nu)$, so (E3) reads

$$(\rho + h_s)V_1 = 1 - 1/\gamma - \delta D + \frac{\delta a_s(D - D^f)}{\rho + h_s + a_s + \nu} \tag{E7}$$

A product loses the value of its lead, D or D^f, when the lead diffuses, and the last term is the part of that loss that fresh ideas spare. By the implicit function theorem applied to (22), with

$$Q_s \equiv (\rho + h_s + \delta + a_s + \zeta^o)(\rho + h_s + \delta + \nu + \zeta^{of}) - a_s\nu > 0$$

the two values of a lead change with the rates as

$$\begin{aligned} \frac{\partial D}{\partial a_s} &= -\frac{(D - D^f)(\rho + h_s + \delta + \nu + \zeta^{of})}{Q_s} & \frac{\partial D^f}{\partial a_s} &= -\frac{\nu(D - D^f)}{Q_s} \\ \frac{\partial D}{\partial h_s} &= -\frac{D(\rho + h_s + \delta + \nu + \zeta^{of}) + a_s D^f}{Q_s} & \frac{\partial D^f}{\partial h_s} &= -\frac{\nu D + (\rho + h_s + \delta + a_s + \zeta^o)D^f}{Q_s} \end{aligned} \tag{E8}$$

so both fall with a_s and with h_s, and so does their difference:

$$\begin{aligned} \frac{\partial(D - D^f)}{\partial a_s} &= -\frac{(D - D^f)(\rho + h_s + \delta + \zeta^{of})}{Q_s} \\ \frac{\partial(D - D^f)}{\partial h_s} &= -\frac{(D - D^f)(\rho + h_s + \delta + \zeta^{of}) + D^f(\zeta^{of} - \zeta^o)}{Q_s} \end{aligned}$$

By (E7), V_1 therefore rises with a_s: the weight $a_s/(\rho + h_s + a_s + \nu)$ on the smaller value of a lead rises, and both values fall. Each of V_1, V_0, V_1^f, and V_0^f is the value of the holder's problem on a product until the product is taken, a present value at the rate $\rho + h_s$ of its profits less its escape research, and the holder can always stop escape research, so all four are nonnegative. By the envelope theorem, the derivative of V_1 with respect to h_s is minus the present value, at the same rate, of the product's values along the way, so V_1 falls as h_s rises. The right side of the free-entry condition (24) is therefore continuous and strictly decreasing in h_s, and it tends to zero as h_s grows.

It rises with a_s, so at $h_s = \zeta_s^f$ it is at least its value at $a_s = 0$, $V_1 + \Pi_s/(\rho + \zeta_s^f)$, which exceeds F by the condition of the lemma. Hence for every $a_s \geq 0$ the free-entry condition has exactly one solution, $h_s(a_s)$, which exceeds ζ_s^f and is continuous and increasing in a_s. Because (E7) gives $V_1 < (1 - 1/\gamma)/(\rho + h_s)$ and (E6) gives $W_s < \Pi_s^f/(\rho + h_s)$, the solution is also below $\overline{h}_s$.

At given rates h_s and a_s, (22) gives the values of a lead, (19) the escape rates, and (14) the steady-state shares. Let $\mathcal{G}_s(h_s, a_s)$ be the sector's innovations per product, $h_s + \zeta^o(n_s - n_s^f) + \zeta^{of} n_s^f$, at these rates and shares, and $\mathcal{G}_s(a_s) \equiv \mathcal{G}_s(h_s(a_s), a_s)$ its value under free entry. It is continuous, positive, and below $\overline{h}_s + \delta$, because by the first line of (14) escapes per product are $\delta(1 - n_s) - h_s n_s \leq \delta$. Rates that satisfy free entry and (13) in every sector are therefore the fixed points of the map that sends the list of arrival rates (a_s) to $(\sum_{s'} \kappa_{ss'} \mathcal{G}_{s'}(a_{s'}))$. The map is continuous and sends the set of lists with $0 \leq a_s \leq \sum_{s'} \kappa_{ss'}(\overline{h}_{s'} + \delta)$ in every sector into itself, so by Brouwer's theorem it has a fixed point. At every fixed point $h_s > \zeta_s^f$. Firms' external research takes products at the rate $\zeta + (\zeta^f - \zeta)k_s$, which is at most ζ_s^f, so entry, $\zeta_s^e = h_s - \zeta - (\zeta^f - \zeta)k_s$, is positive, as assumed, and $\zeta_s^f < \rho + h_s$, so the values of firms are finite. This proves part (i).

For uniqueness, which uses $\phi \geq 1/2$, write $\zeta^o(D_0) = (D_0/\chi)^{1/\phi}$ for the escape rate when no ideas arrive. Every escape rate is below the takeover rate: D_0 and D are below $V_1 < F$, and $D^f < D$, so $\zeta^o(D_0)$ and ζ^o are below $\zeta_s < \zeta_s^f < h_s$ and $\zeta^{of} < \zeta_s^f < h_s$. By (E7) and (E6), free entry holds at the rate h_s exactly when

$$L_s(h_s) = \frac{a_s\left[\Pi_s^f - \Pi_s + \delta(D - D^f)\right]}{\rho + h_s + a_s + \nu} + \delta(D_0 - D) \qquad L_s(h_s) \equiv F(\rho + h_s) - (1 - 1/\gamma) + \delta D_0 - \Pi_s \tag{E9}$$

The left side is the free-entry condition when no ideas arrive, which holds at $h_s(0)$. The right side is $\rho + h_s$ times what ideas add to the value of a new product: cheaper research, and a lead that is worth less when it diffuses, because the holder can restore it more cheaply. Differentiating (22) at $a_s = 0$, and then $\zeta^o(D_0)$,

$$\frac{\partial D_0}{\partial h_s} = -\frac{D_0}{\rho + h_s + \delta + \zeta^o(D_0)} \qquad \frac{\partial \zeta^o(D_0)}{\partial h_s} = -\frac{\zeta^o(D_0)}{\phi\,(\rho + h_s + \delta + \zeta^o(D_0))} \tag{E10}$$

and differentiating once more,

$$\frac{\partial^2 D_0}{\partial h_s^2} = \frac{D_0\left(2 + \partial\zeta^o(D_0)/\partial h_s\right)}{(\rho + h_s + \delta + \zeta^o(D_0))^2}$$

which is positive because $\partial\zeta^o(D_0)/\partial h_s > -1/\phi \geq -2$. By (E10), L_s rises at the rate $F - \delta D_0/(\rho + h_s + \delta + \zeta^o(D_0))$, which is positive because $D_0 < F$. Hence L_s is increasing and convex and zero at $h_s(0) > 0$, so $h_s L_s' - L_s \geq h_s(0) L_s' > 0$.

Each of the three terms on the right side of (E9) rises less than in proportion with a_s and does not rise with h_s. For the first two this follows from (E8), because their ratio to a_s is $[\Pi_s^f - \Pi_s +$

$\delta(D-D^f)]/(\rho+h_s+a_s+\nu)$. For the third, subtracting the first line of (22) at a_s from the same line at zero and using (E1) gives

$$(\rho+h_s+\delta)(D_0-D)+\frac{\phi}{1+\phi}\left[D_0\zeta^o(D_0)-D\zeta^o\right]=a_s(D-D^f) \tag{E11}$$

The bracket rises with the value of a lead at the escape rate, so differentiating (E11) with respect to a_s, with D_0 fixed, gives $(\rho+h_s+\delta+\zeta^o)\,\partial(D_0-D)/\partial a_s = D-D^f+a_s\partial(D-D^f)/\partial a_s$. Substituting (E11), (E8), and $Q_s=(\rho+h_s+\delta+\zeta^o)(\rho+h_s+\delta+\nu+\zeta^{of})+a_s(\rho+h_s+\delta+\zeta^{of})$,

$$\begin{aligned}Q_s\Big[(D_0-D)-a_s\frac{\partial(D_0-D)}{\partial a_s}\Big] &= a_s(\rho+h_s+\delta+\zeta^{of})(D_0-D)\\ &\quad-(\rho+h_s+\delta+\nu+\zeta^{of})\Big[\tfrac{\phi}{1+\phi}\big(D_0\zeta^o(D_0)-D\zeta^o\big)-\zeta^o(D_0-D)\Big]\end{aligned}$$

The last bracket is the rise of the maximized escape bracket from D to D_0 less its slope at D times D_0-D. Between D and D_0 the slope, the escape rate, rises with the value of a lead at a rate below $\zeta^o(D_0)/(\phi D)$, so the last bracket is at most $\zeta^o(D_0)(D_0-D)^2/(2\phi D)$. By (E11), $D_0-D\le a_s(D-D^f)/(\rho+h_s+\delta)$, and by (E2), $\nu(D-D^f)<\zeta^{of}D^f$, so $(D-D^f)(\rho+h_s+\delta+\nu+\zeta^{of})<D(\rho+h_s+\delta+\zeta^{of})$. Together,

$$\begin{aligned}&(\rho+h_s+\delta+\nu+\zeta^{of})\Big[\tfrac{\phi}{1+\phi}\big(D_0\zeta^o(D_0)-D\zeta^o\big)-\zeta^o(D_0-D)\Big]\\ &\qquad<\frac{\zeta^o(D_0)}{2\phi(\rho+h_s+\delta)}\,a_s(\rho+h_s+\delta+\zeta^{of})(D_0-D)\end{aligned}$$

and the fraction is below one because $\phi\ge 1/2$ and $\zeta^o(D_0)<h_s$. Hence $(D_0-D)/a_s$ falls with a_s. Differentiating (E11) with respect to h_s instead, with $\partial D/\partial h_s=\partial D_0/\partial h_s-\partial(D_0-D)/\partial h_s$ and (E10),

$$(\rho+h_s+\delta+\zeta^o)\frac{\partial(D_0-D)}{\partial h_s}=a_s\frac{\partial(D-D^f)}{\partial h_s}+\frac{\zeta^o(D_0)D-\zeta^oD_0-(\rho+h_s+\delta)(D_0-D)}{\rho+h_s+\delta+\zeta^o(D_0)}$$

The first term is negative. Because $\phi\ge 1/2$ and $D<D_0$, $\zeta^o=\zeta^o(D_0)(D/D_0)^{1/\phi}\ge\zeta^o(D_0)(D/D_0)^2$, so $\zeta^o(D_0)D-\zeta^oD_0\le\zeta^o(D_0)(D_0-D)D/D_0$, which is less than $(\rho+h_s+\delta)(D_0-D)$. Hence D_0-D falls as h_s rises.

The takeover rate $h_s(a_s)$ therefore rises less than in proportion with a_s. The right side of (E9) does not rise with h_s, and a_s times its derivative with respect to a_s is at most the right side itself, which equals L_s along $h_s(a_s)$. Differentiating (E9) along $h_s(a_s)$, $a_sh_s'(a_s)$ is therefore at most L_s/L_s', which is less than h_s.

Escapes per product, $\zeta^o(n_s-n_s^f)+\zeta^{of}n_s^f$, depend on h_s and a_s through the shares and through

the escape rates. At given escape rates, the steady state of (14) makes them

$$\frac{\delta\big[a_s\zeta^{of}(a_s+\delta+2h_s+\nu+\zeta^o)+\zeta^o(a_s\nu+\delta h_s+\delta\nu+h_s^2+2h_s\nu+h_s\zeta^{of}+\nu^2+\nu\zeta^{of})\big]}{(a_s+h_s+\nu)\big[a_s(\delta+h_s+\zeta^{of})+(\delta+h_s)(\delta+h_s+\nu+\zeta^o+\zeta^{of})+\nu\zeta^o+\zeta^o\zeta^{of}\big]}$$

and the escape rates respond to the rates through (19) and (E8), with $(D-D^f)/D = \phi(\zeta^{of}-\zeta^o)/[(1+\phi)(\rho+h_s+\delta+\nu+a_s)+\phi\zeta^{of}]$ by (E2). Four facts about innovations per product, $\mathcal{G}_s(h_s,a_s)$, follow. At given a_s, it rises with h_s, by at most one for one, because escapes per product fall with h_s, by less than one for one. At given h_s, it rises with a_s, and $a_s\partial\mathcal{G}_s/\partial a_s$ is at most escapes per product, $\mathcal{G}_s-h_s$. At given escape rates, escapes per product rise with each escape rate, a_s times their derivative with respect to a_s is at most their level, and they fall with h_s; the escape rates fall with a_s and with h_s, which only strengthens the second and third of these, so they hold with the escape rates responding. That escapes fall with h_s by less than one for one, and rise with a_s, takes the responses of the escape rates into account. Clearing denominators, each claim says that a polynomial in δ, h_s, a_s, ν, ζ^o, ζ^{of}, ρ, and ϕ is positive. Written in ζ^o, in the excess $\zeta^{of}-\zeta^o$ of the escape rate with fresh ideas over it, in the excess $h_s-\zeta^{of}$ of the takeover rate over that rate, in $\phi-1/2$, and in the other rates, all of which are positive except $\phi-1/2\geq 0$, every coefficient of each polynomial is positive, which a symbolic computation verifies.[25]

Along $h_s(a_s)$, innovations per product therefore rise with the arrival of ideas, less than in proportion:

$$\mathcal{G}_s'(a_s)>0 \qquad\qquad \frac{\mathrm{d}}{\mathrm{d}a_s}\Big(\frac{\mathcal{G}_s(a_s)}{a_s}\Big)<0 \tag{E12}$$

Indeed $\mathcal{G}_s'(a_s)=h_s'(a_s)\,\partial\mathcal{G}_s/\partial h_s+\partial\mathcal{G}_s/\partial a_s$ is positive, and since $a_sh_s'(a_s)<h_s$ and $0<\partial\mathcal{G}_s/\partial h_s\leq 1$, $a_s\mathcal{G}_s'(a_s)<h_s+(\mathcal{G}_s-h_s)=\mathcal{G}_s$. Now suppose that two different lists of arrival rates, a and a', are steady states, and let t be the largest of the ratios a_s'/a_s over the sectors with $a_s>0$; exchanging the lists if needed, $t>1$. In a sector s with $a_s'=ta_s$,

$$a_s'=\sum_{s'}\kappa_{ss'}\mathcal{G}_{s'}(a_{s'}')\leq\sum_{s'}\kappa_{ss'}\mathcal{G}_{s'}(ta_{s'})<t\sum_{s'}\kappa_{ss'}\mathcal{G}_{s'}(a_{s'})=ta_s$$

because $\mathcal{G}_{s'}$ rises with the arrival of ideas and, by (E12) and $\mathcal{G}_{s'}(0)>0$, $\mathcal{G}_{s'}(ta_{s'})<t\mathcal{G}_{s'}(a_{s'})$. This contradicts the choice of s. Two steady states with the same arrival rates have the same takeover rates by free entry, and the same escape rates and shares, so the steady state is unique. This proves part (ii).

For part (iii), each product that a firm holds is taken at the rate h_s, and the firm's research on it adds products at the rate ζ_s or ζ_s^f, so the firm's expected number of products falls at least at the

[25] At given escape rates, the polynomials for the responses of escapes per product to ζ^o and to ζ^{of}, for their level less a_s times their response to a_s, and for minus their response to h_s have 225, 120, 271, and 155 terms. With the escape rates responding, the polynomials for their response to a_s and for one plus their response to h_s have 8,241 and 28,884 terms.

rate $h_s - \zeta_s^f > 0$, and its expected life is finite. Entrants arrive at a constant rate, so the mass of firms in each state, the rate of entry times the expected time that a firm spends in that state, is constant. The value of all firms is a constant share of output, so it grows at the rate g and earns the interest rate $\rho + g$. It changes through the dividends that firms pay, their profits less their external and escape research, and through entry, which by free entry creates firms worth what entrants spend. Hence ρ times the value of all firms equals profits less the spending on research and entry. Output is labor income plus profits, and consumption is output less the spending on research and entry, so consumption equals labor income plus ρ times the value of all firms. That value is positive, because the first line of (22) gives $\delta(V_1 - V_0) < 1 - 1/\gamma$, so $V_1 > 0$ by (E7), and V_0, V_0^f, V_1^f, W_s, and W_s^f are nonnegative. □

E.2 How valuable is innovation to firms?

Proof of Proposition 1. By (21), a firm's value is the sum of the terms of its products, so an innovation changes the value of a firm only through the terms of the products that it touches. A takeover gives the innovator a led product whose research has no fresh ideas, worth $\lambda_s Y \upsilon_s = \lambda_s Y F$, and removes the former holder's term for the product, $\lambda_s Y[V(\iota) + W(\iota)]$. An escape moves the holder's product from V_0 to V_1, or from V_0^f to V_1^f, and the fringe, which earned nothing on the product, loses nothing. This gives part (i) and the first two claims of part (ii).

Per product and unit of time, own gains in sector s from takeovers and escapes are

$$\lambda_s Y\big[h_s(V_1 + W_s) + (n_s - n_s^f)\zeta^o(V_1 - V_0) + n_s^f \zeta^{of}(V_1^f - V_0^f)\big]$$

Losses from rivalry are h_s times the average of $V(\iota) + W(\iota)$ over the sector's products. The shares of led products without and with fresh ideas are $1 - n_s - k_s + n_s^f$ and $k_s - n_s^f$, and of neck-and-neck products $n_s - n_s^f$ and n_s^f, so the average of $V(\iota)$ is

$$V_1 - (n_s - n_s^f)(V_1 - V_0) - n_s^f(V_1^f - V_0^f) + k_s(V_1^f - V_1)$$

and the average of $W(\iota)$ is $W_s + (W_s^f - W_s)k_s$. Subtracting h_s times their sum from own gains leaves

$$\lambda_s Y\big[(\zeta^o + h_s)(n_s - n_s^f)(V_1 - V_0) + (\zeta^{of} + h_s)n_s^f(V_1^f - V_0^f) - h_s k_s(V_1^f - V_1 + W_s^f - W_s)\big]$$

and substituting $k_s = a_s/(a_s + h_s + \nu)$ gives (25). Leads are created on neck-and-neck products at the rate $(\zeta^o + h_s)(n_s - n_s^f) + (\zeta^{of} + h_s)n_s^f$, which by the first line of (14) equals $\delta(1 - n_s)$ on a steady state.

When ideas arrive on a product of sector s' whose research has none, the holder's research on the product moves from $W_{s'}$ to $W_{s'}^f$ and the product's value from $V(\iota)$ to $V^f(\iota)$, which is (26). On a

neck-and-neck product, (23) gives

$$\xi^T = \frac{\phi}{\rho + h_{s'} + a_{s'} + \nu} \cdot \lambda_{s'} Y \frac{F(\zeta^f - \zeta) + (V_1^f - V_0^f)\zeta^{of} - (V_1 - V_0)\zeta^o}{1 + \phi}$$

and the second factor is the rise in the research spending on the product, because external research at the rate ζ costs $\lambda_{s'} YF\zeta/(1+\phi)$ and escape research at the rate ζ^o costs $\lambda_{s'} Y(V_1 - V_0)\zeta^o/(1+\phi)$, by (19), and similarly with fresh ideas. The holder's sales and profits depend only on the products that it holds and on whether they are led, which do not change when the ideas arrive. This is part (iii). □

Proof of Corollary 1. A takeover adds the external research of one product without fresh ideas, which costs $\lambda_s Y \chi \zeta^{1+\phi}/(1+\phi) = \lambda_s YF\zeta/(1+\phi)$, or $\zeta/(1+\phi)$ per dollar of own news, $\xi^O = \lambda_s YF$. When ideas arrive on a neck-and-neck product, (26) and (23) make its technology news $\phi/(\rho + h_s + a_s + \nu)$ times the rise in the research spending on the product, external and escape, so spending rises by $(\rho + h_s + a_s + \nu)/\phi$ per dollar of news. On a led product, spending rises by $\lambda_s YF(\zeta^f - \zeta)/(1+\phi) = \lambda_s Y(\rho + h_s + a_s + \nu)(W_s^f - W_s)/\phi$, while technology news is $\lambda_s Y(W_s^f - W_s + V_1^f - V_1)$, which is larger. With positive entry, firms' research takes products at a rate of at least ζ and less than h_s, so

$$\frac{\zeta}{1+\phi} < \frac{h_s}{\phi} < \frac{\rho + h_s + a_s + \nu}{\phi}$$

An escape ends the escape research on the product, and a takeover removes the product's research from its former holder. □

E.3 How entry responds to an innovation

On any path, each event still changes a firm's value by the change in the term of one product, so a firm's value is the sum over its products of $V(\iota) + W(\iota)$, and the values solve (17) and (18), with the discount rate (16) in place of ρ and the change of each value over time subtracted on the left side, at the rates (19) of each date. With positive entry, $v_s = F$ at every date, so the maximized brackets of (18) are Π_s and Π_s^f, and (20) holds. Subtracting the second line of (17) from the first, the fourth

from the third, and the first from the third, and the first line of (18) from the second, gives

$$\begin{aligned}
\tfrac{\mathrm{d}}{\mathrm{d}t}(V_1 - V_0) &= \Big(\rho + \tfrac{\mathrm{d}}{\mathrm{d}t}\ln\tfrac{C}{\lambda_s Y} + h_s + \delta + a_s\Big)(V_1 - V_0) + \frac{\phi}{1+\phi}\,\chi^{-1/\phi}(V_1 - V_0)^{(1+\phi)/\phi} \\
&\quad - (1 - 1/\gamma) - a_s(V_1^f - V_0^f) \\
\tfrac{\mathrm{d}}{\mathrm{d}t}(V_1^f - V_0^f) &= \Big(\rho + \tfrac{\mathrm{d}}{\mathrm{d}t}\ln\tfrac{C}{\lambda_s Y} + h_s + \delta + \nu\Big)(V_1^f - V_0^f) + \frac{\phi}{1+\phi}\,(\chi^f)^{-1/\phi}(V_1^f - V_0^f)^{(1+\phi)/\phi} \\
&\quad - (1 - 1/\gamma) - \nu(V_1 - V_0) \\
\tfrac{\mathrm{d}}{\mathrm{d}t}(V_1^f - V_1) &= \Big(\rho + \tfrac{\mathrm{d}}{\mathrm{d}t}\ln\tfrac{C}{\lambda_s Y} + h_s + a_s + \nu\Big)(V_1^f - V_1) - \delta\big[(V_1 - V_0) - (V_1^f - V_0^f)\big] \\
\tfrac{\mathrm{d}}{\mathrm{d}t}(W_s^f - W_s) &= \Big(\rho + \tfrac{\mathrm{d}}{\mathrm{d}t}\ln\tfrac{C}{\lambda_s Y} + h_s + a_s + \nu\Big)(W_s^f - W_s) - (\Pi_s^f - \Pi_s)
\end{aligned} \tag{E13}$$

Entrants supply the takeovers that firms' research does not, so the spending on research and entry per dollar of the sales of sector s is

$$S_s = F h_s + (n_s - n_s^f)\chi\frac{(\zeta_s^o)^{1+\phi}}{1+\phi} + n_s^f \chi^f \frac{(\zeta_s^{of})^{1+\phi}}{1+\phi} - \Pi_s - k_s(\Pi_s^f - \Pi_s) \tag{E14}$$

and $C/Y = 1 - \sum_s \lambda_s S_s$. The sales shares depend on the shares $n_{s'}$ alone, through the average inverse markups $1 - (1 - 1/\gamma)(1 - n_{s'})$, so $\frac{\mathrm{d}}{\mathrm{d}t}\ln\lambda_s = \sum_{s'}(\partial \ln\lambda_s/\partial n_{s'})\,\dot{n}_{s'}$, and free entry (20) and the budget read

$$\begin{aligned}
\rho + \frac{\mathrm{d}}{\mathrm{d}t}\ln\frac{C}{Y} - \sum_{s'}\frac{\partial \ln\lambda_s}{\partial n_{s'}}\,\dot{n}_{s'} + h_s &= \frac{1 - 1/\gamma + \Pi_s - \delta(V_1 - V_0) + a_s(V_1^f - V_1) + a_s(W_s^f - W_s)}{F} \\
\frac{C}{Y} &= 1 - \sum_{s'}\lambda_{s'} S_{s'}
\end{aligned} \tag{E15}$$

with $\dot{n}_{s'}$ from (14) and a_s from (13).

Let Δ_t be the list of the deviations from their steady-state values, at date t, of the shares n_s, k_s, and n_s^f, of $\ln(C/Y)$, and of the values $V_1 - V_0$, $V_1^f - V_0^f$, $V_1^f - V_1$, and $W_s^f - W_s$, in every sector. The values fix the escape rates by (19). Given Δ_t, (E15) with (13) is a set of linear equations, one for each sector and one for the budget, in the takeover rates and the growth rate of $\ln(C/Y)$, so both are functions of Δ_t. With (14) and (E13) they give the change of Δ_t over time, which is zero at the steady state, and to first order

$$\dot{\Delta}_t = \mathcal{A}\Delta_t$$

for a constant matrix $\mathcal{A}$, with the rates linear in Δ_t. The shares are given at date zero, and the other elements of Δ_0 are free. The path $\Delta_t = e^{\mathcal{A}t}\Delta_0$ returns to the steady state exactly when Δ_0 lies in the span of the eigenvectors and generalized eigenvectors of $\mathcal{A}$ whose eigenvalues have negative real parts. Section 7.6 assumes that exactly one Δ_0 in this span has any given small deviations of

the shares. Then Δ_t stays in the span, the deviations of the shares at each date fix Δ_t, the rates are linear in them, and on the span

$$\int_0^\infty e^{-\rho t}\Delta_t \, \mathrm{d}t = (\rho I - \mathcal{A})^{-1}\Delta_0$$

so the present values of the rates are linear in the initial deviations of the shares.

Without ideas the value of a lead does not move. Then $a_s = 0$, $k_s = 0$, and $n_s^f = 0$ in every sector, and (20) makes $\rho + \frac{\mathrm{d}}{\mathrm{d}t}\ln\frac{C}{\lambda_s Y} + h_s$ equal to $[1 - 1/\gamma + \Pi_s - \delta(V_1 - V_0)]/F$. Substituting it into the first line of (E13) gives the change in $V_1 - V_0$ as a function of $V_1 - V_0$ alone,

$$\frac{\mathrm{d}}{\mathrm{d}t}(V_1 - V_0) = \Big(\frac{1 - 1/\gamma + \Pi_s - \delta(V_1 - V_0)}{F} + \delta\Big)(V_1 - V_0) + \frac{\phi}{1+\phi}\,\chi^{-1/\phi}(V_1 - V_0)^{(1+\phi)/\phi} - (1 - 1/\gamma)$$

The right side is zero at the steady state's value of $V_1 - V_0$, and its derivative there is $\rho + h_s + \delta + \zeta^o - \delta(V_1 - V_0)/F$, which exceeds $\rho + h_s + \zeta^o > 0$ because $V_1 - V_0 < V_1 < F$. Near the steady state, $V_1 - V_0$ therefore moves away from its steady-state value whenever it differs from it, so on a path that returns it keeps that value at every date, and so does the escape rate. The takeover rate is then the steady state's h_s less $\frac{\mathrm{d}}{\mathrm{d}t}\ln\frac{C}{\lambda_s Y}$.

With one sector the system can be solved by hand. To first order,

$$\Delta h_t = -\frac{\frac{\mathrm{d}}{\mathrm{d}t}\Delta(C/\lambda Y)}{C/\lambda Y}$$

The sales equation gives $1/\lambda = 1 - (1-\alpha)[1 - (1 - 1/\gamma)(1 - n)]$, and $C/\lambda Y = 1/\lambda - S$ with $S = Fh + n\chi(\zeta^o)^{1+\phi}/(1+\phi) - \Pi$ by (E14), so

$$\Delta(C/\lambda Y) = -\Big[\chi\frac{(\zeta^o)^{1+\phi}}{1+\phi} + (1-\alpha)(1 - 1/\gamma)\Big]\Delta n - F\Delta h$$

and (14) gives

$$\Delta\dot{n} = -(\delta + \zeta^o + h)\Delta n - n\Delta h$$

Conjecture a path on which $\Delta h_t = -\eta\Delta n_t$. On it the deviation of the share shrinks at the rate $\delta + \zeta^o + h - n\eta$, and so does

$$\Delta(C/\lambda Y) = -\Big[\chi\frac{(\zeta^o)^{1+\phi}}{1+\phi} + (1-\alpha)(1 - 1/\gamma) - F\eta\Big]\Delta n$$

The conjecture solves both equations if and only if

$$\eta\,\frac{C}{\lambda Y} = (\delta + \zeta^o + h - n\eta)\Big[\chi\frac{(\zeta^o)^{1+\phi}}{1+\phi} + (1-\alpha)(1 - 1/\gamma) - F\eta\Big]$$

that is, if and only if η solves the quadratic

$$Fn\eta^2 - \Big[F(\delta + \zeta^o + h) + \frac{C}{\lambda Y}\Big]\eta = \Big[\chi\frac{(\zeta^o)^{1+\phi}}{1+\phi} + (1-\alpha)(1-1/\gamma)\Big]\big(n\eta - \delta - \zeta^o - h\big) \tag{E16}$$

At $\eta = 0$ the left side less the right side is the bracket times $\delta + \zeta^o + h$, which is not negative, and at $\eta = (\delta + \zeta^o + h)/n$ it is $-(\delta + \zeta^o + h)C/(\lambda Y n) < 0$. The quadratic therefore has one root in $[0, (\delta + \zeta^o + h)/n)$, along which the deviation of the share shrinks, and one above $(\delta + \zeta^o + h)/n$, along which it grows. Every solution of the two equations combines the paths along the two roots, so exactly one solution returns to the steady state, the one along the smaller root, η. The bracket on the right side is what one more neck-and-neck product takes from consumption per dollar of sales: its escape research, and the goods that it buys because it sells at cost, $(1-\alpha)(1-1/\gamma)$ of its sales more than a led product. Without escape research and intermediate inputs the bracket is zero, so η is zero and an innovation does not move the takeover rate. In this economy (28) is $(\overline{H} - \lambda YF)\,\eta/(\rho + \delta + \zeta^o + h - n\eta)$ for an escape or a takeover of a neck-and-neck product, and zero for a takeover of a led product, which changes no share.

E.4 The value of innovation to consumers

Proof of Proposition 2. Values to the household are per unit measure of products: the value of an innovation is the derivative of the household's value with respect to the measure of a set of products on which the innovation happens. It therefore depends only on the first-order responses of the economy. I first compute it with every rate at its steady-state value, which proves part (i), and then add the value of the responses, which proves part (ii).

With log utility, a small change in the path of consumption is worth, in dollars of the date of the change,

$$C\int_0^\infty e^{-\rho t}\Delta \ln C_t \,\mathrm{d}t \tag{E17}$$

where C is consumption at that date. At the steady state's rates, spending on research and entry in sector s' is $\lambda_{s'}Y$ times the constant $S_{s'}$, except for the changes ΔS_t that the innovation brings directly: in the escape and external research on the product and on the products on which its ideas arrive, and in the entry that keeps each sector's takeover rate fixed. Consumption is therefore $C_t = Y_t(1 - \sum_{s'}\lambda_{s',t}S_{s'}) - \Delta S_t$, with $\sum_{s'}\lambda_{s'}S_{s'} = 1 - C/Y$ on the steady state, and to first order

$$\Delta \ln C_t = \Delta \ln Y_t - \frac{Y}{C}\Big(\sum_{s'} S_{s'}\Delta\lambda_{s',t} + \frac{\Delta S_t}{Y_t}\Big) \tag{E18}$$

By (E17), the innovation is worth C times the present value of $\Delta \ln Y_t$, less Y times the present value of $\sum_{s'} S_{s'}\Delta\lambda_{s',t} + \Delta S_t/Y_t$, both discounted at ρ, with C and Y at the date of the innovation.

Consider first the wage. After a takeover of a led product, the price per unit of quality is the

former holder's unit cost per unit of quality, which is the old price divided by γ. A neck-and-neck product already sold at the unit cost per unit of its best quality, and after a takeover or an escape the new leader charges the price at which producers with that quality just break even, which is the same price per unit of quality. Compare the paths with and without the innovation, with the product's next takeover at the same exponential date on both. Measure the product's quality from its best quality before the innovation, and let B_1, B_0, B_1^f, and B_0^f be the present values of $\ln(q_t/\mu_t)$ in the four states, at the steady state's rates. A takeover raises the best quality by $\ln\gamma$ and makes the product led without fresh ideas, an escape raises it by $\ln\gamma$ and makes the product led with the ideas that it had, diffusion makes the product neck and neck, with markup one, and ideas arrive and become obsolete, so

$$\begin{aligned}
\rho B_1 &= -\ln\gamma + \delta(B_0 - B_1) + a_s(B_1^f - B_1) + \frac{h_s \ln\gamma}{\rho} \\
\rho B_0 &= (\zeta^o + h_s)\Big(\frac{\ln\gamma}{\rho} + B_1 - B_0\Big) + a_s(B_0^f - B_0) \\
\rho B_1^f &= -\ln\gamma + \delta(B_0^f - B_1^f) - \nu(B_1^f - B_1) + h_s\Big(\frac{\ln\gamma}{\rho} + B_1 - B_1^f\Big) \\
\rho B_0^f &= \zeta^{of}\Big(\frac{\ln\gamma}{\rho} + B_1^f - B_0^f\Big) - \nu(B_0^f - B_0) + h_s\Big(\frac{\ln\gamma}{\rho} + B_1 - B_0^f\Big)
\end{aligned} \tag{E19}$$

whose differences give the equations for $B_1 - B_0$ and $B_1^f - B_0^f$ in Section 7.7. With the innovation the product's best quality is γ times higher and the product is in its new state; without it the product keeps its state. By (15), the present value of the log wage therefore changes by $\widetilde{\lambda}_s \Delta B_t$. Ideas that arrive on a product move it to its state with fresh ideas at the same quality, which changes the present value of the log wage by $\widetilde{\lambda}_{s'} \Delta B_t$ for that product.

Now turn to markups. Write the sales equations as $\lambda' = b' + \lambda' \mathcal{D} \widetilde{\Omega}$, where $\mathcal{D}$ is the diagonal matrix of the sectors' average inverse markups, labor's share as $\Lambda = \lambda' \mathcal{D} \alpha$, and the definitions of ℓ and ψ as $\alpha = (I - \widetilde{\Omega}\mathcal{D})\ell$ and $\widetilde{\Omega} S = (I - \widetilde{\Omega}\mathcal{D})\psi$, where S is the vector of the spending shares $S_{s'}$. When sector s's average inverse markup rises by the small amount $\Delta\mathcal{D}_{ss}$, the sales shares change by $\Delta\lambda$, where $\Delta\lambda'(I - \mathcal{D}\widetilde{\Omega})$ is $\lambda_s \Delta\mathcal{D}_{ss}$ times the s-th row of $\widetilde{\Omega}$. Labor's share rises by $\alpha_s \lambda_s \Delta\mathcal{D}_{ss} + \Delta\lambda' \mathcal{D}\alpha$, and

$$\Delta\lambda' \mathcal{D}\alpha = \Delta\lambda' \mathcal{D}(I - \widetilde{\Omega}\mathcal{D})\ell = \Delta\lambda'(I - \mathcal{D}\widetilde{\Omega})\mathcal{D}\ell = \lambda_s \Delta\mathcal{D}_{ss} \sum_{s'} \widetilde{\Omega}_{ss'} \mathcal{D}_{s's'} \ell_{s'} = \lambda_s \Delta\mathcal{D}_{ss}(\ell_s - \alpha_s)$$

so labor's share rises by $\lambda_s \ell_s \Delta\mathcal{D}_{ss}$ in all. Because $\widetilde{\Omega}(I - \mathcal{D}\widetilde{\Omega})^{-1} = (I - \widetilde{\Omega}\mathcal{D})^{-1}\widetilde{\Omega}$, spending relative to output, $\sum_{s'} S_{s'} \lambda_{s'}$, changes by

$$\Delta\lambda' S = \lambda_s \Delta\mathcal{D}_{ss}\big[\widetilde{\Omega}(I - \mathcal{D}\widetilde{\Omega})^{-1} S\big]_s = \lambda_s \Delta\mathcal{D}_{ss} \psi_s$$

The product's inverse markup is one minus its profits per dollar of sales, which are $1 - 1/\gamma$ when

the product is led and zero when it is neck and neck. Let M_1, M_0, M_1^f, and M_0^f be the present values of the product's profits per dollar of sales until its next takeover in the four states. They solve

$$\begin{aligned}(\rho + h_s)M_1 &= 1 - 1/\gamma + \delta(M_0 - M_1) + a_s(M_1^f - M_1)\\ (\rho + h_s)M_0 &= \zeta^o(M_1 - M_0) + a_s(M_0^f - M_0)\\ (\rho + h_s)M_1^f &= 1 - 1/\gamma + \delta(M_0^f - M_1^f) - \nu(M_1^f - M_1)\\ (\rho + h_s)M_0^f &= \zeta^{of}(M_1^f - M_0^f) - \nu(M_0^f - M_0)\end{aligned} \tag{E20}$$

whose differences give the equations for $M_1 - M_0$ and $M_1^f - M_0^f$ in Section 7.7. After the next takeover of a product that the innovation touches, its profits per dollar of sales are the same on both paths, so the innovation changes the present value of its inverse markup by $-\Delta M_\iota$. Output is the wage divided by Λ, so the present value of $\Delta \ln Y_t$ is $\sum_\iota [\widetilde{\lambda}_{s(\iota)}\Delta B_\iota + (\ell_{s(\iota)}/\Lambda)\lambda_{s(\iota)}\Delta M_\iota]$, and the present value of $\sum_{s'} S_{s'}\Delta\lambda_{s',t}$ is $-\sum_\iota \psi_{s(\iota)}\lambda_{s(\iota)}\Delta M_\iota$, where the sums run over the products that the innovation touches.

It remains to count spending. Until a product's next takeover its profits go to its holder, and after the takeover both paths give them to the next holder in the same way. The value of a product that the innovation touches therefore changes by $\lambda_{s(\iota)}Y\Delta M_\iota$ less $\lambda_{s(\iota)}Y$ times the change in the present value of escape research on it, and at a takeover the new holder's V_1 takes the place of the former holder's $V(\iota)$. The external research on the product passes to its new holder without fresh ideas. If the research had them, it falls by $\lambda_s YF(\zeta^f - \zeta)/(1 + \phi)$ while they would have lasted. Since the sector's takeover rate stays fixed, entry rises by $\lambda_s YF(\zeta^f - \zeta)$ per unit of time, so spending rises by

$$\lambda_s Y\frac{\phi F(\zeta^f - \zeta)}{1 + \phi} = \lambda_s Y(\Pi_s^f - \Pi_s)$$

per unit of time. The difference lasts until the fresh ideas become obsolete, the product is taken, or fresh ideas arrive on the new holder's research, so by (23) its present value is $\lambda_s Y(\Pi_s^f - \Pi_s)/(\rho + h_s + a_s + \nu) = \lambda_s Y(W_s^f - W_s)$, which is what the former holder loses beyond the $\lambda_s YW_s$ that the new holder gains. In the same way, on each product on which the innovation's ideas arrive, the external research that the ideas add saves the spending on entry that it replaces, and the holder's gain ξ^T is $\lambda_{s'}Y\Delta M_\iota$ plus that saving less the change in the present value of escape research on the product. In all,

$$\xi^O - \xi^R + \sum\xi^T = \sum_\iota \lambda_{s(\iota)}Y\Delta M_\iota - Y\int_0^\infty e^{-\rho t}\frac{\Delta S_t}{Y_t}\,\mathrm{d}t \tag{E21}$$

Collecting the three parts, at the steady state's rates the household's value is

$$C\sum_\iota\left[\widetilde{\lambda}_{s(\iota)}\Delta B_\iota + \frac{\ell_{s(\iota)}}{\Lambda}\lambda_{s(\iota)}\Delta M_\iota\right] + Y\sum_\iota \psi_{s(\iota)}\lambda_{s(\iota)}\Delta M_\iota - Y\int_0^\infty e^{-\rho t}\frac{\Delta S_t}{Y_t}\,\mathrm{d}t$$

Substituting (E21) for the last term gives

$$\xi^O - \xi^R + \sum \xi^T + \sum_\iota \widetilde{\lambda}_{s(\iota)} C \,\Delta B_\iota + \sum_\iota \Big(\frac{\ell_{s(\iota)} C}{\Lambda Y} + \psi_{s(\iota)} - 1 \Big) \lambda_{s(\iota)} Y \,\Delta M_\iota$$

which is H in (27). This proves part (i).

For part (ii), the innovations change the shares by their measure times the changes listed before the proposition, so the takeover and escape rates move, to first order, by that measure times $\Delta h_{s',t}$, $\Delta \zeta^o_{s',t}$, and $\Delta \zeta^{of}_{s',t}$. A Poisson process at the rate $h_{s'} + \Delta h_{s',t}$ is the process at the rate $h_{s'}$ together with an independent process at the rate $\Delta h_{s',t}$, with events removed at random where the change is negative, and the same holds for escapes. The path with the responses is therefore the path at the steady state's rates plus takeovers added at the rate $\Delta h_{s',t}$ on every product of sector s' and escapes added at the rates $\Delta \zeta^o_{s',t}$ and $\Delta \zeta^{of}_{s',t}$ on each of the $n_{s'} - n^f_{s'}$ neck-and-neck products of sector s' without fresh ideas and each of the $n^f_{s'}$ with them. By part (i), an added event at date t changes the household's value, in dollars of date t, by H for the product's state at t, with all other events following the steady state's process. The states at t differ from the steady state's by an amount proportional to the measure, and two added events interact only in proportion to the product of their rates, so to first order an added takeover is worth $\overline{H}_{s'}$ and an added escape $H^o_{s'}$ or $H^{of}_{s'}$. The value H counts the spending that an event brings after it happens. The research that brings the added events costs in addition, at the margin, $\lambda_{s'} YF$ per unit of the takeover rate, whoever runs it, because an entrant spends that much and a firm's marginal cost of external research is the value of a new product, and $\lambda_{s'} Y(V_1 - V_0)$ or $\lambda_{s'} Y(V^f_1 - V^f_0)$ per unit of the rate of escapes, the marginal cost of escape research. All these values grow with output at the rate g and are discounted at $\rho + g$, so an added event at date t counts $e^{-\rho t}$ times its value at the date of the innovation. Summing over the added events gives (28). □

E.5 Where to subsidize innovation

Proof of Proposition 3. The value of a new product at given rates, $v_s = V_1 + W_s$, rises with a_s and falls with h_s: W_s by (E6), and V_1 by (E7) and (E8) for a_s and by the envelope theorem for h_s, because the values of the product along the way are positive. The implicit function theorem applied to the free-entry condition (24) therefore gives (29), which is part (i). By (E6) and (23), $W_s = \Pi_s/(\rho + h_s) + a_s(W^f_s - W_s)/(\rho + h_s)$ with $W^f_s - W_s = (\Pi^f_s - \Pi_s)/(\rho + h_s + a_s + \nu)$, so

$$\frac{\partial W_s}{\partial a_s} = \frac{(W^f_s - W_s)(\rho + h_s + \nu)}{(\rho + h_s)(\rho + h_s + a_s + \nu)}$$

$$-\frac{\partial W_s}{\partial h_s} = \frac{\Pi_s}{(\rho + h_s)^2} + \frac{a_s(W^f_s - W_s)}{\rho + h_s}\Big(\frac{1}{\rho + h_s} + \frac{1}{\rho + h_s + a_s + \nu} \Big)$$

and the derivatives of V_1 follow from (E7) and (E8).

Under the condition of Lemma 2, (E12) gives

$$0 < \mathcal{G}_s'(a_s) < \frac{\mathcal{G}_s(a_s)}{a_s}$$

wherever $a_s > 0$, and $\mathcal{G}_s'(a_s)$ is the derivative that defines $\mathcal{J}$. At a steady state, the s-th element of $\mathcal{J}\mathcal{G}$, with $\mathcal{G}$ the vector of innovations per product, is $\mathcal{G}_s'(a_s)\sum_{s'}\kappa_{ss'}\mathcal{G}_{s'} = \mathcal{G}_s'(a_s)a_s$, which is below $\mathcal{G}_s$, and zero where $a_s = 0$. The nonnegative matrix $\mathcal{J}$ therefore maps the positive vector $\mathcal{G}$ to a vector that is smaller in every element, so its spectral radius is below one, which is part (ii).

The arrival of ideas is $a = \kappa\mathcal{G}$, so a change that raises sector s's innovations per product directly by one unit changes them in total by the vector $\Delta\mathcal{G}$ that equals $\mathcal{J}\Delta\mathcal{G}$ plus one unit in sector s. When the spectral radius of $\mathcal{J}$ is below one, $I - \mathcal{J}$ is invertible, $(I-\mathcal{J})^{-1} = I + \mathcal{J} + \mathcal{J}^2 + \cdots$ has nonnegative elements, and $\Delta\mathcal{G}$ is the s-th column of $(I-\mathcal{J})^{-1}$, which is part (iii). The steady states are the fixed points of the map that sends the innovations per product $(\mathcal{G}_s)$ to $(\mathcal{G}_s(\sum_{s'}\kappa_{ss'}\mathcal{G}_{s'}))$, whose Jacobian is $\mathcal{J}$, so a steady state at which $I - \mathcal{J}$ is invertible is locally unique. □

Proof of Corollary 2. A subsidy that pays part of the entry cost in sector s makes free entry there hold at a value of a new product v_s slightly below F, with external research rates $(v_s/\chi)^{1/\phi}$ and $(v_s/\chi^f)^{1/\phi}$, and it leaves the conditions of the other sectors unchanged. At a given arrival of ideas, sector s's steady-state takeover rate is then higher, because $V_1 + W_s - v_s$ falls with h_s and with v_s: the value of research rises with v_s at the rate $\partial W_s/\partial v_s$, an average of ζ_s and ζ_s^f divided by $\rho + h_s$, which is below one. Per unit of that rise, sector s's innovations per product rise by $\partial\mathcal{G}_s/\partial h_s$, so by part (iii) of Proposition 3 the innovations of all sectors move by $\partial\mathcal{G}_s/\partial h_s$ times the s-th column of $(I-\mathcal{J})^{-1}$, and the arrival of ideas by κ times those changes. Each sector's takeover rate then changes by $\partial h_{s'}/\partial a_{s'}$ times the change in its arrival of ideas, plus the unit rise in sector s, and its escape rates change by (19) and (E8); these are $\Delta h_{s'}$, $\Delta\zeta_{s'}^o$, and $\Delta\zeta_{s'}^{of}$. The shares start at the old steady state's values, so along the way the rates are the new steady state's plus their first-order responses to the deviations of the old shares from the new ones.

The subsidy and the tax are transfers, so the household's value changes only through the paths of output and spending, which the events on all products determine. As in the derivation of (28), the path with the policy is the path without it plus takeovers added at the rate $\Delta h_{s'}$ on every product of sector s', escapes added at the rates $\Delta\zeta_{s'}^o$ and $\Delta\zeta_{s'}^{of}$ on every neck-and-neck product of sector s' without and with fresh ideas, and the events of the responses, and to first order each added takeover is worth $\overline{H}_{s'}$ and each added escape $H_{s'}^o$ or $H_{s'}^{of}$. The research that brings these events costs at the margin $\lambda_{s'}YF_{s'}$ per unit of the takeover rate, whoever runs it, because an entrant spends that much and a firm's marginal cost of external research is the value of a new product, which differs from $\lambda_{s'}YF_{s'}$ only by the subsidy, and it costs $\lambda_{s'}Y(V_1 - V_0)$ or $\lambda_{s'}Y(V_1^f - V_0^f)$ per unit of the rate of escapes. In sector s the subsidy also moves research from firms to entrants at a given takeover rate, which costs nothing to first order, because their marginal costs differ only

by the subsidy. The changes in the shares and in spending that follow are consequences of the added events, and their values count them. Every flow grows with output at the rate g and is discounted at $\rho + g$, so the present value of a constant flow at the date the policy begins is $1/\rho$ times the flow then. Multiplying the added takeovers of the new steady state, $\Delta h_{s'}$, and its added escapes, $(n_{s'} - n^f_{s'})\Delta\zeta^o_{s'}$ and $n^f_{s'}\Delta\zeta^{of}_{s'}$, by their values net of their costs and summing over sectors gives (30), and the events of the responses give (28) for the deviations of the old shares from the new ones, per unit of the rise in sector s's rate. This proves part (i).

For part (ii), an improvement of a led product makes the technology that it replaces available to the fringe, so the holder stays one step ahead, its value does not change, and no firm runs that research. The product keeps its state, so, as for a takeover of a led product without fresh ideas, the improvement lowers the product's price per unit of quality by the factor γ for good, with $\Delta M_\iota = 0$ and $\Delta B_\iota = \ln\gamma/\rho$ on the product. Its ideas reach other products as those of any innovation do, so by Proposition 2 it is worth $\widetilde{\lambda}_s C \ln\gamma/\rho$ to the household plus what its ideas are worth. A takeover of a led product without fresh ideas is worth the same to the household, because its own news and its rivalry cancel, $\lambda_s YF = \lambda_s Y(V_1 + W_s)$, and it too changes the shares only through its ideas. Internal research at the rate ζ costs $\lambda_s Y\chi\zeta^{1+\phi}/(1+\phi)$, or the same with χ^f, whose derivative is zero at $\zeta = 0$. □

F Related evidence and patent-grant information

F.1 Private, external, and social returns

Estimates of innovation's return differ in both the gains they count and the research costs against which they compare them. Technology case studies can include buyer surplus and displaced rivals' profit losses; firm-level research regressions measure effects on producers' output, profits, or market value; aggregate productivity accounts include gains that reach buyers through lower prices. Table F1 preserves these distinctions. Annual rates of return on research, patent yields per dollar of public funding, and capitalized values per dollar of private patent value are different economic objects. The last row reports this paper's corporate account and model-based household valuation on their respective samples.

TABLE F1: Estimates of the private and social returns to research and development

Study	Sample and method	Concept and unit	Private estimate	Social / external estimate
Panel A: Microeconomic case studies of individual innovations				
Griliches (1958)	U.S. hybrid corn (1910–1955) and hybrid sorghum; consumer-surplus gains against public and private research costs	Annual IRR (% / yr)	Not separately estimated (public + private R&D)	35–40% / yr (corn); 20% / yr (sorghum)
Mansfield et al. (1977)	17 industrial innovations by U.S. firms, 1950s–1970s; innovator pre-tax cash flows, imitator profits, and buyer surplus net of rival losses	Annual IRR on R&D cost (% / yr, median and range)	25% / yr median (range < 0% to 214% / yr; pre-tax)	56% / yr median (range < 0% to 307% / yr; median social / private = 2.2×)
Panel B: Industry and international production-function regressions				
Scherer (1982)	U.S. industries, labor-productivity growth 1973–1978; 1974 R&D of 443 firms traced to using industries via 15,112 patents	Marginal annual return on R&D stock (% / yr)	Product R&D in performing industry: weak, mostly insig.	71–104% / yr on R&D used by an industry (own process + purchased-input R&D)
Coe and Helpman (1995)	21 OECD countries and Israel, 1971–1990; country TFP on domestic R&D stock and import-weighted foreign R&D stock	Economy-wide marginal return on R&D stock (% / yr)	Not estimated (country-level aggregate data)	≈ 120% / yr domestic in G-7 (123% in 1990), 80–85% / yr in other OECD; + ≈ 30% / yr to trade partners
Panel C: Firm-level regressions with R&D stocks, patent classes, and licensing				
Jaffe (1986)	432 U.S. manufacturing firms, 1973 and 1979; patents, Tobin's q, and profits on own R&D and patent-class neighbor R&D pool	Gross profit return on R&D (% / yr) and +10% R&D effect	27% / yr gross private profit return on R&D	+3% aggregate profit if all firms raise R&D by 10% (one-third from neighbor pool; net loss for low-R&D firms)
Bloom et al. (2013)	715 U.S. listed firms, 1981–2001; output, market-value, patent, and R&D equations with technology-peer and product-rival R&D stocks	Gross marginal annual return on R&D stock (% / yr)	20.7% / yr (OLS); 39.3% / yr (tax-credit IV)	55.0% / yr (OLS; 2.7× private); 59.4% / yr (tax-credit IV; 1.5× private)
Bloom et al. (2019)	1,985 U.S. listed firms, 1985–2015; replication and extension of Bloom, Schankerman, and Van Reenen equations	Gross marginal annual return on R&D stock (% / yr)	13.6% / yr (OLS)	57.7% / yr (OLS; social / private = 4.2×)
Zacchia (2020)	736 U.S. listed firms, 1976–2001; output and market-value regressions with R&D spillovers across co-inventor networks	Marginal annual return on yearly R&D outlay (% / yr)	≈ 20% / yr	≈ 23% / yr (112% of private return, or 1.12×, via co-inventor networks)
Arqué-Castells and Spulber (2022)	U.S. listed firms, 1990–2014; Bloom et al. equations augmented with patent licensing and reassignment transactions	Gross marginal annual return on R&D stock (% / yr)	5–7% / yr (3% / yr without licensing and patent sales)	37% / yr (42% / yr without licensing and patent sales; 5.3× to 7.4× private)
Panel D: Macroeconomic calibration, growth accounting, and narrative fiscal shocks				
Jones and Williams (1998)	Endogenous growth model showing productivity regressions understate social returns, applied to U.S. industry estimates	Annual social return (% / yr) and optimal / actual R&D	Calibrated against 7–14% / yr real interest rate	≥ 30% / yr social return (conservative benchmark); optimal R&D is 2× to 4× actual
Nordhaus (2004)	U.S. nonfarm business sector, 1948–2001; corporate profit margins regressed on total factor productivity growth	Innovator share of PV social gains from new technology (%)	2.2% of PV social gains kept as above-normal profits (1.3–3.3%)	Most of the remaining ≈ 98% of PV social gains passes to consumers in lower prices
Jones and Summers (2022)	All U.S. R&D (2.7% of GDP) set against aggregate productivity growth of 1.8% / yr	PV output benefit per $1 R&D ($ / $1) and IRR (% / yr)	Not separately estimated (public + private R&D)	$13.3 PV benefit per $1 at 5% discount rate (67% / yr IRR); $4–$5 per $1 with capital costs or long lags

TABLE F1: Estimates of the private and social returns to research and development (continued)

Study	Sample and method	Concept and unit	Private estimate	Social / external estimate
Panel D: Macroeconomic calibration, growth accounting, and narrative fiscal shocks (continued)				
Fieldhouse and Mertens (forthcoming)	Narrative shocks to U.S. federal nondefense R&D appropriations, 1948–2021; effect on business-sector TFP	Gross marginal annual return on federal R&D (% / yr)	Not applicable (federal R&D appropriations)	140–210% / yr gross return (preferred 171% / yr; net subtracts ≈ 16% / yr depreciation)
De Souza et al. (2026)	Narrative shocks to U.S. federal R&D appropriations matched to TFP in 69 foreign economies, 1980–2019	Global / domestic productivity return ratio (multiple)	1.0× domestic U.S. productivity return benchmark	Global returns at least 1.8× to 2.2× domestic returns (nondefense federal R&D)
Panel E: Quasi-experimental shocks to public research and defense R&D				
Azoulay et al. (2019)	National Institutes of Health (NIH) grants, 1980–2005; funding windfalls near peer-review paylines as IV	Private patents per $10M grant and drug sales per $1	Public research grant (no direct private R&D outlay)	2.7 private-sector patents per $10M (SE 1.4; half outside funded disease); ≈ $2.3 drug sales revenue per $1
Myers and Lanahan (2022)	U.S. Department of Energy SBIR grants to small firms, 1997–2018; state matching windfalls as IV	Patents produced per $1M of public R&D grant	0.75 patents per $1M at grant recipients (26% of total)	2.94 total patents per $1M counting all other firms and inventors (3.9× recipient patents)
Dyèvre (2024)	U.S. federal vs. corporate patents, 1926–2019; patent text, citations, and firm TFP responses	Firm TFP growth response to public R&D spillovers	1.0× private R&D spillover benchmark	−0.17% firm TFP growth per 1% drop in public R&D spillovers (≈ 3× private spillover impact)
Moretti et al. (2025)	OECD industry-country panel of defense R&D shocks; IV estimates of private R&D crowd-in and TFP growth	Private R&D elasticity and annual TFP growth effect	0.43 elasticity of private R&D to defense R&D (+4.3% per +10%)	+0.08 pp annual TFP growth per +1 pp defense R&D / value added (≈ +8.3% over mean)
Panel F: Literature surveys and meta-analyses				
Griliches (1992)	Agricultural case studies and industry regressions separating within-industry and outside-industry R&D	Marginal annual return on R&D (% / yr)	9–69% / yr on own R&D within the industry	10–160% / yr on outside-industry R&D (mostly 28–80% / yr); 11–83% / yr in public agricultural research
Nadiri (1993)	Survey of 63 firm-, industry-, and country-level production- and cost-function studies in the OECD	Net marginal annual return on R&D (% / yr)	20–30% / yr (firms); 10–30% / yr (industries)	20% to over 100% / yr indirect and social returns, averaging close to 50% / yr
Alston et al. (2000)	Meta-analysis of 292 published studies (1,886 estimates) of rates of return to agricultural R&D	Annual IRR on agricultural R&D (% / yr, median and mean)	Not separately reported across full meta-sample	44.3% / yr median and 81.3% / yr mean across all 1,886 estimates (48.0% / yr median for research only)
Hall et al. (2010)	Handbook survey of firm, industry, and country production- and cost-function studies of R&D returns	Marginal annual return on R&D stock (% / yr)	Most likely 20–30% / yr (up to ≈ 75% / yr)	Returns to other firms' R&D from near zero to ≈ 100% / yr; social "almost always" above private
Panel G: This paper (stock-market grant reactions, 1981–2024, and general-equilibrium consumer welfare, 1997–2024)				
This paper	Equity: 23,697 U.S. listed firms and 3.0M patents, 1981–2024; 3-day stock returns on grant Tuesdays. Consumption: GE model calibrated to listed nonfinancial companies that patent, 1997–2024, at their U.S. shares	Capitalized equity and PV consumption per $1.00 private patent value	$1.00 at innovator ($32.7T total, 1981–2024)	$2.05 equity, 1981–2024 ($1.72 tech, −$0.67 rivals, +$1.05 net external with suppliers and customers, $34.3T); $5.3 PV consumption, 1997–2024 ($1.33 economic profits; $4.01 lower prices)

Notes: The private return accrues to the firm that pays for the research and the social return to the economy or to all sample firms, but the studies estimate different concepts, stated in the third column: annual internal rates of return (IRR, in % / yr) or marginal annual returns on R&D stocks (in % / yr); output or R&D elasticities (unitless); patent yields per dollar of public grant; or present-value (PV) dollar ratios. The annual return estimates for Griliches (1958) follow Griliches (1992, Table 11.1); they are not present-value benefit–cost ratios. Mansfield et al. (1977) compute ex post IRRs on pre-tax cash flows; their social return adds buyer surplus and imitator profits and subtracts displaced rivals' profit losses, and about 30 percent of their innovations were privately unprofitable but socially worthwhile. Scherer (1982) R&D used by an industry includes its own process R&D and R&D embodied in purchased inputs. Coe and Helpman (1995) describe their country-level estimates as social or economy-wide rates of return. In Bloom et al. (2013), Bloom et al. (2019), Zacchia (2020), and Arqué-Castells and Spulber (2022), the social return is the marginal return to a firm's R&D in the output of the listed firms in the sample; in Bloom et al. and Lucking et al. it nets out business stealing and excludes consumer surplus from lower prices, and Zacchia converts returns on the R&D stock into returns on yearly R&D. The drug sales of Azoulay et al. (2019) are revenues, not surplus. In Panel G, every figure is a capitalized present value in 2025 dollars per $1.00 of private stock-market value at the patenting firm, with no research cost in the denominator. The equity figures use all listed firms over 1981–2024. The consumption figures come from the model calibrated to listed nonfinancial companies that patent, 1997–2024, at their U.S. shares, weighted by private value and pooled over years. The model matches that sample's pooled technology gains and leaves its losses from rivalry untargeted. Pooled over 1997–2024, the sample's technology gains and losses from rivalry are $1.52 and $0.65 per private dollar, not the full-panel figures beside them.

F.2 Valuing patent grants in the stock market

A patent grant is an economic event for both the patentee and other firms because the allowed claims define the legal boundary between exclusive monopoly rights and publicly usable knowledge. A patent gives its owner the right to exclude others from making, using, or selling the invention defined by its claims for a term that begins on the Tuesday the patent issues.[26] During examination, a USPTO examiner compares the initial application against prior art and typically rejects or narrows the proposed claims over one or more rounds of amendments before issuing a notice of allowance and, once the issue fee is paid, publishing the granted patent in the weekly Tuesday *Official Gazette*.[27] The claims that survive examination govern how the patent affects every connected firm. For product-market rivals and trading partners, the allowed claims determine which competing products infringe and how securely the patentee can price the goods that embody the invention. For technology peers, the specification and allowed claims disclose how the invention works while establishing which related techniques remain free to use without a license.

Because investors may partially anticipate a patent before the Tuesday it issues, the stock-market reaction on the grant date measures the unanticipated component of its value at both the innovator and connected firms. Following Kogan et al. (2017), call a patent's dollar value to its owner its private value, and suppose that, prior to issuance, investors assign a probability below one that the patent will be granted. On the Tuesday the patent issues, the unexpected news changes the owner's equity value by the patent's private value times the unanticipated share, one minus the probability that investors assign to the grant. Because stock prices also move on grant days for reasons unrelated to the patent, Kogan et al. (2017) decompose the owner's three-day idiosyncratic return into the part due to the patent and unrelated return noise, and recover the patent's private value from the expected return due to the patent, given the observed return, under a truncated-normal signal distribution. The same pricing logic applies to any other firm i whose expected profits change when the patent is granted. On the grant date, firm i's equity value changes by the unanticipated share of that change in its expected profits. Prior anticipation therefore scales down the level of both the innovator's gain and connected firms' gains and losses by the unanticipated share, which makes grant-window dollar estimates conservative in level while leaving the ratio of external to private value unchanged patent by patent whenever investors share a common prior, and in totals over patents exactly when, in addition, the unanticipated share does not covary across patents, weighted by each patent's dollar value to its owner, with each patent's ratio of external to private value.

Stock-market reactions and trading volume around grant Tuesdays show that patent issuance

[26] 35 U.S.C. 154(a). The account of patent procedure follows Title 35 of the U.S. Code, Title 37 of the Code of Federal Regulations, and the USPTO *Manual of Patent Examining Procedure* (Ninth Edition, January 2024; Fifth Edition, August 1983).

[27] 35 U.S.C. 111–115, 131–134, and 151; 37 CFR 1.113–1.114 and 1.311–1.316.

conveys material news about both the innovating firm and its peers. Building on Pakes (1985) and on Austin (1993, 2000), who estimate grant-date abnormal returns for biotechnology patentees and their rivals, Kogan et al. (2017) value every patent granted to a U.S. listed firm from its three-day grant-window return. They show that abnormal share turnover in the owner's stock rises by 0.2 percentage points over the first two days after a grant (against a 1.3 percent median daily turnover) and that firm-level patent values predict subsequent growth in the innovator's sales, profits, and TFP as well as contractions at industry competitors (see also Kline et al., 2019, on worker outcomes). Farre-Mensa et al. (2020) instead estimate how winning a first patent affects startup employment, sales, subsequent innovation, and financing. Subsequent methodological studies show that accounting for return noise and same-day patent batches matters when comparing or aggregating grant-day signals across firms (Arora et al., 2026; Federle et al., 2026; Haddad et al., 2022; Shu et al., 2022; Chemmanur et al., 2026). Extending event studies from the patentee to connected firms, Walter (2024) documents negative stock-price reactions at close product-market rivals and positive reactions at technology peers around patent announcements, and Aghdasi and Tagade (2025) find on patent grant dates that an innovator's grants raise stock returns at citing firms and at firms with a high propensity for vertical integration with the innovator, while lowering returns at product-market rivals.

Although the American Inventors Protection Act of 1999 introduced pre-grant publication for applications filed after November 2000, the Tuesday grant date remains the relevant event for measuring private and external value across the 1981–2024 corporate panel. For applications filed before November 29, 2000, the USPTO kept pending applications confidential until issuance, so the Tuesday grant was the first official disclosure of both the invention and the allowed claims.[28] Under the 1999 Act, utility applications filed on or after November 29, 2000 are published 18 months after their earliest filing date unless they have already issued, been abandoned, or opted out of publication by certifying that no foreign patent will be sought.[29] Several recent studies find larger stock-price reactions around 18-month publication dates than around subsequent grant dates for applications published before issuance (Chen et al., 2019; Houston and Roskelley, 2024; Wang, 2023; Hegde et al., 2026). In pharmaceuticals, Dang et al. (2025) find pre-grant publication reactions nearly as large as grant reactions. By contrast, Kogan et al. (2017) find weak publication-date price movements and no discontinuity in grant-date return informativeness across the November 2000 filing cutoff, and Hege et al. (2025) find positive post-grant abnormal returns for examiner-instrumented climate patents with no response at publication.[30] I use

[28] 35 U.S.C. 122(a); 37 CFR 1.221(a). Applications also filed abroad under the Patent Cooperation Treaty were published 18 months after priority filing (35 U.S.C. 374).

[29] 35 U.S.C. 122(b); 37 CFR 1.211–1.215. About 10 percent of applications opted out in the early years of the Act (GAO-04-603, May 2004).

[30] Related studies examine how 18-month publication affects price discovery, institutional trading, patent-text explanatory power, and follow-on innovation and licensing (Johnson and Popp, 2003; Hegde and Luo, 2018; Hegde et al., 2020; Baruffaldi and Simeth, 2020; Kim and Valentine, 2021; Saidi and Žaldokas, 2021; Hegde et al., 2023; Beyhaghi et al., 2023; Zheng, 2025; Blanco et al., 2026).

Tuesday grant dates for three reasons: grant dates exist consistently for every patent from 1981 to 2024, issuance is the date on which the legal right to exclude competitors takes effect, and the granted patent reveals the final claims allowed after examination rather than the initial claims requested at filing.