Antitrust Limits on Startup Acquisitions

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Abstract

Should there be limits on startup acquisitions by dominant firms? Efficiency requires that startups sell their technology to the right incumbents, that they develop the right technology, and that they invest the right amount in R&D. In a model of differentiated oligopoly, we show distortions along all three margins if there are no limits on startup acquisition. Leading incumbents make acquisitions partially to keep lagging incumbents from catching up technologically. When startups can choose what technology they invent, they are biased toward inventions which improve the leader's technology rather than those which help the laggard incumbent catch up. Further, upon obtaining a pure monopoly, the leading incumbent's marginal willingness to pay for new technologies falls abruptly, diminishing private returns on future innovations. We consider antitrust measures that could help to mitigate these problems.

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1 Introduction

Startup acquisitions are ubiquitous, particularly in high-tech industries. Frequently the acquiring firms are established incumbents with significant market power, as illustrated by Facebook's acquisition of WhatsApp or Google's acquisition of Waze. Many large technology firms acquire ten or more startups per year. To be sure, startup acquisitions play an important role in facilitating entrepreneurship and innovation (e.g., Rasmusen (1988)). However, over time, persistent startup acquisitions by highly dominant incumbents may provoke countervailing competition policy concerns. In the aggregate, such acquisitions may have significant adverse effects on market structure, competition, and the diffusion of innovations. Indeed, there is growing empirical evidence that decreased business dynamism and lower productivity growth may be related to the growing productivity gap between "superstar" firms and others (Autor et al. (2017), Decker et al. (2018)).

Nevertheless, in any *particular* acquisition, it is not obvious that traditional merger analysis could support a viable antitrust challenge. In most cases, the startup's technology is currently just an input or complement to the acquirer's product, not a full-fledged competitor (let alone a "disruptive" competitor). It may be quite plausible that the startup would eventually have entered the product market if not for the acquisition, but in practice this is rarely provable. Further, even if there is clear evidence that the merger is horizontal, the startup's market share will typically be small or zero, and any estimates of its future market share will likely be too speculative to meet the plaintiff's burden of proof. Despite this uncertainty, it does not follow that the best policy is to let dominant incumbents absorb all new startups as they emerge. An alternative option is to acknowledge that such cases involve significant uncertainties, but that limited intervention under certain verifiable conditions may nevertheless leave society better off in the aggregate.[1] This paper makes some preliminary arguments in support of such a policy.

Our analysis considers how startup acquisitions influence both static competition and innovation incentives, with focus on whether certain antitrust limitations might improve the balance of these effects. We consider a market with one dominant firm (the "leader") and one less efficient rival (the "laggard"). Market shares are determined by the relative quality levels of the firms' products, with the leader growing more dominant as its technological

[1] Along similar lines, in a recent interview on the subject, Jean Tirole remarked that "[t]he suppression of competition in the absence of data is hard to prove. My guess is that we should err on the side of competition, while recognizing that we will make mistakes in the process." Allison Schrager, "A Nobel-Winning Economist's Guide to Taming Tech Monopolies," Quartz Magazine (June 27, 2018; available at https://qz.com/1310266/).

advantage increases. A startup is modeled as a promising new "component technology" (an upstream input technology[2]) that has resulted from some ex ante R&D investment, and which could be utilized within one or both incumbent products. There is no assumption that the startup would enter the product market absent an acquisition; the theory of harm assumes only that the relevant technology may influence competition and consumer welfare based on how its diffusion influences product quality levels.[3] In particular, we focus on technologies which are improve the state of the laggard and potentially the leader's product, but not so radical that they would permit a laggard to leapfrog a leader.

One core feature of our analysis is that all relevant technology rights can be transacted endogenously, subject to any stipulated antitrust limitations, in a *technology trade game*. This has a major impact on private valuations for new technologies (and by extension R&D incentives) and on the extent to which new technologies are utilized. Through this model, we consider three dimensions of efficiency in startup acquisitions. First, once a technology exists, is it licensed to the set of incumbents which maximize either consumer surplus or total welfare? Second, if technology is endogenous, does the startup work on the right technology component? Third, if the startup works on the right technology, do they invest an efficient amount in total R&D? That is, we are concerned with the *diffusion*, the *direction*, and the *rate* of startup activity. Our results indicate that, under laissez-faire acquisition rules, startup behavior is inefficient in all three dimensions.

Why? When a laggard incumbent acquires a startup technology, its own product gets better, but the differentiation between leader and laggard declines. If joint-profits of the leader and laggard fall following an acquisition by the laggard, the leader would have an incentive to buy the startup instead and refuse to license its invention. The leader does so even if the startup's invention is entirely incapable of improving the quality of the leader's own product. The outcome is that the laggard's product is worse than it could have been, and that the leader has more market power, both harmful for consumer surplus.

Under a laissez-faire regime, the leading incumbent continues to buy startups partially to keep the laggard from reducing differentiation. However, the acquisition price is highest for inventions which both directly improve the leader's product as well as indirectly increase differentiation. Startups therefore produce too few inventions which help laggards catch up to leaders. Note that the harm here is not the traditional antitrust concern that future "potential competitors" are being bought, but rather that startup acquisitions affect the

[2]Each firm's overall product quality is modeled as an aggregate of its component-wise quality levels.

[3]However, if there is evidence of likely downstream entry by the startup, this would lend further support to likelihood of harm.

technological gap and thereby influence competition and market structure.

What can be done to limit these harms? We do not propose that any startup be categorically denied the opportunity to be acquired. Instead, we argue in favor of intervention in situations where a highly-dominant incumbent acquires a startup whose technology could plausibly influence competition if rivals are excluded from using it. Alternatively, intervention could be predicated on a dominant firm's pattern of acquiring promising startups and then declining to license competitors.[4] To that end, we focus mainly on intervention in the form of a compulsory licensing requirement, although we also consider a policy that would preemptively block the dominant firm from acquiring a startup. In all cases, the resulting equilibrium involves both incumbents getting access to the startup technology, usually because the laggard acquires the startup and then strikes a licensing deal with the leader. Unsurprisingly, the impact on static consumer welfare is always positive, since there is greater diffusion.

While efficient diffusion can be achieved, we also consider how such an antitrust policy would impact ex ante R&D decisions by a startup. Recall that in laissez faire, startups are biased toward inventions which help improve the leader's product versus those which help the laggard catch up technologically. The consumer surplus maximizing invention given equilibrium price setting by the oligopolists does not involve any bias in favor of improving one product versus the other; the marginal benefit of a small quality improvement is the same for both products. Compulsory licensing or limits on exclusive licensing by leading incumbents decrease the acquisition price of startups with inventions that help the leader, and hence partially mitigate the directional distortion.

Though directional distortions are improved, lower acquisition prices due to antitrust intervention will lead the innovator to invest less in R&D, provided the leader has not yet obtained a pure monopoly. The startup gets the largest payouts for inventions that widen the technology gap, while antitrust intervention prevents this by compelling licensure of the laggard. But, critically, this property vanishes as soon as the technological gap is large enough for the leader to become a pure monopolist: its marginal willingness to pay for a technological improvement falls abruptly, becoming permanently flatter. This reflects that market *contestability* plays a key role in shaping private valuations of new technologies.[5] This suggests that innovation rate incentives could be bolstered over the long run by a policy that maintains at least some amount of contestability over time. Our proposed intervention strategy would accomplish this by requiring compulsory licensing when the acquiring

[4] See our discussion in Section 5.

[5] The market is "contestable" if the laggard is still applying some competitive pressure, thereby preventing the leader from extracting a full monopoly profit. This is formalized below.

firm is sufficiently dominant.

We close this section with a discussion of related research. Section 2 then introduces the baseline model of duopoly competition with differentiated product quality and endogenous inter-firm licensing. In Section 3 we model startup acquisitions, both with and without antitrust restrictions. Section 4 then evaluates the impact of antitrust intervention on ex ante innovation incentives. Finally, the policy implications of our analysis are discussed in Section 5, after which the paper concludes.

1.1 Prior Literature

There are long related literatures on the operation of markets for technology, and antitrust in innovative markets.

In markets for technology, the classic results of Gilbert and Newbery (1982) and Katz and Shapiro (1985) show that, contrary to the Arrow replacement effect, if an innovation would be used by a laggard, the leader prefers to buy it from the laggard to limit competition, and is able to pay more than the laggard's marginal profits to do so. This persistent technological leadership is a longstanding issue in the literature than has begged the question of why laggards or entrepreneurs ever do anything other than sell to a technological leader, thus allowing the leader to maintain market power. A number of authors have attempted to answer this question (e.g., Gans and Stern (2000), Gans and Stern (2003), Arora (1995), Spulber (2012)), suggesting informational frictions, missing markets for technology, tacit knowledge as a complement to technology, among other factors. Most of this literature concerns licensing from potential competitors (including those who enter solely to induce the incumbent to buy them out, as in Rasmusen (1988)). We restrict to a model where startups can never be competitors, but can license useful technology. Katz and Shapiro (1985) has pure licensors selling cost-reducing technology, rather than our startups developing components with differential value to product market competitors. Nonetheless, their propositions 7 and 8 are closely related to our proposition 2. We further discuss how startup acquisition rules affect the direction of innovation performed by startups, in addition to simply the rate.

Three germane papers in the literature on antitrust in innovative markets are Aghion et al. (2005), Segal and Whinston (2007) and especially Cabral (2018). The first two papers discuss the tradeoff between strong product market competition and innovation. Competition today incentivizes firms to escape competition by vertically differentiating with innovation, but the benefit of that innovation depends on how long the innovator can prevent laggards from replicating or surpassing their invention. Gans (2017) expands the Segal and Whinston (2007) model to show how the acquisition of dynamic capabilities causes firms to avoid selling to incumbent leaders even when there is a static product market reason to do so. These papers generally involve "drastic" innovation where startup technology allows them to supercede the leader, something we assume away in our model of component improvement. Cabral (2018) models fringe and dominant firms innovating over time with the possibility of licensing. When the fringe firm can license, its incentive to innovate increase, and strict merger policy for dominant firms can therefore lower the rate of innovation.

On the empirical side, Andrews et al. (2015) and Baily and Montalbano (2016) find evidence of widening productivity gaps between market leaders and laggards. This effect plays a major role in our model, and it occurs endogenously. Wollmann (2019) shows that mergers between large and small firms become much more common when the Hart-Scott-Rodino Act was modified in 2001 to exempt mid-sized firms from per-merger notification. Mergers outside the purview of the Act result in a combined concentration of activity adding up to 32-44% of the total growth in 4 and 8 firm industry concentration ratio between 1994 and 2001. These "submarine" acquisitions are therefore cumulatively important for market structure. Cunningham et al. (2019) find that acquisitions in biotechnology often involve "killer acquisitions" of potential competitor drugs. As our results show, incumbents are incentivized to maintain vertical differentiation with "killer" acquisitions, but if startup technology is endogenous, startups will only develop technology that will be killed in equilibrium if improvements to components where the leader has a large technology advantage are particularly inexpensive to develop relative to those where the leader and laggard are both at the frontier. The innovator would prefer to introduce innovations that would induce a profitable structural effect, which requires that it extend the technology gap by affirmatively improving the leader's product.

2 Model Preliminaries

There are two incumbent firms, $i = 1, 2$. For reasonable tractability, we will utilize the Singh and Vives (1984) model of differentiated oligopoly competition. In this framework, a representative consumer has utility

$$\mathcal{U}(q_1, q_2) = \sum_i \alpha_i q_i - \frac{1}{2}\Big(\sum_i q_i^2 + 2q_1 q_2\Big) \tag{1}$$

where q_i is the output of good i. The α_i are positive scalars, which can be interpreted as governing the strength of demand for good i. Letting p_i denote the price of good i, the representative consumer picks (q_1, q_2) to maximize $\mathcal{U}(q_1, q_2) - \sum_i q_i p_i$. The first order conditions yield a Cournot demand system with inverse demand functions $p_i = \alpha_i - q_1 - q_2$ for each i. Marginal costs are assumed to be constant and are denoted c_i. Each firm i chooses q_i to maximize $(\alpha_i - \sum_k q_k - c_i)q_i = (z_i - \sum_k q_k)q_i$ where

$$z_i \equiv \alpha_i - c_i.$$

We interpret z_i as firm i's *product quality.* As the definition implies, an increase in product quality arises when either the good becomes more desirable to consumers (α_i rises) or else the good becomes cheaper to produce (c_i falls). In either case, the relevant firm will pass through some welfare gains to consumers.

Throughout the paper, we assume that firm 1 is the technological "leader," while firm 2 is the "laggard": $z_1 > z_2$. The equilibrium is a function of the quality profile $\mathbf{z} \equiv (z_1, z_2)$. When both firms are active, the equilibrium levels of output, profits, and consumer welfare are

$$q_i(\mathbf{z}) = \frac{2z_i - z_j}{3}, \qquad \pi_i(\mathbf{z}) = [q_i(\mathbf{z})]^2, \qquad CS(\mathbf{z}) = \frac{1}{2}\left(\frac{z_1 + z_2}{3}\right)^2. \tag{2}$$

And we denote joint profits by $\Pi(\mathbf{z}) = \sum_i \pi_i(\mathbf{z})$. Comparative statics involving joint profit effects will be important in what follows, since they determine when inter-firm licensing (which raises the licensee's product quality) would be mutually beneficial. To that end, it is easy to verify that joint profits are necessarily increasing in the leader's quality, whereas they may or may not be increasing in the laggard's quality. This is illustrated in the figure below.

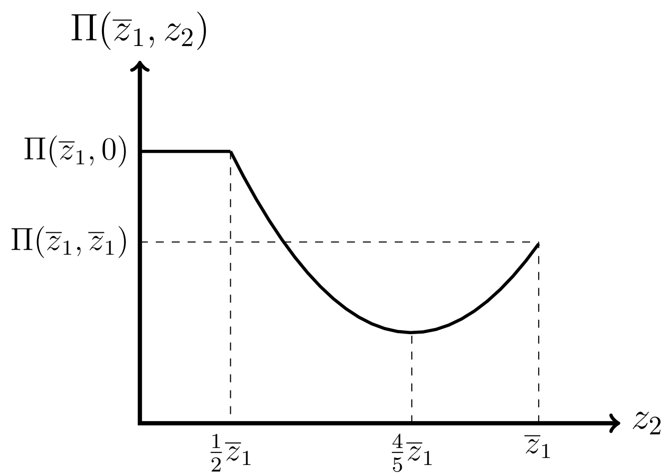

Figure 1: Joint profits as a function of z_2, holding fixed $z_1 = \overline{z}_1$.

The figure plots joint-profits as a function of z_2, holding z_1 fixed. When $z_2 \leq \frac{1}{2}z_1$, joint profits are invariant in z_2 because the laggard is not active. Over this range, firm 1 is a true monopolist and the market is non-contestable in the sense that small changes in z_2 do not affect profits or consumer surplus. When $z_2 > \frac{1}{2}z_1$, both firms are active and hence the market is contestable. Over this range, joint profits are initially falling in z_2, but eventually start rising when z_2 is sufficiently large in relation to z_1.[6] This non-monotonicity arises from the countervailing effects of increasing z_2. The first-order effect of making firm 2's good more desirable (or cheaper to produce) is profit-enhancing, but there is also a structural effect of reducing *quality differentiation*, which makes inter-firm competition more intense. The latter effect dominates when z_2 is sufficiently low in relation to z_1.[7]

In what follows, $\mathbf{z}$ is taken as exogenous and fixed. It describes the ex ante levels of product quality, before any potential startup acquisitions or other technology transfers. We make the following assumptions on $\mathbf{z}$:

(A1) $q_1(\mathbf{z}) > q_2(\mathbf{z}) > 0$.

(A2) $\frac{\partial}{\partial z_2}\Pi(\cdot) < 0$ in a neighborhood of $\mathbf{z}$.

[6] It is easy to verify that this follows under much more general modeling assumptions. Assuming profit functions are symmetric in $\mathbf{z}$, this nonmonotonicity in z_2 arises if, for any $z > 0$, we have $[\mathrm{d}/\mathrm{d}z]\Pi(z, z) > 0$ and $\Pi(z, 0) > \Pi(z, z)$, where the latter says that monopoly is more profitable than symmetric competition. Note also that for $\frac{1}{2}z_1 \leq x_2 \leq \frac{7}{11}z_1$, total surplus is also falling in z_2. That improved technology for laggard firms can reduce total surplus is well known (e.g., Lahiri and Ono (1988)).

[7] Our broad qualitative results can be shown using marginal conditions on the effect of rival-quality and own-quality on price and output. They do rely on unusual aspects of the Singh-Vives functional form.

In words, we assume for now that both firms are active in equilibrium, although firm 1 has a stronger market position. A later section addresses the relevant incentive effects arising when firm 1 becomes a pure monopolist. Moreover, throughout the paper we assume that firm 1 is sufficiently dominant to ensure that joint profits are locally strictly decreasing in z_2.[8]

2.1 Component Technologies

For each i, there are various complementary components and features that collectively determine the overall quality of i's product. A startup will be modeled as an inventor of an improved component technology.[9] In particular, suppose that there are T components, indexed by $t = 1, 2, .., T$. Each product quality level z_i is determined as an aggregate of component characteristics. In particular:

$$z_i = \sum_{t=1}^{T} \lambda^t x_i^t$$

Here $x_i^t \geq 0$ is the quality of the component-t technology utilized in firm i's product. That is, when firm i switches to an improved component-t technology, this is reflected by an increase in x_i^t. The λ^t are positive scalars with $\sum_t \lambda^t = T$, and describe the relative importance of different components to the aggregate quality level.[10]

2.1.1 Inter-Firm Component Licensing

We assume that component technologies are nonrivalrous in the sense that one firm's use of such a technology does not inhibit the other firm's capacity to use it.[11] Thus, if a given component technology is not patented, then neither firm will use a lower quality technology for that component, since the unpatented one is better and free to use. However, we con-

[8] In the region where joint-profits are increasing in z_2, technology is always licensed in both directions (i.e. cross-licensing), and hence no antitrust concerns arise.

[9] Intuitively, this makes it hard to say whether the startup is a prospective entrant (in the product market), which is a common complication in real-world startup acquisitions.

[10] Thus, a component with $\lambda^t > 1$ is "more important than average."

[11] For simplicity we will ignore the costs of adopting a new technology. In practice, one expects there are various frictions (including switching costs) that might prevent a firm from switching to a different component technology that is slightly better.

template that many or most of the firms' component technologies are patented.[12] In this case, a rival of the patentee can use the technology only if it receives a license. To that end, we allow the firms to enter into mutually-beneficial licensing agreements for their patented component technologies.[13]

Suppose that we have $x_i^t > x_j^t$ for some component t. Then licensing of i's component technology would induce a transition in j's aggregate product quality from z_j to $\widehat{z}_j \equiv z_j + \lambda^t(x_i^t - x_j^t)$. This is mutually-beneficial if and only if it raises joint profits, i.e. $\Pi(z_i, \widehat{z}_j) \geq \Pi(\mathbf{z})$. Note that the licensor would never prefer to use a royalty over a lump sum license fee in cases where licensing is mutually-beneficial.[14] Let us suppose that all possible mutually-beneficial licensing deals have already occurred, and are reflected in the values of x_i^t for all i and t. Given our assumption on firm 1's dominance, the following result is immediate.

Proposition 1. *Suppose that, conditional on $\{x_1^t, x_2^t\}_{t=1}^T$, there are no possible mutually-beneficial licensing deals. Then we have $x_1^t \geq x_2^t$ for all t.*

Proof. We have $[\partial/\partial z_1]\Pi > 0$, so it is always profitable for the laggard to license its patented components to the leader. Thus $x_2^t > x_1^t$ would imply that the firms could strike a mutually-beneficial licensing deal—a contradiction. □

This reflects that technology transfers always enhance joint profits when they run from the laggard to the leader, since the first-order quality improvement effect is accompanied by an increase in quality differentiation, which is independently profitable. By contrast, due to firm 1's dominance in the product market, licensing in the other direction would diminish joint profits under assumption (A2).

3 Startup Acquisitions

Suppose a startup has successfully developed a new invention, which is a technology for some component τ. To start, suppose there is an unregulated market for ownership of the startup

[12] Alternatively, they could be covered by some other form of intellectual property, but our discussion will focus on the case of patented technologies.

[13] However, we assume the firms cannot implement collusive licensing contracts. It is well-known that rivals can charge each other countervailing royalties to induce the cartel outcome as a Nash equilibrium (e.g. Shapiro, 1985; Jeon and Lefouili, 2018). We assume that antitrust prohibits this.

[14] A royalty would raise the licensee's costs, effectively cancelling out some of its quality improvement. But if it were jointly-profitable to reduce the licensee's product quality, licensing would not be mutually-beneficial in the first place. And there are more rents to bargain over when double marginalization is avoided.

and, independently, for licensing the startup's technology.[15] This is modeled by what we call the *Technology Trade Game* (TTG). The TTG serves to capture: (a) the endogenous diffusion of a new invention, which emerges from private transactions over technology rights; and (b) the resulting impact on market structure and consumer welfare.

The TTG begins just after the startup's component-τ technology has been developed. (We consider ex ante innovation incentives later.) The quality of the startup technology is x_s^τ. If firm i obtains the right to use the invention, its aggregate product quality transitions as $z_i \to \widehat{z}_i \equiv z_i + \lambda^\tau \max\{x_s^\tau - x_i^\tau, 0\}$. We assume that

(A3) $\Pi(\widehat{z}_1, z_2) \geq \max\{\Pi(\widehat{\mathbf{z}}), \Pi(\mathbf{z})\} > \Pi(z_1, \widehat{z}_2)$ and $\pi_2(\widehat{z}_1, z_2) > 0$.

where $\widehat{\mathbf{z}} \equiv (\widehat{z}_1, \widehat{z}_2)$. The first part of (A3) implies that $\widehat{z}_1 \geq z_1 > \widehat{z}_2 > z_2$, so that the leader would not necessarily benefit from the invention, but the laggard definitely would. However, the latter effect is not so strong as to outweigh the profit-reducing effect of reducing quality differentiation. This just reflects an assumption that the startup technology is not so drastic as to substantially eliminate firm 1's dominance.[16] The second part of (A3) ensures that both firms will remain active, even if only the leader uses the new technology. Taking $\widehat{\mathbf{z}}$ as given, the TTG has the following setup:

(a) The startup can choose either to engage in nonexclusive licensing with both firms or to enter into an acquisition agreement with one firm. In all cases, prices are set through Nash bargaining.

(b) In the case of nonexclusive licensing, the startup bargains separately with both firms simultaneously. In each of these bargains, the parties assume that the other bargain will not fail.

(c) In negotiations over an acquisition, the parties assume that, if bargaining fails, there will be nonexclusive licensing.

(d) After an acquisition, the acquiring firm may license the startup technology to its rival, with the price set by Nash bargaining.

This setup reflects that the startup has different options for monetizing its technology, and is entitled to choose the one it likes best. The assumption of "simultaneous bargains" under

[15] The caveat is that we do not allow the incumbent firms to buy one another (i.e. to merge), as we assume this would be blocked by an antitrust authority.

[16] If this condition is not satisfied (i.e. if $\Pi(\widehat{\mathbf{z}}) > \Pi(\widehat{z}_1, z_1)$), then if firm 1 acquired the startup it would subsequently license the technology to firm 2. But that would allay the antitrust concerns we are focusing on.

nonexclusive licensing is merely a way of fixing disagreement payoffs in the two bargains, since each firm cares about whether its rival obtains access to the startup technology.[17] Note that, if any licensing occurs, the game terminates thereafter. Hence, working by backward induction, we start by calculating the license fees that would arise (on or off the equilibrium path). This is given in the lemma below, which uses the notations $\mathbf{e}_1 = (1, 0)$ and $\mathbf{e}_2 = (0, 1)$.

Lemma 1. *The TTG subgames involving licensing result in the following prices:*

(i) Under nonexclusive licensing, each incumbent i pays a license fee of

$$\ell_{is}^*(\widehat{\mathbf{z}}) = \frac{1}{2}\Big[\pi_i(\widehat{\mathbf{z}}) - \pi_i(\mathbf{z} + \widehat{z}_j\mathbf{e}_j)\Big] \tag{3}$$

(ii) If firm j acquires the startup and then supplies a license to firm i, the latter will pay the former a license fee of

$$\ell_{ij}^*(\widehat{\mathbf{z}}) = \frac{1}{2}\Big[\pi_j(\mathbf{z} + \widehat{z}_j\mathbf{e}_j) - \pi_j(\widehat{\mathbf{z}}) + \pi_i(\widehat{\mathbf{z}}) - \pi_i(\mathbf{z} + \widehat{z}_j\mathbf{e}_j)\Big] \tag{4}$$

Proof. Appendix. □

Where no confusion arises, we will omit the argument $\widehat{\mathbf{z}}$. Note that $\ell_{12}^* \geq \ell_{1s}^*$, meaning that the leader will pay more for technology rights when it buys them from its rival rather than the startup. The reason is that the startup is not a participant in the product market, and thus does not care about how the transaction affects competition; it just cares about the size of the payments it receives. By contrast, when firm 2 is the licensor, it internalizes a "cost" from licensing firm 1, and can thus credibly demand a larger payout than could the startup.[18] Unsurprisingly, in lieu of antitrust intervention, the leader will always acquire the startup and decline to license the laggard. This is established in the proposition below.

Proposition 2. *In the subgame perfect equilibrium of the TTG, firm 1 acquires the startup for price*

$$\mathcal{A}_1^*(\widehat{\mathbf{z}}) = \frac{1}{2}\Big[\pi_1(\widehat{z}_1, z_2) - \pi_1(z_1, \widehat{z}_2) + \ell_{2s}^*(\widehat{\mathbf{z}})\Big] \tag{5}$$

[17] Note that the Nash bargaining assumption in our TTG places payoffs between that which would prevail with "offer games" where innovators make simulatenous take-it-or-leave-it offers to sell, and "bidding games" where incumbents make simultaneous offers to buy. See Segal (1999), Segal and Whinston (2003) and Galasso (2008) on how de facto bargaining power affects outcomes in these non-cooperative bargains with externalities, and Segal (2003) on how buyer coordination affects outcomes.

[18] The internalized cost is the difference $\pi_2(z_1, \widehat{z}_2) - \pi_2(\widehat{\mathbf{z}})$, which is the only term that distinguishes ℓ_{12}^* from ℓ_{1s}^*.

Moreover, firm 1 declines to sell firm 2 a license after the acquisition.

Proof. Appendix.

It is easy to verify that $\mathcal{A}_1^* > \mathcal{L}_s^*$, where $\mathcal{L}_s^* \equiv \sum_i \ell_{is}^*$ is the total payout the startup would get from nonexclusive licensing. Intuitively, along the equilibrium path, the TTG will always ensure that technology rights are allocated in the way that maximizes total profits. The various off-equilibrium transactions merely shape the ensuing distribution of rents by accounting for the startup's outside options. Because of firm 1's market dominance, total profits are always maximized when it obtains exclusive rights, even if it happens to derive little or no value from the startup technology. The resulting consumer surplus is thus $CS(\widehat{z}_1, z_2)$, whereas it would be the larger amount $CS(\widehat{\mathbf{z}})$ if both firms acquired the rights to the startup technology.

3.1 Antitrust Intervention

Consider two antitrust policies that would limit the leader's ability to acquire startups and maintain exclusive rights over the acquired technologies. One option is prophylactic, like traditional merger enforcement; the other is retroactive.

1. **Preemptive Blocking.** Firm 1 is blocked from acquiring the startup, although it may purchase a nonexclusive license.
2. **Compulsory Licensing.** After firm 1 has acquired the startup it is required to sell a license to firm 2 at a reasonable price.[19]

The two approaches (which are not mutually exclusive[20]) have different strengths and weaknesses. On one hand, preemptive blocking ostensibly requires antitrust to take an active role in monitoring (or mandating ex ante disclosures) of many acquisitions by powerful firms. This would be very costly in practice, given the prevalence of startup acquisitions generally. On the other hand, a problem with compulsory licensing is that it will require a court to

[19]Compulsory licensing as a potential remedy for economic inefficiencies in innovation-heavy markets is an old idea. For instance, see Tandon (1982) on compulsory licensing to mitigate the deadweight loss created by patents.

[20]For instance, private enforcement efforts might rely on the retrospective approach while the antitrust authorities might attempt to challenge some prospective acquisitions before they occur.

perform the difficult task of identifying a "reasonable price."[21] However, as outlined below, the latter problem may be avoidable if the *prospect* of antitrust litigation (and the attending price determination process) deters the leader from attempting to obtain exclusive rights in the first place.

Consider the policy that would block the acquisition preemptively. In this resulting equilibrium, the startup chooses to enter into an acquisition agreement with the laggard rather than engaging in nonexclusive licensing. However, both incumbents will ultimately obtain the rights to use the startup technology. Explicitly:

Proposition 3. *Suppose that firm 1 is blocked from acquiring the startup. Then, in the new equilibrium, the startup will be acquired by firm 2 at price*

$$\mathcal{A}_2^*(\widehat{\mathbf{z}}) = \mathcal{L}_s^*(\widehat{\mathbf{z}}) + \frac{1}{2}\Big[\ell_{12}^*(\widehat{\mathbf{z}}) - \ell_{1s}^*(\widehat{\mathbf{z}})\Big] \tag{6}$$

Further, after the acquisition, firm 2 will sell firm 1 a license at price $\ell_{12}^*(\widehat{\mathbf{z}})$*.*

Proof. Appendix.

This provides the startup with a weakly greater return than nonexclusive licensing because, as noted earlier, firm 2 can credibly demand a weakly larger license fee from firm 1 than could the startup. Now consider intervention in the form of compulsory licensing. In this case, firm 1 is able to acquire the startup, and intervention takes the form of a court-specified license fee ℓ_{21}^c that firm 2 must be entitled to pay in exchange for a license. Of course, this policy will only have an impact if the fee is acceptable to the laggard, and so we stipulate that the fee takes the form

$$\ell_{21}^c(\widehat{\mathbf{z}}) \equiv \theta[\pi_2(\widehat{\mathbf{z}}) - \pi_2(\widehat{z}_1, z_2)] \tag{7}$$

$$= 2\theta\ell_{2s}^*(\widehat{\mathbf{z}}) \tag{8}$$

where $\theta \in (0, 1)$. The bracketed term is the laggard's maximal willingness to pay for a license, so this specification ensures that the fee is acceptable.

Proposition 4. *Suppose that, if firm 1 acquires the startup, a court would prescribe a*

[21] Note that there is no "market price" for the license sold to firm 2, as such licensing lowers total profits and hence no price could render it mutually-agreeable. Thus, the license fee will just have to be set to some fraction of firm 2's maximal willingness to pay.

compulsory fee of $\ell^c_{21}(\hat{\mathbf{z}})$. *In the resulting equilibrium, firm 2 acquires the startup at price*

$$\mathcal{A}^c_2(\hat{\mathbf{z}}) = \mathcal{A}^*_2(\hat{\mathbf{z}}) + \left(\theta - \tfrac{1}{2}\right)\ell^*_{2s}(\hat{\mathbf{z}}) \tag{9}$$

Further, after the acquisition, firm 2 sells a license to firm 1 at price ℓ^*_{12}.

Proof. Appendix.

Note that both $\mathcal{A}^*_2$ and $\mathcal{A}^c_2$ are strictly lower than $\mathcal{A}^*_1$, and hence the startup gets a smaller payout under either antitrust intervention strategy.

4 Incentives for Invention

We have seen that, taking the arrival of a new startup as exogenous, a sufficiently-dominant technology leader is always willing to pay more than its rivals to acquire the startup. The motivation is either to widen the technology gap, or, in cases where the invention does not benefit the leader, to purchase and "kill" startups that would otherwise have enabled rivals to catch up. We have also seen that policies such as compulsory licensing can mitigate this diffusion problem, and may do so without a court having to explicitly administer the licensing requirement along the equilibrium path.[22]

We now address how such policies would influence ex ante R&D activity by an innovator—a potential startup. First, we consider the impact on what line of research the innovator chooses to pursue. We then consider effects on the return to innovations, which determines the innovator's level of R&D.

4.1 The Direction of Innovation

The innovator can choose which component technology in which to make an R&D investment, reflecting endogenous choice over the "direction of innovation." For each component τ, there is a "project" the innovator could pursue, which, if successful, would yield a new component-τ technology with quality level x^τ_s, where $x^\tau_s > x^\tau_2$.[23] Let $\hat{z}^t_i = z_i + \lambda^\tau \max\{x^\tau_s - x^\tau_i, 0\}$ denote the transition in i's product quality as a result of using the new technology. In this section,

[22]That is, the prospect of antitrust litigation induces an equilibrium in which all private dealings are already antitrust-compliant, making express litigation unnecessary.

[23]If $x^\tau_s \leq x^\tau_2 \leq x^\tau_1$, then the invention is superfluous (no one will use it).

it will be convenient to characterize inventions as pairs $\mathbf{\Delta}^\tau = (\Delta_1^\tau, \Delta_2^\tau)$, where $\Delta_i^\tau \equiv \widehat{z}_i^\tau - z_i$. This captures the possible incremental changes in (z_1, z_2) (depending on which firms get to use the invention), which determines firms' willingness to pay and also the incremental impact on consumer welfare. We continue to follow assumption (A3), so that, regardless of which firms use the invention, firm 1 will remain a dominant leader (no "leapfrogging") and both firms remain active. Also, recall from Proposition 1 that, by the endogeneity of inter-firm licensing, firm 1 is initially (weakly) ahead of firm 2 in all component quality levels. These conditions ensure that

$$\Pi(z_1 + \Delta_1^\tau,\, z_2) \geq \max\left\{\Pi(\mathbf{z} + \mathbf{\Delta}^\tau),\, \Pi(\mathbf{z})\right\} > \Pi(z_1, z_2 + \Delta_2^\tau) \tag{10}$$

$$\pi_2(z_1 + \Delta_1^\tau,\, z_2) > 0 \tag{11}$$

$$\Delta_2 \geq \Delta_1 \tag{12}$$

We will not explicitly model the relative costs or success probabilities of different innovation projects; rather, we focus on the preference rankings of the innovator and consumers over the set of possible pairs $\mathbf{\Delta}^\tau = (\Delta_1^\tau, \Delta_2^\tau)$.[24] To that end, consider consumer preferences over innovation outcomes, which depend in part on how the invention is diffused. This will provide a benchmark for drawing normative conclusions about the innovator's decision-making.

Lemma 2. $\frac{\partial}{\partial z_1} CS(\cdot) = \frac{\partial}{\partial z_2} CS(\cdot)$, *and therefore*

$$CS(z_1 + \Delta, z_2) = CS(z_1, z_2 + \Delta) = CS(z_1 + \Delta', z_2 + \Delta') \quad \Longleftrightarrow \quad \Delta = 2\Delta'.$$

Proof. Immediate, by inspection of (2). □

Thus, at the margin, and given equilibrium price responses, consumers get the same benefit from increasing either individual quality level z_i by a given amount. Therefore, consumers strictly prefer broad diffusion of innovations, and their preferences are not "skewed" in favor of either incumbent's product, regardless of preexisting relative quality levels. In order for consumers to prefer an increase in z_i alone to a symmetric increase in both quality levels, the former increase must be twice as large as the latter.

We now consider the innovator's preferences over pairs $\mathbf{\Delta}^\tau = (\Delta_1^\tau, \Delta_2^\tau)$ in terms of the payout (i.e. the acquisition price) it would obtain in the ensuing TTG equilibrium. Proposition 5

[24] This is sufficient to determine optimal project choices (i.e. choices of τ) for any possible assignment of costs (or success probability functions) to each project τ. But any particular assignment would be somewhat arbitrary, and so we will suppress this aspect of the decision problem.

shows that, when startups choose which technology to work on, their decisions will tend to skew toward components which benefit the leader rather than those which solely benefit the laggard. That is, in laissez faire, innovators are biased toward inventions which generate consumer surplus by pushing the frontier versus those which generate surplus by helping technological laggards catch up and therefore increasing competition.

Proposition 5. *We have*

$$\frac{\mathrm{d}}{\mathrm{d}\Delta_1^\tau}\mathcal{A}_1^*(\mathbf{z}+\boldsymbol{\Delta}^\tau) \;>\; \frac{\mathrm{d}}{\mathrm{d}\Delta_2^\tau}\mathcal{A}_1^*(\mathbf{z}+\boldsymbol{\Delta}^\tau)$$

for all $\boldsymbol{\Delta}^\tau$ *satisfying* (10)-(12)*.*

Thus, in the absence of antitrust intervention, choices over the direction of innovation will tend to skew toward inventions that increase the quality of product 1. The reason is that, because firm 1 will acquire exclusive access to the invention, this will widen the technology gap, which is the most profitable structural effect that an innovation can elicit. The upshot is that the innovator's choice of direction will generally be inefficient, given that consumer preferences do not skew in favor of either firm's product. That is, inventions that would help the laggard catch up would provide significant consumer value, but are comparatively disfavored by the innovator.

Under antitrust intervention, this distortion diminishes significantly (albeit not completely). To see this, let us suppose for simplicity that the compulsory licensing parameter takes the value $\theta = \frac{1}{2}$, so that both possible intervention approaches would result in equivalent payouts to the innovator, i.e. $\mathcal{A}_2^c = \mathcal{A}_2^*$. We now show that, when the acquisition price function switches from $\mathcal{A}_2^*$ to $\mathcal{A}_1^*$ (i.e. when antitrust intervention is eliminated), the innovator's preferences become strictly more biased in favor of inventions with large Δ_1^τ.

Proposition 6. *Let* $\psi(\boldsymbol{\Delta}^\tau)$ *be defined by*

$$\psi(\boldsymbol{\Delta}^\tau) \equiv \mathcal{A}_1^*(\mathbf{z}+\boldsymbol{\Delta}^\tau) - \mathcal{A}_2^*(\mathbf{z}+\boldsymbol{\Delta}^\tau).$$

Then we have $\dfrac{\partial}{\partial\Delta_1^\tau}\psi(\boldsymbol{\Delta}^\tau) > \dfrac{\partial}{\partial\Delta_2^\tau}\psi(\boldsymbol{\Delta}^\tau)$ *for all* $\boldsymbol{\Delta}^\tau$ *satisfying* (10)-(12)*.*

The function $\psi(\boldsymbol{\Delta}^\tau)$ simply gives the incremental increase in the innovator's payout under a laissez-faire regime, relative to case with antitrust intervention. This increment grows strictly more rapidly in Δ_1^τ than in Δ_2^τ, and hence the innovator's preferences are strictly more skewed under a laissez-faire regime. It follows that, with respect to the direction of innovation, antitrust intervention acts to better align the innovator's interests with those of consumers.[25]

4.2 Contestability and the Return on Innovation

Suppose that, conditional on choosing to pursue a project in component τ, the probability of success is an increasing function of the innovator's R&D expenditure. Since $\mathcal{A}_1^* > \mathcal{A}_2^*$, antitrust intervention will lead the innovator to invest less money, as the payout for success is diminished to some extent.[26] If the social return to invention exceeds the private return, as is the case in many existing innovation models, one may worry that antitrust policy which helps solve diffusion and direction distortions will exacerbate the rate distortion by causing further underinvestment in R&D.

However, there is a critical caveat, which is that the leader's marginal willingness to pay for an invention will abruptly fall after the market becomes non-contestable, meaning that industry profits and consumer surplus become locally invariant in z_2. When the market is non-contestable, firm 1 is a pure monopolist, and its profit function changes.[27] The upshot is that, once contestability vanishes, the leader is not willing to spend as much for a given quality improvement, relative to what it would pay if the laggard had been able to remain active. To see this, we must redefine firm 1's profit function to take the piecewise form

$$\pi_1(\mathbf{z}) \equiv \begin{cases} \pi_1^d(\mathbf{z}), & \text{if } z_1 \in (z_2,\, 2z_2) \\ \\ \pi^m(z_1), & \text{if } z_1 \geq 2z_2. \end{cases}$$

Here $\pi_1^d(\mathbf{z})$ denotes the standard duopoly profit function that we having been working with throughout the previous sections.[28] By contrast, $\pi^m(z_1) \equiv z_1^2/4$ is the profit of a pure monopolist with quality level z_1. When the market becomes non-contestable ($z_1 \geq 2z_2$), the

[25]It can be shown that, if there is equal cost of providing an arbitrarily small amount of consumer surplus via an invention which helps both firms increase z_i by Δ' or one which helps the laggard increase z_2 by Δ, the startup strictly prefers producing the former even under preemptive blocking or compulsory licensing with any $\theta \in [0, 1]$.

[26]Recall from Lemma 2, however, that this reduction in *R&D* would have to be quite large in order for consumers to be worse off, given that antitrust intervention also provides the countervailing benefit of broader diffusion.

[27]Note: in general, non-contestability is not equivalent to the condition that only one firm is active. An inactive firm may nevertheless apply some competitive pressure, which manifests as limit pricing, leading to a sub-monopoly price level.

[28]That is, $\pi_1^d(z_1) = \big([2z_1 - z_2]/3\big)^2$, as specified in (2).

leader's profits become less sensitive to increases in z_1. This is captured by the proposition below.

Proposition 7. *We have*

$$\frac{\mathrm{d}}{\mathrm{d}z_1}\pi^m(z_1) < \frac{\partial}{\partial z_1}\pi_1^d(z_1, z_2) \qquad \text{and} \qquad \frac{\mathrm{d}^2}{\mathrm{d}z_1^2}\pi^m(z_1) < \frac{\partial^2}{\partial z_1^2}\pi_1^d(z_1, z_2)$$

whenever $z_1 > \frac{8}{7}z_2$. *Note that this condition always holds under Assumptions* (*A*1) *and* (*A*2).

Proof. Appendix. □

Thus, once the market becomes non-contestable, the leader's marginal profits fall discontinuously, becoming permanently flatter. This is depicted in the figure below. This discontinuous downward shift will carry over to the acquisition price $\mathcal{A}_1^*$, since this price is strictly increasing in firm 1's willingness to pay, which is determined by $[\partial/\partial z_1]\pi_1$. This implies that incentives for innovation will abruptly fall after the leader becomes a pure monopolist. The intuition for this result is simple. When the leader is not yet a monopolist, an increase in z_1 has two reinforcing profit effects. There is a direct effect of making the leader's product more desirable or cheaper to produce. But there is also a profitable structural effect: by increasing the leader's advantage, the market becomes less competitive and the leader steals some sales from the laggard. But this secondary effect vanishes when the market is non-contestable, as the market's structure cannot be made any more favorable to the leader than it already is.

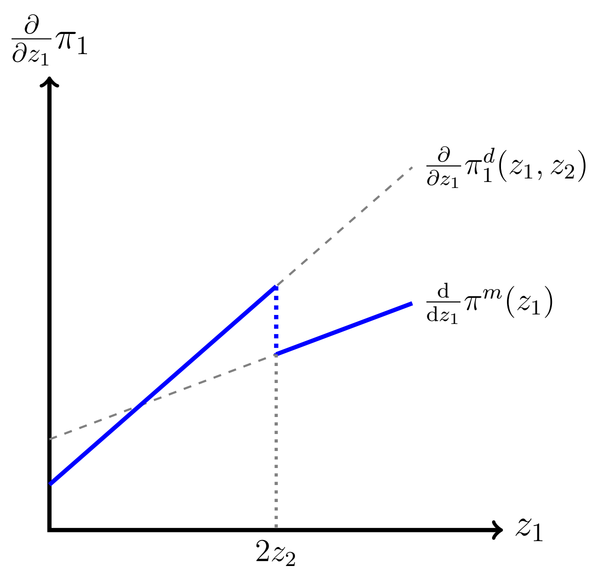

Figure 2: The leader's marginal profits, depicted in blue, as z_1 surpasses the monopoly threshold ($z_1 = 2z_2$).

This suggests that, even accounting for the rate of invention, an antitrust policy requiring compulsory licensing of an acquired technology would be socially beneficial when the acquirer is sufficiently close to the monopoly threshold. The incentive to innovate is highest when the laggard is far behind but the market is still contestable. But such a state will not persist if the leader is permitted to continually acquire exclusive rights to any new startup technologies that emerge. Once the leader obtains a full monopoly, such behavior will lead to a reduction in *both* static competition and the incentive to innovate.

4.2.1 A Note on Dynamics

Although our model is static, we will offer a brief, back-of-the-envelope argument that the preceding result would carry over to a dynamic game in which there is a new innovator (and hence a potential new startup) in each period. A fully dynamic model with Nash bargaining introduces many technical complexities. Essentially, the Nash bargain for a startup today depends on expectations about what startups will arise tomorrow: the amount the leader is willing to pay to keep the laggard from acquiring an invention today depends on the frequency with which these inventions arise, and the Nash bargains that will be made with other startups.[29]

Despite these complications, the expected present value of each firm's profit flows will still be driven by market-structural considerations, since this determines within-period payoffs. One therefore expects that, absent antitrust intervention, the leader would still be the acquirer in most or all periods (and will not license the laggard), leading the ratio z_1/z_2 to increase over time. Firm 1 will thus become a monopolist after finitely-many periods, after which the marginal profits it derives from future quality improvements would fall. This reduces its willingness to pay for new technologies in all subsequent periods, relative to what it would pay if firm 2 were still tagging along. This, in turn, would suggest that dynamic consumer welfare would benefit from intermittent antitrust intervention in periods where the leader is sufficiently dominant. First, this will maintain higher acquisition prices (and hence stronger innovation incentives) on average over time. Second, by maintaining more competition over time, prices will be lower on average.

[29]Though there exist proposed solution concepts to Nash bargains with externalities (e.g., Collard-Wexler et al. (2019)), they often are not analytically tractable.

5 Discussion

The foregoing analysis suggests that some limited antitrust restrictions on startup acquisitions by highly-dominant incumbents would be socially beneficial. Aside from invigorating static competition, such a policy may also maintain stronger innovation incentives over time. It would also lead to greater efficiency with respect to what research projects innovators choose to invest in, as an innovator's private interests become more aligned with those of consumers.

How might such an antitrust policy work in practice? As stated in the introduction, the best approach intervenes when (a) the acquirer is highly dominant; and (b) the acquired technology could plausibly have an appreciable impact on competition if it is used exclusively by the acquirer. An additional possibility is that intervention could be contingent on an established *pattern* of buying promising startups and then declining to license rivals. Of course, part (b) is unavoidably speculative, which necessarily creates a risk of judicial errors. However, this does not imply that social welfare is best-served by a policy that permits dominant firms to acquire all emergent startups without qualification, which is effectively the what current regime does.

In fact, this is not such a novel compromise. Most areas of law sacrifice some amount of precision in exchange for reasonable administrability based on an expectation that this tradeoff will be net-beneficial on average. But it is hard to conceive of an administrable antitrust policy toward startup acquisitions that could match the same degree of precision that is demanded in conventional merger cases, given the speculative nature of a startup's future prospects and the uncertain impact of its technology. A better approach may be to concede that there are unavoidable uncertainties, but also that limited intervention based on certain verifiable criteria may be an improvement over doing nothing at all.

To that end, the arguments in this paper suggest that the acquiring firm's market power could be a reasonably effective indicator for the risk of harm. Indeed, the results obtained above are driven entirely by the problematic incentives (among both incumbents and outside innovators) arising when the leading incumbent is sufficiently dominant. This avoids an intractable requirement to estimate what the startup's future prospects would have been in lieu of the acquisition. The focus is instead on the potential harm arising when a dominant incumbent buys up promising startups and declines to sell rivals' access to their new technologies.

A secondary benefit of a compulsory licensing mandate is that mistakes by a regulator in this context are not "too costly". Note that there is a static consumer surplus benefit from universal licensing of *any* component technology, since wide licensing both reduces vertical differentiation and improves directly the quality of both products. If wide licensing is also joint profit improving, then firms would license even in the absence of the mandate, hence the license fee and the extent of diffusion are unaffected by a regulator error. Bryan and Hovenkamp (2019) discusses in greater depth the link between the economics of startup acquisitions and "error cost" arguments for regulator inaction.

Note that we do not propose compulsory licensing of a dominant firm's own internally-developed inventions. This is consistent with general antitrust principles. It is not an antitrust violation to obtain a monopoly by inventing a much better mousetrap. But antitrust frequently condemns efforts to obtain a monopoly through *contract*, such as a merger or collusive agreement. Similarly, intervention may be appropriate when a technological leader obtains monopoly power simply by purchasing exclusive rights to important new technologies and then declining to sell licenses to rivals.[30]

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[30] One might suggest that an acquisition by a dominant firm is justifiable due to the "elimination of double marginalization" (EDM), which is a common argument in vertical merger cases. See, e.g., Sokol (2018) (discussing this in the context of startup acquisitions). However, EDM could not further explain a post-acquisition refusal to license rivals.

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Appendix: Proofs

Proof of Lemma 1

Proof. Part (i): Consider the bargain between firm i and the startup. Since they assume that the other bargain (between j and the startup) will not fail, disagreement payoffs are

$d_i = \pi_i(\mathbf{z}+\widehat{z}_j\mathbf{e}_j)$ for firm i and $d_s = 0$ for the startup.[31] If bargaining is successful, payoffs are $u_i = \pi_i(\widehat{\mathbf{z}}) - \ell_{is}$ for firm i and $u_s = \ell_{is}$ for the startup, where ℓ_{is} is the fee being negotiated. The Nash solution is the fee ℓ^*_{is} that maximizes the Nash product:

$$\begin{aligned}\ell^*_{is} &= \arg\max_{\ell_{is}} (u_i - d_i)(u_s - d_s) \\ &= \arg\max_{\ell_{is}} \Big(\pi_i(\widehat{\mathbf{z}}) - \ell_{is} - \pi_i(\mathbf{z} + \widehat{z}_j\mathbf{e}_j)\Big)\ell_{is}\end{aligned}$$

Solving the FOC yields the desired result.

Part (ii): Letting ℓ_{ij} denote the negotiated fee, the Nash product is

$$\Big(\pi_j(\widehat{\mathbf{z}}) + \ell_{ij} - \pi_j(\mathbf{z} + \widehat{z}_j\mathbf{e}_j)\Big)\Big(\pi_i(\widehat{\mathbf{z}}) - \ell_{ij} - \pi_i(\mathbf{z} + \widehat{z}_j\mathbf{e}_j\Big)$$

Solving the FOC yields the desired result. □

Proof of Proposition 2

Since $\Pi(\widehat{z}_1, z_2) > \Pi(\widehat{\mathbf{z}})$, total profits are highest when firm 1 alone gets the rights to the startup technology. Thus firm 1 is willing to pay more for an acquisition than any total amount the startup could hope to get through an alternative way of monetizing its technology. In the acquisition bargain with firm 1, let $\mathcal{A}_1$ denote the acquisition price being negotiated. Since the parties anticipate that bargaining failure will lead to nonexclusive licensing, the Nash product is

$$\Bigg(\pi_1(\widehat{z}_1, z_2) - \mathcal{A}_1 - [\pi_1(\widehat{\mathbf{z}}) - \ell^*_{1s}(\widehat{\mathbf{z}})]\Bigg)\Bigg(\mathcal{A}_1 - \mathcal{L}^*_s(\widehat{\mathbf{z}})\Bigg)$$

where $\mathcal{L}^*_s(\widehat{\mathbf{z}}) \equiv \sum_i \ell^*_{is}(\widehat{\mathbf{z}})$. Solving the FOC and plugging in the definition of $\ell^*_{1s}(\widehat{\mathbf{z}})$ yields the desired solution, $\mathcal{A}^*_1(\widehat{\mathbf{z}})$. It is easy to verify that the startup could not earn more than $\mathcal{A}^*_1(\widehat{\mathbf{z}})$ through either nonexclusive licensing or an acquisition by firm 2.[32]

[31] The startup anticipates getting some fee ℓ_{js} from firm j whether or not the present bargain fails, so this fee would cancel out of the Nash product and can thus be ignored.

[32] Firm 2 would license firm 1 post-acquisition, which increases its willingness to pay to acquire the startup. But firm 1 is still willing to pay more.

Proof of Proposition 3

Proof. Suppose that the startup chooses to enter into an acquisition agreement with firm 2 (after which firm 2 will of course license firm 1). This must provide firm 2 and the startup with a larger joint profit than nonexclusive licensing, because both scenarios ultimately elicit the same allocation of rights, but the acquisition extracts a larger payment from firm 1 (because $\ell_{12}^* > \ell_{1s}^*$). Thus, when a firm-1 acquisition is prohibited, the startup's next best option is an acquisition by firm 2. By Lemma 1, firm 2 will then sell firm 1 a license for ℓ_{12^*}. Letting $\mathcal{A}_2$ denote the negotiated price, the Nash product is

$$\begin{aligned}&\Big([\pi_2(\widehat{\mathbf{z}}) + \ell_{12}^* - \mathcal{A}_2] - [\pi_2(\widehat{\mathbf{z}}) - \ell_{2s}^*]\Big)\Big(\mathcal{A}_2 - \mathcal{L}_s^*\Big)\\ =\ &\Big(\ell_{12}^* - \mathcal{A}_2 + \ell_{2s}\Big)\Big(\mathcal{A}_2 - \mathcal{L}_s^*\Big)\end{aligned}$$

Solving the FOC and plugging in $\ell_{12}^* = \ell_{1s}^* + (\ell_{12}^* - \ell_{1s}^*)$ yields the desired solution. □

Proof of Proposition 4

Proof. It is easy to verify that, if firm 2 acquires the startup, the acquisition price is given by the desired expression for $\mathcal{A}_2^c$. Suppose instead that firm 1 acquired the startup. Then, anticipating licensing to firm 2 at price ℓ_{21}^c, it is straightforward to show that the acquisition price would be $\mathcal{A}_1^c = \mathcal{L}_s^* + (\theta - \frac{1}{2})\ell_{2s}^*$. We then have $\mathcal{A}_2^c \geq \mathcal{A}_1^c$ iff $\mathcal{A}_2^* \geq \mathcal{L}_s^*$, which is true. Thus the startup will not be acquired by firm 1. Further, one can verify that $\mathcal{A}_2^c \geq \mathcal{L}_s^*$ iff

$$\pi_2(z_1, \widehat{z}_2) - \pi_2(\widehat{\mathbf{z}}) \geq \pi_2(\widehat{\mathbf{z}}) - \pi_2(\widehat{z}_1, z_2)$$

which is true, because $\widehat{z}_2 - z_2 \geq \widehat{z}_1 - z_1$ and $\frac{\partial}{\partial z_2}\pi_2(\mathbf{z}) > |\frac{\partial}{\partial z_1}\pi_2(\mathbf{z})|$ for any $\mathbf{z}$. Thus, under compulsory licensing, the startup's preferred option is to be acquired by firm 2 at price $\mathcal{A}_2^c$.

□

Proof of Proposition 5

Proof. Taking derivatives of $\mathcal{A}_1^*$ directly, we find that the desired expression obtains if and only if

$$3z_1 + 5\Delta_1 > 3z_2 + 2\Delta_2,$$

which is true under (10)-(12), given that we also have $\frac{1}{2}z_1 < z_2 < z_1$ by assumption (A1), which is illustrated in Figure 1. □

Proof of Proposition 6

Proof. It is straightforward to verify that ψ simplifies to

$$\psi(\boldsymbol{\Delta}^\tau) = \frac{1}{2}\Big\{\pi_1(z_1 + \Delta_1, z_2) - \pi_1(\mathbf{z} + \boldsymbol{\Delta}^\tau) + \frac{1}{2}\Big[\pi_2(z_1, z_2 + \Delta_2) - \pi_2(z_1 + \Delta_1, z_2)\Big]\Big\}$$

Then taking derivatives and combining terms, we obtain

$$\frac{\partial}{\partial \Delta_1^\tau}\psi > \frac{\partial}{\partial \Delta_2^\tau}\psi \quad \iff \quad 4z_2 + 10\Delta_2 > z_1 + 3\Delta_1.$$

And, analogous to the previous proof, the righthand inequality is true in light of (10)-(12) and the fact that $\frac{1}{2}z_1 < z_2 < z_1$. □

Proof of Proposition 7

The result follows from calculating the relevant derivatives, which are:

$$\frac{\mathrm{d}}{\mathrm{d}z_1}\pi^m(z_1) = \frac{z_1}{2}, \quad \frac{\partial}{\partial z_1}\pi_1^d(z_1, z_2) = \frac{4}{3}\left(\frac{2z_1 - z_2}{3}\right), \quad \frac{\mathrm{d}^2}{\mathrm{d}z_1^2}\pi^m(z_1) = \frac{1}{2}, \quad \frac{\partial^2}{\partial z_1^2}\pi_1^d(z_1, z_2) = \frac{8}{9}.$$