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The missing middle: Value capture in the market for startups☆

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ABSTRACT

We argue that innovations that involve both upstream (technological) and downstream (commercialization) challenges are disadvantaged in a startup-based innovation system where startups develop inventions, while incumbents acquire startups. We propose an analytical model in which startups are more efficient at solving technological challenges and incumbents are more efficient at solving commercialization challenges, and where uncertainty about the best acquirer prevents complete contracts. We find that when both technological and commercialization challenges are present, as commonly observed in deep tech innovations, startups are able to capture a smaller fraction of the value created. This introduces a bias in the direction of innovation as projects that are primarily characterized by one type of challenge are more attractive investments compared to projects, equally or more valuable, which face both challenges. We discuss the implications of our model for startup strategies, empirical research and deep tech innovation policies.

> "On one side, ICT with mostly low technology risk and high market risk (i.e., we can build it, but is there a market for it?), and on the other side, biotech with high technology risk and low market risk (i.e., if the drug gets approved, very little market risk is associated with it). … The problems start when we move outside of these two well-defined blueprints, …" (BCG, 2021, pp. 15).

1. Introduction

The current innovation ecosystem is marked by a division of innovative labor between startups, which develop new inventions, and incumbents, which commercialize the inventions (Arora et al., 2020).[1] This division of innovative labor has delivered efficiency gains as it allows startups and incumbents to focus on their respective comparative advantage (Arora et al., 2001). However, the startup-based innovation system appears to be more effective for software and digital products, and life-sciences but not for deep tech sectors such as quantum computing, photonics, advanced materials, and energy storage (BCG, 2021; Lerner and Nanda, 2020; Nanda, 2020). Understanding why the market for startups favors innovation in some sectors compared to others is an important research question because deep tech innovations could play a crucial role in addressing some of humanity's most complex problems (Nanda, 2020).

In this paper we study how value capture (Brandenburger and Stuart, 1996, 2007; Gans and Ryall, 2017) can bias the direction of innovation in a startup-based innovation system. We propose a stylized model in which innovations are characterized by upstream investments in developing new technology, followed by downstream investments, typically for product optimization, scale-up, manufacturing, marketing and distribution (Teece, 1986). We assume that the first investment must be completed successfully before the second investment can be made.[2] Second, we assume that incumbent firms, with existing

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[1] Successful startups are typically acquired by large corporations (Cunningham et al., 2021; Gans et al., 2002; Henkel et al., 2015; Higgins and Rodriguez, 2006).

[2] Although technology development and commercialization may involve feedback loops (Kline and Rosenberg, 1986), technology development logically precedes scale-up, sales, and distribution.

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production and sales capabilities, and established links with suppliers and customers, are better placed at commercialization activities, or as we label it, solving *commercialization challenges*. By contrast, startups are typically better at the initial technology development and design, which we label *technological challenges*. This difference in the comparative advantage of startups and incumbents generates efficiency gains if the startup is acquired after the technology challenges have been solved.[3]

Finally, we assume that the incumbent that is best suited to solve the commercialization challenges cannot be identified before the technology is developed. One reason is "application uncertainty" (Kapoor and Klueter, 2021): technologies often have multiple potential applications. The incumbent best suited to commercialize the technology depends on the most attractive commercial application, which is unknown before completion of technology development. In addition, the product development pipelines and strategic direction of potential buyers also change with time.[4] The net result is that it is difficult for a startup to identify and sign a contract with an incumbent before the startup has successfully overcome the technological challenges.

The case of Biomason, a North Carolina based startup, is exemplary. Biomason is developing technology to grow biocement from bacteria. Instead of producing carbon dioxide as conventional cement production does, biocement involves bacteria removing carbon dioxide from the air to produce calcium carbonate, similar to how coral reefs grow. Potential applications of the technology include cement to protect shorelines against erosion, dust control in mining operations, and decorative tiles. The incumbent best suited to scale up and commercialize the technology ranges from marine contractors and mining companies to tile producers. In our model, the first set of investments is needed to develop the technology and to discover its best application. If Biomason overcomes the challenge of producing biocement, a second round of investments is required to establish customer relationships, develop the supply and distribution capabilities, and persuade skeptical users to replace Portland cement with biocement.[5]

We show that the startup's value-capture ability is lower when both technological and commercialization challenges are intermediate than when only one type of challenge is significant. Thus, when both types of challenges are present, the startup is less attractive to potential investors and, in turn, less likely to be founded in the first place. To the best of our knowledge, the resulting bias in innovation is a novel result and adds to existing theories on frictions in the markets for technology (Gans et al., 2008; Hegde and Luo, 2018; Chondrakis et al., 2021). Also, our model offers a novel explanation for why deep tech startups, which face both technological and commercialization challenges, may find it difficult to attract adequate investment (Nanda, 2020; Lerner and Nanda, 2020).

The economic intuition for our result can be understood by considering three projects with the same value and the same total cost of bringing the innovation from lab to market but with different cost structures. One of the projects involves primarily technological challenges, and one involves primarily commercialization challenges, whereas the third involves both types of challenges. The startup is responsible for solving the technological challenges. Because the startup's investment in addressing the technological challenges is sunk at the time of acquisition negotiations, the startup can be held up by the incumbent (Grossman and Hart, 1986). This problem is particularly severe for the project suffering primarily from technological challenges. But, in this case, the commercialization challenges are minor. Therefore, the startup has a viable outside option when negotiating the acquisition price with the incumbent. The outside option is either commercializing the innovation on its own or be acquired by another buyer (albeit one less efficient than the incumbent best positioned to commercialize the startup's innovation). Conversely, although a startup working on a project that involves mainly commercialization challenges would not have a viable outside option, the modest upfront investment limits the hold-up problem. If, however, the technological and commercialization challenges are comparable in size, the startup has the lowest value capture ability: The outside option is not viable but the substantial upfront cost still exposes it to being held up.

After formalizing this insight, we analyze its implications for the direction of innovation. Under certain circumstances, the expected value of the startup, net of the cost of due diligence and financing, is negative and no rational investor will be willing to fund the venture. That is, the problem of value capture reduces the share of otherwise valuable projects that feature both technological and commercialization challenges, leading to what we call the missing middle. Next, by introducing a competitive market for capital, we show that the allocation of capital is inefficient since projects in the middle face a higher hurdle to obtain funding than projects characterized mainly by one type of challenge.

Section 2 provides a review of the literature and establishes our contributions to various streams of research. Section 3 presents the model and its main insights. Section 4 delves into the implications for startup strategies and the direction of innovation. It also addresses the empirical implications of the theory and outlines the case in which the incumbent can also solve the technological challenges, albeit at a higher cost. Section 5 discusses some policy implications for deep tech startups and Section 6 concludes the paper.

2. Literature review and contribution

The distinction between technological and commercialization challenges and their temporal sequencing are well-established in the innovation literature. Freeman (1982) noted that innovation is frequently a problem of matching technological advances to market needs. Anderson and Tushman (1990) evolutionary model of technological change stresses the importance of addressing technological problems in the pre-entry industry evolution phases while Teece (1986) seminal work focuses on the importance of complementary assets in the scale-up and growth phases. Maine and Garnsey (2006) explicitly distinguish between technological and commercialization challenges. Their case study of the commercialization of advanced materials technologies reveals that even when the startups were successful in solving technological challenges, they needed external partners to solve commercialization challenges. Moreover, these partnerships were difficult to pull off until after the technological challenges had been solved. Consistent with Maine and Garnsey (2006), we assume that startups and incumbents differ in their technological and commercialization capabilities, with implied gains from trade.

Kapoor and Klueter (2021) develop a taxonomy of uncertainty types related to emerging technologies, and offer some guidance about how firms should manage these uncertainties. Unlike Kapoor and Klueter (2021), we ignore the managerial problems related to coping with the different challenges and focus instead on how the combination of technological and commercialization challenges, coupled with application uncertainty, affects value capture in an innovation ecosystem characterized by a division of innovative labor.

In the large literature on the market for technology (Arora et al., 2001), our paper contributes to the growing stream of work analyzing the conditions under which high-tech startups are acquired by incumbents (Gans et al., 2002), the consequences of such acquisitions for

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[3] In some cases, a key part of technology development is identifying the relevant consumer segment and the appropriate business model. This is common in software, digital, social media and mobile apps startups. From our perspective, what matters is that startups are better at executing the initial set of activities, but not at commercialization, and therefore would seek to be acquired by incumbents that are better placed to commercialize the innovation.

[4] For instance, a pharmaceutical firm whose own drug fails in clinical trial can turn into a potential buyer for a biotech firm that has developed a new drug.

[5] Betting on Bacteria to Fix the Cement Industry's Emissions Problem. https://financialpost.com/pmn/business-pmn/betting-on-bacteria-to-fix-the-cement-industrys-emissions-problem

startup exit strategy (Arora et al., 2021) and consolidation of market power (Cunningham et al., 2021). Within this literature, there is a strand of work investigating how value capture strategies create inefficiencies in technology transactions because of uncertainty and asymmetric information. Coff (1999) shows that when buyers attempt to acquire firms in knowledge-intensive sectors, they cope with uncertainty by reducing bid premia and engaging in lengthy negotiations. Other authors have shown how both startups and potential buyers may strategically delay acquisition in order to extract a bigger share of the gains from trade (Allain et al., 2016; Luo, 2014; Marx et al., 2014). However, these strategies also increase the probability of startup failure before acquisition (Arora et al., 2021).

In this paper, we abstract from asymmetric information in order to focus on bargaining and value capture in markets for technology in contexts in which application uncertainty prevents complete contracts. Like the seminal work by Green and Scotchmer (1995), our focus is here on the division of rents when innovation is sequential. Green and Scotchmer (1995) show that early innovators are under-rewarded; they face a hold-up problem because R&D costs are sunk when selling the technology (Grossman and Hart, 1986; Williamson, 1975). While Green and Scotchmer derive implications for the design of the patent system, we study how the distribution of costs in a two-stage sequential innovation process affects startups' ability to capture value. Our main theoretical advance over Green and Scotchmer is to show that the severity of the hold-up problem is the greatest for intermediate values of the ratio of technological to commercialization costs. This is, to the best of our knowledge, a novel result that adds to our understanding of inefficiencies in markets for technology and that, unlike most of the existing literature, does not rely on asymmetric information.

Finally, this paper contributes to the emerging literature on deep tech ventures, which has identified several reasons behind the difficulties these startups face in raising venture capital (VC) funds (Nanda, 2020). For instance, Dalla Fontana and Nanda (2022) argue that stage investing might not be well-suited for deep tech startups due to the high costs of experimentation, which eliminate the advantage of gaining more insights into the startup's potential before committing further (Ewens et al., 2018). Bolton et al. (2023) develop a model where scientists and investors prefer different types of experiments leading to an agency problem that could potentially discourage VC funding. Fosfuri and Nagar (2023) show that the agency conflict between founder scientists and investors delays VC funding. We contend that the market for technology experiences contracting frictions, thereby contributing to the challenges faced by deep tech startups in securing VC funds.

3. Model

3.1. Assumptions, timing and key parameters

Innovation projects: We assume that an innovation project is characterized by a value v and a combination of technological and commercialization challenges, captured by the parameter $u \in [0,1]$, where $u = 1$ denotes a project with only technological challenges, and $u = 0$ denotes a project with only commercialization challenges. Intermediate values of u represent projects with both types of challenges.

We consider u as a feature of an industry or a technology field. Software, digital, and social media companies require a low upstream investment relative to the downstream investment (i.e. low u).[6] By contrast, the bio-pharma sector faces a substantial initial investment in discovery and clinical trials relative to sales and distribution (i.e. high u), especially when adjusting for the risk of failure. Deep tech projects tend to fall in the middle. They are similar to bio-pharmaceutical projects as both require a substantial investment in R&D for discovery and development. However, unlike pharmaceuticals, technological success is not enough to guarantee commercial success.[7] Scaling up, sales and distribution pose significant challenges as well (Nanda, 2020). Supporting this view, Maine and Seegopaul (2016) argue that the ratio of commercialization to technological challenges is highest in information technology, lowest in biomed, with advanced materials – a deep tech field – falling in between.

Note that the relevant comparison is the ratio of the upstream to downstream investment – technological challenges relative to commercialization challenges – not whether commercialization challenges are higher in social media relative to deep tech, or whether the technological challenges are higher in deep tech or biopharma.

Timing: Startups seek financing with the purpose of developing innovation projects. If financing is obtained, a startup solves the technological challenges. Then, the startup may sell the project to an incumbent firm which can solve the commercialization challenges more efficiently, or continue on its own and bring the innovation to the market. Finally, payoffs are realized.

Financing: There is a competitive capital market, and all projects with a return above the minimum required by capital market investors, which we normalize to zero, receive funding. We are thus abstracting from information asymmetries but we return to this issue in Section 4.1.

Costs of addressing challenges: Let $T(u)$ be the cost of addressing the technological challenges, with $T'(u) > 0$. Thus, higher values of u imply higher costs for finding technological solutions. The cost to the incumbent best suited to solve the commercialization problems is $C(u)$ with $C'(u) < 0$. Thus, higher values of u imply lower costs of addressing the commercialization challenges.

To focus on how the relative importance of the technological and commercialization challenges affects the division of rents between the startup and the incumbent, we fix the total costs of all projects to be the same. However, projects have a different distribution of these costs, parameterized by u. Formally,

Assumption 1. The total cost of a project $\mathrm{T(u)} + \mathrm{C(u)}$ is independent of u if developed in the most efficient way: $\mathrm{T'(u)} + \mathrm{C'(u)} = 0$.

Assumption 1 means that an increase in u is associated with a smaller share of commercialization costs over the total costs of a project. To reduce the number of different cases, let $T(0) = C(1) = 0$.

Finally, innovation projects differ also in the value v. For any given u there is a distribution of project values $v \in [\underline{v}, \overline{v}]$ which is independent of u.

Acquisition stage: After the technological challenges are solved, a startup has the possibility to sell the project to an incumbent that can commercialize it more efficiently. To model the market for startup acquisitions, assume that there are n incumbents located equidistantly around a circle with circumference equal to 1. After addressing the technological challenges, the startup's project falls on the location of one of the incumbents (allowing the startup's project to fall on any point of the circle does not change any of the insights but substantially complicates the algebra). The probability of falling on a given incumbent is uniform across incumbents and equal to $1/n$. The incumbent's cost of addressing the commercialization challenges is $C(u)(1 + x)$ where x is the distance between incumbent and startup. The closest incumbent ($x = 0$) and the second-closest incumbents ($x = 1/n$) can solve the commercial challenges at costs $C(u)$ and $C(u)\left(1 + \frac{1}{n}\right)$, respectively. Alternatively, the startup can address the commercialization challenges by itself at a cost $C(u)(1 + \gamma)$ with $\gamma > 0$ capturing the disadvantage compared to

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[6] Ewens et al. (2018) argue that the availability of IT infrastructure services such as webhosting, DNS, and especially cloud computing has greatly reduced the setup and initial operating cost for online startups, relative to the large investments required to acquire customers and scale up.

[7] A number of contract manufacturing organizations and other specialized intermediaries have emerged to help startups through the drug development and clinical trial phase (Moreira et al., 2023).

the best-suited incumbent in solving these challenges. The acquisition price is determined through a Nash bargaining solution (NBS) where the startup's bargaining power is equal to b.[8]

We follow Green and Scotchmer (1995) and assume that ex ante contracts are not possible. Before solving the technological challenges, the startup does not know which incumbent will be the closest ex post. We assume that this application uncertainty precludes ex ante contracting. Thus, the startup can negotiate a deal with a potential incumbent only after the technological challenges have been addressed. Although an ex ante agreement would achieve the first-best outcome in our model (see, for instance, Noldeke and Schmidt, 1998), identifying the appropriate incumbent would be difficult before the technological challenges are resolved.

3.2. *Solving the model: Value of a startup*

We solve the model backwards by first analyzing the bargaining between the startup and incumbents after the technological challenges have been addressed. In this subsection, we keep the value of the project v constant and focus on the effect of u on value capture. In the next section, we analyze the financing stage and show which projects are funded as a function of both u and v.

After the technological challenges have been solved, the value of the project is $v - C(u)$ for the closest incumbent, $Max\{v - C(u)\left(1 + \frac{1}{n}\right), 0\}$ for the second-closest incumbents, and $Max\{v - C(u)(1 + \gamma), 0\}$ for the startup. There are no frictions at the acquisition stage so that the startup is always acquired by the closest incumbent as this maximizes value creation.

In order to derive the sale price, one needs to know the outside options of the two parties. The closest incumbent has no outside option at the time of the price negotiation. The outside options for the startup are either to be acquired by one of the second-closest incumbents or to solve the commercialization challenges by itself. Since the second-closest incumbents lose the competition for acquiring the startup, they submit the most aggressive bid that they can make without risking losing money.[9] Hence, the second-closest incumbents bid $Max\{v - C(u)\left(1 + \frac{1}{n}\right), 0\}$. Define $\theta \equiv Min\{\gamma, \frac{1}{n}\}$, the startup's outside option can be compactedly written as $Max\{v - C(u)(1 + \theta), 0\}$. Define: $u^* : v - (1 + \theta)C(u) = 0 \Leftrightarrow u^* = C^{-1}\left(\frac{v}{1+\theta}\right)$. For $u > u^*$, the startup has a viable outside option while for $u < u^*$, the startup's outside option is 0. Thus, the outcome of the bargaining between the startup and the incumbent will change significantly depending on whether u is greater or smaller than u^*.

Assumption 2: $\frac{v - [C(u) + T(u)]}{[C(u) + T(u)]} = m < \theta$.

Assumption 2 is a technical assumption to ensure that u^* is between 0 and 1. It means that the rate of return for all projects (if there were no value-capture problem), m, is smaller than the value created by the acquisition by the best-suited incumbent represented by θ. Given Assumption 2 and $C(0) = T(u) + C(u)$, it follows that u^* is interior, i.e. $0 < u^* < 1$.[10]

Let $\pi_S(u)$ and $\pi_I(u)$ be the respective expected payoffs of the startup and the closest incumbent, which depend on whether $u \le u^*$ or $u > u^*$. If $u \le u^*$, the outside options of both the startup and the incumbent are equal to 0. The expected payoffs are:

$$\pi_S(u) = 0 + b(v - C(u)) - T(u) = bS - (1 - b)T(u), \tag{1}$$

$$\pi_I(u) = 0 + (1 - b)(v - C(u)) = (1 - b)(S + T(u)),$$

where $S = v - C(u) - T(u)$ is constant in u.

If $u > u^*$, the startup's outside option is $v - (1 + \theta)C(u)$ and the incumbent's outside option is 0. The expected payoffs are:

$$\begin{aligned} \pi_S(u) &= v - C(u)(1 + \theta) + b[C(u)(1 + \theta) - C(u)] - T(u) \\ &= S - (1 - b)\theta C(u), \end{aligned} \tag{2}$$

$$\pi_I(u) = 0 + (1 - b)\theta C(u).$$

If the startup does not invest in solving the technological challenges, the payoff for both is zero.

We now present the key result of the paper:

Lemma 1. **[Profit of the startup]** For a given value of the project v, the profit of a startup first declines and then increases with u. It is lowest at u = u*.

Proof: Using eqs. (1) and (2), we obtain:

$$\partial \pi_S(u) / \partial u = \begin{cases} -(1 - b)T'(u) < 0 & for \quad u \le u^* \\ -(1 - b)\theta C'(u) > 0 & for \quad u > u^* \end{cases}. \tag{3}$$

Hence, $\pi_S(u)$ has a global minimum for $u = u^*$. □.

Note that the total value created, $S = v - C(u) - T(u)$, is held constant. Thus, this result is driven entirely by the startup's ability to capture value, which is lowest at $u = u^*$. The intuition is that the upfront investment by the startup to solve the technological challenges is subject to an ex post hold-up problem. If the startup cannot credibly threaten to go it alone or to sell to another incumbent ($u \le u^*$), the hold-up problem becomes less severe as u declines and the upfront investment *T(u)* to resolve the technological challenges decreases. However, when the project involves mostly technological challenges ($u > u^*$), the hold-up problem is partially mitigated because the startup has a viable outside option. In this case, as u increases, the cost of commercialization falls, which improves the attractiveness of going it alone or selling to another (albeit less suited) incumbent and thus the startup's value capture ability increases. However, for u in the neighborhood of u^* the technological and commercialization challenges are comparable. If the startup invests in solving the technological challenges, it faces both a sizable hold-up problem and limited outside options, giving the incumbent the upper hand in the negotiations.

A first implication of Lemma 1 is that innovation projects which involve both technological and commercialization challenges provide startups with lower rates of return compared to more specialized projects, and thus may remain unfunded even if VC funding were abundant. The idea that these projects are required to offer a higher rate of return in order to be funded is consistent with anecdotal evidence on deep tech innovations (BCG, 2021; Lerner and Nanda, 2020; Nanda, 2020). We show this more formally in the next section.

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[8] The Nash bargaining solution also arises as the equilibrium of a non-cooperative game where the startup and the incumbent make alternating offers with respective probability of b and *1-b* (Rubinstein, 1982). The Nash bargaining solution implies that an outside option of strictly positive value improves a startup's ability to capture value. However, it has been argued in the literature on bargaining that the outside option only improves value capture if exercising it results in a greater payoff to the startup than splitting the gains from trade; see, e.g., Binmore et al. (1989). Using the latter approach instead of Nash bargaining reduces the impact of the outside option on value capture but yields otherwise similar results.

[9] Formally, there are other equilibria where the second-closest incumbents are outbid by the closest incumbent but bid more than their valuation. However, if there is just a very small (exogenous) probability that the deal with the closest incumbent falls through, the second-closest incumbents would never bid more than their valuation.

[10] To ensure that $0 < u^* < 1$, the startup must be neither very bad nor very good at addressing the commercialization challenges relative to the acquiring incumbent, and the competition among incumbents for acquiring the startup should not be very tough; otherwise, the startup's outside option will be the same for all u.

4. The missing middle

In this section, we derive the implications of the problem of value capture in the middle for total value creation.

4.1. Missing middle and the direction of innovation

A project creates value $\nu - (C(u) + T(u))$ to society. It follows that the first-best allocation of capital is such that all projects for which $\nu \geq C(u) + T(u)$ are funded. Expressing this condition in terms of a hurdle rate – the required minimum rate of return – the socially optimal hurdle rate is $m^o = 0$.

Turning to the market equilibrium, let $m^*(u)$ be the market hurdle rate such that $\pi_S(u) = 0$. Using eqs. (1) and (2), we obtain:

$$m^*(u) = \begin{cases} \dfrac{(1-b)T(u)}{b(C(u)+T(u))} & if\ u \leq u^* \\ \dfrac{(1-b)\theta C(u)}{C(u)+T(u)} & otherwise \end{cases}. \tag{4}$$

Projects with a hurdle rate lower than $m^*(u)$ are not funded because they have a negative private net present value. It follows from our assumptions on $C'(u)$ and $T'(u)$ that $m^*(u)$ is increasing in u for $u < u^*$ and decreasing in u for $u > u^*$. Furthermore, $m^*(0) = m^*(1) = 0 = m^o$ since $T(0) = C(1) = 0$.

These observations have two important implications for value creation and for the direction of innovation. First, the market hurdle rate for obtaining funding is strictly greater than the first-best hurdle rate for all projects characterized by $0 < u < 1$. Because the startup must give up value to its commercialization partner in excess of commercialization costs, there exist projects with positive net value that are not funded. Second, projects in the middle (i.e., around u^*) face the highest market hurdle rate. This introduces a bias in the direction of innovation as capital markets fund projects that are primarily characterized by one type of challenge, while other projects, equally or more valuable, which face both challenges, cannot obtain funding. This is not to imply that projects in the middle are never funded; in fact, highly valuable projects always secure funding. However, projects in the middle need to be more profitable than other projects to receive funding.

The following proposition summarizes this analysis and derives the market hurdle rate for projects in the middle, $m^*(u^*)$.

Proposition 1. **[Missing middle]**. The market hurdle rate $\mathrm{m}^*(\mathrm{u})$ is increasing in u for $\mathrm{u} < \mathrm{u}^*$ and decreasing in u for $\mathrm{u} > \mathrm{u}^*$. Hence, projects in the middle $(\mathrm{u} = \mathrm{u}^*)$ face the highest market hurdle rate and receive funding if and only if the ex ante return is greater than or equal to $\mathrm{m} \geq \mathrm{m}^*(\mathrm{u}^*) = \frac{(1-\mathrm{b})\theta}{1+b\theta}$.

Proof: Since $m^*(u)$ increases in u for $u < u^*$ and decreases thereafter, it must achieve its maximum at u^*. The only thing left to show is that $m^*(u^*) = \frac{(1-b)\theta}{1+b\theta}$. Using $\nu = (1+\theta)C(u^*)$ and Eq. (2), we can write the condition $\pi_S(u^*) = 0$ as $\frac{\nu - C(u^*) - T(u^*)}{C(u^*)+T(u^*)} = \frac{(1-b)\theta\nu}{(1+\theta)(C(u^*)+T(u^*))} \Leftrightarrow m^*(u^*) = \frac{(1-b)\theta}{1+\theta}(m^*(u^*)+1)$. Rewriting this condition yields the market hurdle rate $m^*(u^*)$ in the proposition. □

Proposition 1 is illustrated in Fig. 1. It shows how the market hurdle rate $m^*(u)$ is greatest for $u = u^*$, and the grey area between $m^*(u)$ and m^o represents socially desirable projects that are not undertaken because they are not privately profitable for investors. The problem arises due to the cumulativeness of the innovation process, wherein the first and thus enabling innovator (in this case, the startup) tends to be under-rewarded (Green and Scotchmer, 1995). Our contribution is to highlight that this issue is most pronounced for startups positioned in the middle (i.e., near u^*), where value capture is the lowest, and investors demand the highest project value to supply funds.

Interestingly enough, the outcome resembles one of Grossman and Hart (1986) main predictions: when investments by both parties are substantial, as is the case here in the middle, there is underprovision of effort and thus inefficiency. However, in our model, investments are sequential, and the incumbent buyer is not exposed to a hold-up. If this were a Grossman-Hart model, underinvestment would have increased with u because the hold-up problem intensifies with the cost to address the technological challenges, $T(u)$. Instead, in our framework, differing from Grossman and Hart (1986), there is a countervailing effect driven by an improvement in the bargaining position of the startup, which indeed is at the core of our contribution.

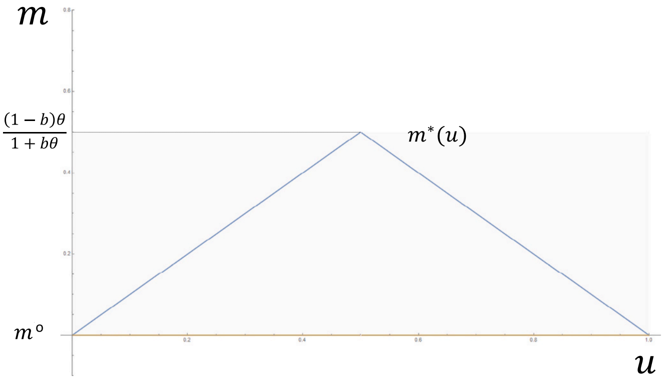

Fig. 1. The market hurdle rate $m^*(u)$ and the first-best hurdle rate m^o.
Notes: $C(u) = 1 - u$, $T(u) = u$. The parameters are $\gamma = 2$ and $b = 0.5$.

In addition to the problem of underfunding of innovative startups, the differences in the ability to capture value across startups lead to an inefficient allocation of the available capital. Indeed, taking the amount of capital invested in startups in equilibrium as given, overall value creation could be enhanced by reallocating capital from marginal projects at the extremes (i.e. high and low values of u) to unfunded projects in the middle with higher value.

The result in Proposition 1 contributes to the recent debate on the difficulties faced by deep tech startups to attract risk capital (BCG, 2021; Lerner and Nanda, 2020; Nanda, 2020), and the potential failure of the startup-based system for deep tech innovation. A number of explanations have been proposed ranging from the lack of regulation, and the need for complementary infrastructure (Janeway, 2018) to the costs and difficulty of de-risking (Nanda, 2020; Dalla Fontana and Nanda, 2022) and the potential frictions in the supply of risk capital for such ventures (Ewens et al., 2018; Lerner and Nanda, 2020). We argue here that the difficulties faced by deep tech startups to raise VC funding might be attributed to the relatively small portion of value created they are able to capture.

To maintain focus, we have assumed thus far that all ventures face the same conditions in terms of the number of potential acquirers and the supply of complementary services. However, it is plausible that deep tech projects have fewer potential acquirers. In terms of our model, this would increase θ. In the same vein, market intermediaries, such as contract development organizations that provide clinical testing and development services in the pharmaceutical industry (Moreira et al., 2023), or service providers such as Amazon Web Services, benefit startups by reducing the cost of R&D. Deep tech startups may suffer relatively more from an inadequate supply of such complementary inputs. Indeed, the next proposition shows that changes in the bargaining power and the outside option of startups are especially salient for startups in the middle.

Proposition 2. [Comparative statics]

i. An increase in the bargaining power of startups (an increase in b) increases a startup's value capture and reduces the market hurdle rate $\mathrm{m}^*(\mathrm{u})$ for all $0 < \mathrm{u} < 1$.

ii. An improvement in the outside option of startups (a reduction in θ) increases a startup's value capture, reduces u^* and the market hurdle rate $m^*(u)$ for all $u^* < u < 1$.

iii. The effects described in i.) and ii.) are most pronounced for startups in the middle.

Proof: Consider the comparative statics with respect to b. Using eqs. (1), (2), and (4), we have that $\partial\pi_S(u)/_{\partial b} > 0$ and $\partial m^*(u)/_{\partial b} < 0$ for all $0 < u < 1$. Furthermore, $\partial^2\pi_S(u)/_{\partial b\partial u} > 0$ for $u < u^*$ and $\partial^2\pi_S(u)/_{\partial b\partial u} < 0$ for $u > u^*$, while $\partial^2 m^*(u)/_{\partial b\partial u} < 0$ for $u < u^*$ and $\partial^2 m^*(u)/_{\partial b\partial u} > 0$ for $u > u^*$. The comparative statics with respect to θ are derived in a similar manner. Further, note that $\partial u^*/_{\partial\theta} = -C'/_{(1+\theta)C} > 0$.□

Proposition 2 shows that all startups benefit privately from increased bargaining power but that startups in the neighborhood of u^* benefit the most. Empirically, this implies that the benefits of an increase in bargaining power are moderated by the nature of the project. If one identifies digital or IT projects with low u, for such projects the benefits of an increase in bargaining power (e.g., a more commercially savvy CEO and board) are lower than for deep tech projects. Put differently, deep tech startups may benefit more from an experienced CEO than other types of startups.

Startups' investments in reducing θ might be thought of as efforts to accumulate downstream capabilities in circumstances where the best outside option is always to commercialize itself, i.e., when $\theta = \gamma < 1/n$. These investments can take a number of different forms such as hiring manufacturing or marketing experts, and seeking agreements with distributors, etc. Proposition 2 shows that startups' incentives to invest in own commercialization capabilities are highest for $u = u^*$ where the startup's threat of own commercialization becomes effective, but the commercialization cost is still substantial. Thus, a second important implication is that startups facing both technological and commercialization challenges have stronger incentives to make downstream investments that improve their value capture position.

Alternatively, if $\theta = 1/n > \gamma$, startups' investments in reducing θ might be thought of as efforts in making the market for technology more competitive, for instance, by selecting technologies that appeal to more potential buyers or developing features that make the technology less application specific.

Increases in startups' bargaining power and improvements in their outside option have a direct and positive effect on total value creation as the gap between the market and the first-best hurdle rate is narrowed. More projects with positive social returns are thus able to obtain funding from investors. However, in order to evaluate the overall impact on total value creation, it is also essential to take the associated costs into account. For example, a startup's investment in increasing its outside option may result in wasteful duplication.[11] Still, some changes are exogenous to the affected startups, making them easier to evaluate. For example, we predict that a lowering of trade barriers enhances the value created by deep tech startups by giving them access to contract manufacturers that reduce the cost of self-commercialization.

4.2. Frictions in the capital market

There is a large and important literature that studies the financing of risky ideas by entrepreneurs in the presence of information asymmetries, see Da Rin et al. (2013) for an overview. We have abstracted from financial frictions to focus on value capture by startups in a market for technology. However, the cost of solving the technological challenges in the model can be thought of as including a cost of incentivizing the entrepreneur. Consider a simplified version of the canonical model due to Holmstrom and Tirole (1997). An entrepreneur has to exert non-contractible effort to solve the technological challenges that the startup faces. If the effort is exerted, the technological challenges are solved with probability $p = 1$. If no effort is exerted, $p = 0$ and the entrepreneur enjoys a private benefit $B(u)$, which captures benefits such as the joys of working on a pet technology or the opportunity cost of managing the project diligently. Assuming that the entrepreneur has no funds to invest and enjoys limited liability, the optimal contract pays nothing in case of failure and $B(u)$ in case of success to the entrepreneur. This contract incentivizes the entrepreneur to exert effort at the lowest possible cost. Essentially, $B(u)$ is, in this framework, a fixed cost of incentivizing the entrepreneur. In addition to entrepreneurial effort, assume that solving the technological challenges requires an investment $I(u)$ to cover expenses related to laboratory, computing power, personnel, etc.

Now, if we define $T(u) \equiv B(u) + I(u)$ and keep the assumptions $T'(u) > 0$ and $C'(u) + T'(u) = 0$, the analysis goes through unaltered. This is, e.g., the case if the investment is increasing in u ($I'(u) > 0$) and the agency cost is constant across projects ($B(u) = B$). Lerner and Malmendier (2010) argue that agency costs are higher for research that is closer to science. This is consistent with Stern (2004)'s findings that scientists enjoy private benefits by engaging in science. Thus, it is plausible that $B'(u) > 0$. This would push the missing middle to the right of the u support, but, unless agency costs are overwhelming, our analysis holds qualitatively unchanged.

4.3. Incumbent's technology investment

We have considered an extension of the model where incumbent can also solve the technological challenges at a cost $T(u)(1+\lambda)$ with $\lambda > 0$ representing the relative disadvantage of the incumbent in resolving the technological challenges. The incumbent moves first and decides whether to invest or not in solving the technological challenges. The startup makes its investment decision after observing the incumbent's choice. This more complex model is solved analytically in the online Appendix.

The main takeaway from this extension is that if the incumbent is sufficiently disadvantaged compared to the startup in solving the technological challenges our main result of Sections 3 and 4 holds qualitatively unchanged. Put it differently, for the missing middle to emerge the comparative advantage of startups in solving technological challenges and of incumbents in solving commercialization challenges should be substantial. Incidentally, this is also the case where a market for technology offers the greatest gains.

4.4. Empirical implications

Differences in value capture across industries and technology fields is the key prediction of our theory. One possible way to estimate value capture directly is by using an event study approach where publicly traded firms announce the acquisition of startups. We can measure the buyer's payoff, $\pi_I(u)$ by the increase in the market value of the acquirer.[12] Similarly, we can measure T using the investment the startup has made. If the purchase price is P, then net value created $S = \pi_I(u) + P - T$. The net value of the startup, $\pi_S(u) = P - T$. Our model implies that the ratio $\frac{\pi_S(u)}{S} = \frac{P-T}{\pi_I(u)-T+P}$ will be higher for ventures with high and

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[11] A biotech company might develop in-house capability for manufacturing key compounds. It is likely that the acquirer will have its own manufacturing operations and put a low value on the biotech's manufacturing assets. However, the ability to produce these compounds endows the biotech firm with greater credibility in terms of solving commercialization problems which increases its ability to capture value from the acquisition.

[12] Note that $\pi_I(u) = v - C - P$, so that $v - C = \pi_I(u) + P$

low u as compared with ventures in the middle with intermediate u.[13] This empirical framework can be used to test other implications as well. Proposition 2 implies that this ratio should increase with an increase in the bargaining power of the startup, especially for ventures in the middle. Similarly, an increase in the number of potential acquirers should increase this ratio, especially for ventures in the middle.

We have thus far ignored the problem that solving technological challenges is about resolving uncertainty, and that the ex-ante value of a startup embeds a real option. The latter perspective suggests that deep tech startups are less attractive to investors because, unlike software ventures, uncertainty resolution is costly and time-consuming, resulting in a lower option-value (Dalla Fontana and Nanda, 2022). Under this perspective, deep tech ventures are not just privately, but also socially, less valuable.

Cast in terms of our model, the real option perspective implies that the net value created is smaller for u in the middle than at the extremes. The value capture perspective implies that the share of net value captured by the startup is smaller in the middle than at the extremes. While distinct, these perspectives are not mutually exclusive. Still, the two theories yield different implications that allow comparison. For instance, consider an increase in the number of potential acquirers. This would not necessarily increase the value created, unless the presence of more potential buyers improves the quality of the match between the startup and the buyer (Arora et al., 2021). However, it would shift a greater share of the value created to startups. Proposition 2 would imply an increase in the number of ventures, especially deep tech ventures. By contrast, the option-value framework would not predict such an increase. A similar intuition applies to a reduction in commercialization costs.

5. Policy implications

In this section, we discuss the implications for policy aimed at encouraging deep tech startups. Acknowledging that startup projects potentially differ in many respects, not just in the share of value that the startup can capture, we focus here on the policy implications of the latter.

Many countries have implemented a set of policies for stimulating an “entrepreneurial ecosystem” (Stam and van de Ven, 2021). A thriving entrepreneurial ecosystem can contribute to reducing the startup’s disadvantage in resolving commercialization challenges (γ) as it becomes easier to find partners and suppliers with complementary skills and assets. To the extent that the startup’s relevant outside option is solving the commercialization problems on its own, which occurs if there are few potential buyers, these policies increase the startup’s expected profit and reduce the market hurdle rate as shown in proposition 2. These policy tools are more effective for startups operating in industries around u^* where the problem of socially valuable projects yielding negative private returns is most pronounced. A potential downside of such policies is that few of the startups would actually develop the invention by themselves. Still, a startup may initially use the commercialization infrastructure to demonstrate the viability of its technology to a potential buyer, much as Cambridge Display Technology did before licensing the technology to Philips (Maine and Seegopaul, 2016). Furthermore, by improving the startups’ bargaining position, these policies may create value even if the infrastructure created appears to be under-used.

Business incubators and accelerators are also popular policy tools. They can reduce the technological challenges by helping startups navigate application uncertainty and find the best suited acquirer. This could be modeled as a proportional reduction in $T(u)$ and/or an increase in v. Based on the analysis in Section 4, it is easy to see that $m^*(u^*)$, the market hurdle rate in the missing middle, increases in v and declines in $T(u^*)$. On the other hand, accelerators weed out ideas with low private value for the startup (Yu, 2020), which are the projects around u^*. In our model, investors cull projects for which value capture is low. Accelerators can - at the most - save on resources by killing projects sooner than the market would.

Some countries operate government VC funding (GVCs) that invest directly in startups in return for an equity stake. An example is the EIC Accelerator program introduced by the European Commission as part of Horizon Europe, whose multi-billion-euro budget is aimed at equity investments in innovative ventures during the 2021–27 period. GVC funding is usually accompanied by some sort of co-investment requirements to minimize crowding-out of private investors and to exploit private investors’ comparative advantage at performing due diligence and providing mentoring and oversight. Since GVCs typically have less expertise than private VCs, the role of GVCs is ultimately to fill gaps in the supply of private risk capital and perhaps also to provide funding at below the market rate.

In our model, there are no financing frictions which reduce the supply of private risk capital. Instead, the problem is that of a market hurdle rate that is higher than the socially optimal hurdle rate, especially for projects in the middle. In this context, GVCs will be effective only insofar as they reduce the cost of capital below the market rate. However, if GVCs aim only at increasing the supply of private risk capital but behave otherwise like private VCs, by requiring positive returns on investment, our model suggests that they will not be effective in solving the inefficient functioning of the market for deep tech startups.

Mowery (1998) has stressed the importance of government procurement in nurturing innovation, especially by startups.[14] Innovation procurement by public authorities contains elements of both financial support and support for commercialization. First, it provides the winning firm with the funding required for R&D. Second, it opens up the market for applications of the technology. For instance, Biomason has benefitted from Department of Defense contracts that use its technology to prevent coastal erosion. Similarly, the Marine Corps and US Air Force have supported the development of technology for creating helicopter landing strips on isolated islands. These contracts can also provide invaluable experience to Biomason in scaling up its technology.

Procurement works best when the government agency can act as a sophisticated lead user, not just as a source of funds. For instance, in lasers, the Air Force, Advanced Research Projects Agency, and the Signal Corps funded competing research teams to build the first laser, and the first successful laser, the ruby laser was demonstrated in 1960. Large-scale commercial applications in supermarket scanners and optical discs took another twenty years and government purchases of measurement and optical communication lasers sustained laser R&D in the meantime (Hecht, 2010).[15]

6. Discussion and conclusion

Our findings have implications for research on both the markets for technology (Arora et al., 2001; Gans and Stern, 2003) and value capture (Brandenburger and Stuart, 1996, 2007; Gans and Ryall, 2017). Many inventions, and especially those rooted in science and basic research, are initiated in startups. However, startups often lack the complementary

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[13] In addition to the announced purchase price and the market reaction, this approach also requires data on the investment made by the startup.

[14] “Defense-related R&D and procurement programs provided a powerful impetus to the development and commercialization of new civilian technologies in commercial aerospace, semiconductors, computers, and computer software …. In almost all of these industries other than commercial aerospace, new firms played a prominent, and in some cases dominant, role in the commercialization of important technological advances.” (Mowery, 1998: 640).

[15] In 1969, the Department of Defense’s share as a laser customer was 63.4 % (Bromberg, 1991).

assets required to scale up and commercialize the technology. Complementary assets tend to be owned by incumbents (Teece, 1986). Startups will often profit from their inventions by partnering with incumbents (including acquisitions) in the market for technology (Arora et al., 2001). An extensive literature has focused on various inefficiencies in this market, mostly centered around information frictions.

We build on the notion of value capture (Brandenburger and Stuart, 1996, 2007; Gans and Ryall, 2017) to propose a different source of inefficiency. We show that, holding total value creation constant, the combination of technological and commercialization challenges reduces the startup's ability to capture value, and ultimately its ability to raise capital. This can distort the direction of innovation through the existence of a missing middle: Potential startups facing both technological and commercialization challenges may fail to find investors. Since deep tech startups face both technological and commercialization problems, our model proposes a novel explanation for why they find it difficult to attract adequate investment (Nanda, 2020; Lerner and Nanda, 2020).

Our main insight is derived from a purposely streamlined setting with no information asymmetry in which technological and commercialization problems arise sequentially, without interdependencies. We conjecture that asymmetric information and interdependencies are likely to exacerbate the missing middle problem. Projects characterized by both technological and commercialization challenges are more difficult for potential buyers to assess which creates greater space for information asymmetry. Interdependencies, which are likely to be more relevant in the middle – when both technological and commercialization challenges are salient – may compound the problem created by information frictions. These extensions constitute potential avenues for future research.

In our analysis, we have ignored competition among startups developing competing technologies. We would expect it to arise in industries where the startup's ability to capture value is sufficient as to ensure that several startups could expect to be profitable. This is more likely in industries characterized by either mainly technological or mainly commercialization challenges. Notice, however, that competition among startups will not solve the problem of the missing middle: if a single startup cannot make a positive profit in the industry, neither can several startups.

Our analysis addresses the tradeoff faced by startups between value capture and value creation. Startups have an incentive to increase their ability to capture value, potentially even at the cost of reducing the value created. We show that startups located in the middle faced with both technological and commercialization challenges have the strongest incentives to engage in distortionary investments which increase value capture at the expenses of value creation. They are more likely to invest in useless (to the acquirer) commercialization capabilities, or in resources aimed solely at increasing bargaining power in negotiations. Future research could test empirically how such investments vary with different combinations of technological and commercialization challenges.

The division of innovative labor between startups facing technological problems and incumbents responsible for commercializing the innovation lowers the cost and enhances efficiency but potentially also biases the direction of innovation away from innovations in the middle. Extant policies such as R&D subsidies and government VC, even when focused on specific sectors typically tend not to be tailored to increase startup ability to capture value. Anecdotal evidence suggests that R&D contracts, which both provide funding and follow-on procurement demand, can be effective for promoting deep tech ventures. A more systematic evaluation of these types of public policies is a promising and important avenue for future research.

CRediT authorship contribution statement

Ashish Arora: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Andrea Fosfuri:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. **Thomas Rønde:** Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Appendix A. Supplementary analysis

Supplementary data to this article can be found online at https://doi.org/10.1016/j.respol.2024.104958.

References

Allain, M.L., Henry, E., Kyle, M., 2016. Competition and the efficiency of Markets for Technology. Management Science 62 (4) (1000.1019).

Anderson, P., Tushman, M., 1990. Technological discontinuities and dominant designs: a cyclical model of technological change. Adm. Sci. Q. 35 (4), 604–663.

Arora, A., Fosfuri, A., Gambardella, A., 2001. Markets for Technology: The Economics of Innovation and Corporate Strategy. MIT Press, Cambridge, MA.

Arora, A., Belenzon, S., Patacconi, A., Suh, J., 2020. The changing structure of American innovation: some cautionary remarks for economic growth. Innov. Policy Econ. 20 (1), 39–93.

Arora, A., Fosfuri, A., Rønde, T., 2021. Waiting for the payday? The market for startups and the timing of entrepreneurial exit. Management Science 67 (3), 1453–1467.

BCG, 2021. Deep Tech: The Great Wave of Innovation. Hello Tomorrow, Boston Consulting Group.

Binmore, K., Shaked, A., Sutton, J., 1989. An Outside Option Experiment. The Quarterly Journal of Economics 104 (4), 753–770.

Bolton, P., Shannon, L., Nanda, R., Sundaresan, S., 2023. Experiment Design for Deep Tech Learning: Validation and Financing. Manuscript presented at the NBER Lunch seminar, Cambridge, MA.

Brandenburger, A., Stuart, H., 1996. Value- based business strategy. Journal of Economics & Management Strategy 5 (1), 5–24.

Brandenburger, A., Stuart, H., 2007. Biform games. Management Science 53 (4), 537–549.

Bromberg, J.L., 1991. The Laser in America, 1950–1970. The MIT Press, Cambridge, Massachusetts.

Chondrakis, G., Serrano, C., Ziedonis, R., 2021. Information disclosure and the market for acquiring technology companies. Strategic Management Journal 42 (5), 1024–1053.

Coff, R., 1999. How buyers cope with uncertainty when acquiring firms in knowledge-intensive industries: caveat emptor. Organ. Sci. 10 (2), 144–161.

Cunningham, C., Ederer, F., Ma, S., 2021. Killer acquisitions. Journal of Political Economy 129 (3), 649–702.

Da Rin, M., Hellmann, T., Puri, M., 2013. A survey of venture capital research. In: Handbook of the Economics of Finance, vol. 2. Elsevier, pp. 573–648.

Dalla Fontana S., Nanda R. 2022. Innovating to net zero: can venture capital and startups play a meaningful role? In *entrepreneurship and innovation policy and the economy* (editors: Lerner J., Scott S.), National Bureau of economic research, pp. 79-105.

Ewens, M., Nanda, R., Rhodes-Kropf, M., 2018. Cost of experimentation and the evolution of venture capital. J. Financ. Econ. 128 (3), 422–442.

Fosfuri, A., Nagar, J.P., 2023. Timing Is Key: Navigating Venture Capital Funding for Science-Based Startups. Unpublished manuscript. Bocconi University.

Freeman, C., 1982. The Economics of Industrial Innovation, 2nd edition. London, Francis Pinter.

Gans, J., Ryall, M., 2017. Value capture theory: a strategic management review. Strateg. Manag. J. 32 (1), 17–41.

Gans, J.S., Stern, S., 2003. The Product Market and the Market for "Ideas": Commercialization Strategies for Technology Entrepreneurs. Res. Policy 32, 333–350.

Gans, J., Hsu, D., Stern, S., 2002. When does start-up innovation spur the Gale of creative destruction? RAND Journal of Economics 33 (4), 571–586.

Gans, J., Hsu, D., Stern, S., 2008. The impact of uncertain intellectual property rights on the market for ideas: evidence from patent grant delays. Management Science 54 (5), 982–997.

Green, J.R., Scotchmer, S., 1995. On the division of profit in sequential innovation. RAND J. Econ. 26 (1), 20–33.

Grossman, S., Hart, O., 1986. The costs and benefits of ownership: a theory of vertical and lateral integration. J. Polit. Econ. 94 (4), 691–719.

Hecht, J., 2010. A short history of laser development. Appl. Optics 49 (25), F99–F122.

Hegde, D., Luo, H., 2018. Patent publication and the market for ideas. Management Science 64 (2), 652–672.

Henkel, J., Rønde, T., Wagner, M., 2015. And the winner is—acquired. Entrepreneurship as a contest yielding radical innovations. Research Policy 44 (2), 295–310.

Higgins, M., Rodriguez, D., 2006. The outsourcing of R&D through acquisitions in the pharmaceutical industry. J. Financ. Econ. 80 (2), 351–383.

Holmstrom, B., Tirole, J., 1997. Financial intermediation, loanable funds, and the real sector. Q. J. Econ. 112 (3), 663–691.

Janeway, W.H., 2018. Doing Capitalism in the Innovation Economy: Markets, Speculation and the State. Cambridge University Press, Cambridge, UK.

Kapoor, R., Klueter, T., 2021. Unbundling and managing uncertainty surrounding emerging technologies. Strategy Science 6 (1), 62–74.

Kline, S., Rosenberg, N., 1986. An overview of innovation. In: Landau, R., Rosenberg, N. (Eds.), The Positive Sum Strategy. Harnessing Technology for Economic Growth. National Academy Press, Washington.

Lerner, J., Malmendier, U., 2010. Contractibility and the design of research agreements. Am. Econ. Rev. 100 (1), 214–246.

Lerner, J., Nanda, R., 2020. Venture capital's role in financing innovation: what we know and how much we still need to learn. J. Econ. Perspect. 34 (3), 237–261.

Luo, H., 2014. When to sell your idea: theory and evidence from the movie industry. Management Science 60 (12), 3067–3086.

Maine, E., Garnsey, E., 2006. Commercializing generic technology: the case of advanced materials ventures. Research Policy 35 (3), 375–393.

Maine, E., Seegopaul, P., 2016. Accelerating advanced-materials commercialization. Nat. Mater. 15 (5), 487–491.

Marx, M., Gans, J.S., Hsu, D.H., 2014. Dynamic commercialization strategies for disruptive technologies: evidence from the speech recognition industry. Management Science 60 (12), 3103–3123.

Moreira, S., Klueter, T.M., Asija, A., 2023. Market for technology 2.0? Reassessing the role of complementary assets on licensing decisions. Research Policy 52 (7), 104787.

Mowery, D.C., 1998. The changing structure of the US national innovation system: implications for international conflict and cooperation in R&D policy. Res. Policy 27 (6), 639–654.

Nanda, R., 2020. Financing innovation "Tough Tech". In The Global Innovation Index. Chapter 5, 113–119.

Noldeke, G., Schmidt, K.M., 1998. Sequential investments and options to own. RAND Journal of Economics 29 (4), 633–653.

Rubinstein, A., 1982. Perfect equilibrium in a bargaining model. Econometrica 50 (1), 97–109.

Stam, E., van de Ven, A., 2021. Entrepreneurial ecosystem elements. Small Bus. Econ. 56, 809–832.

Stern, S., 2004. Do scientists pay to be scientists? Manag. Sci. 50 (6), 835–853.

Teece, D., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Research Policy 15 (6), 285–305.

Williamson, O., 1975. Markets and Hierarchies: Analysis and Antitrust Implication. Free Press, New York.

Yu, S., 2020. How do accelerators impact the performance of high-technology ventures? Management Science 66 (2), 530–552.