A Dynamic Model of Predation *

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Abstract

We study the feasibility and profitability of predation in a dynamic environment, using a parsimonious infinite-horizon, complete information setting in which an incumbent repeatedly faces potential entry. When a rival enters, the incumbent chooses whether to accommodate or predate it; the entrant then decides whether to stay or exit. We show that there always exists a Markov perfect equilibrium, which can be of three types: accommodation, monopolization, and recurrent predation. We then analyze and compare the welfare effects of different antitrust policies, accounting for the possibility that recurrent predation may be welfare improving.

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1 Introduction

Predatory behavior arises when a firm adopts an aggressive strategy –e.g., by charging low prices, expanding output, launching an extensive advertising campaign, or introducing fighting brands– intended to prevent entry or induce exit.[1] That a firm intentionally engages in such behavior is highly controversial. Chicago school scholars such as Bork (1978, p. 154) claim that predatory behavior is "a phenomenon that probably does not exist."[2] The U.S. Supreme Court summarized these views in *Matsushita* as a "consensus among commentators that predatory pricing schemes are rarely tried, and even more rarely successful."[3] Other scholars however, including Bolton, Brodley, and Riordan (2000) and Edlin (2012), find instead evidence of predatory behavior in a variety of industries.

After years of little enforcement in the area of predatory pricing, there is now a renewed interest in predatory behavior due to the concern that big tech giants may drive small rivals out of the market.[4] For example, the U.S. House Judiciary Committee's Antitrust Subcommittee on the state of competition in the digital economy states in a 2020 report that "[p]redatory pricing is a particular risk in digital markets."[5] This concern has led policymakers, politicians, and academics to call for a reform of antitrust laws, and in particular for a more effective treatment of predation. The U.S. House Judiciary recommends changes in the standard of proof for predatory pricing cases in order to strengthen antitrust enforcement. Similar calls were made by Khan (2017) and by the Stigler Committee on Digital Platforms.[6]

One reason for Bork's claim that predation "probably does not exist" is that, following the prey's exit, the predator will quickly face a new entrant and will therefore be unable to recoup the losses incurred during the predatory episode. But

[1]For instance, at the turn of the 20th century, the American Sugar Refining Company (ASRC) responded to entry with extended periods of below cost pricing; it also reacted to entry by the leading U.S. coffee roaster by entering and waging a price war in the coffee roasting market; see Genesove and Mullin (2006). In the early 1970's, Maxwell House reacted to Folger's entry into several cities in the East coast of the U.S. with low prices, extensive promotions and advertising, and a fighting brand of regular coffee; see Hilke and Nelson (1989).

[2]Easterbrook (1981) raises similar doubts and writes "there is no sufficient reason for antitrust law or the courts to take predation seriously."

[3]*Matsushita Elec. Indus. Co. v. Zenith Radio Corp.*, 475 U.S. 574, 589 (1986).

[4]A case in point is the European Commission's 2019 decision that Qualcomm abused its dominant position by offering targeted below-cost prices to eliminate Icera, its main competitor at the time in the leading edge segment of the UMTS chipset; see Case AT.39711 – Qualcomm (predation), 2019/C 375/07.

[5]See U.S. House Judiciary (2020). In the same vein, Khan (2017) argues that Amazon and Uber engage in predatory behavior, and Oremus (2021) argues that several services of big tech giants, such as Facebook Bulletin, Google Photos, Apple TV Plus, and Amazon subscription service, which are offered for free or for low prices, may be predatory and intended to drive smaller rivals out of business.

[6]The Stigler Committee states that "Predatory pricing law should be modified so that it will be better able to combat anticompetitive pricing by digital platforms and other firms." See Stigler Committee (2019), p. 97.

as Edlin (2012) points out, entry cannot be presumed. Moreover, if a potential entrant expects the incumbent to be aggressive once it enters, it may prefer to stay out of the market. In turn, the incumbent's reaction to entry depends on its expectations about future entrants' behavior.

Another controversy concerns the welfare effects of predation. Scholars such as Areeda and Hovenkamp (2002) and Posner (2001) argue that predatory behavior potentially harms consumers by reducing competition once the prey exits. Others, however, point out that the benefit to consumers during the predatory phase is a sure thing, whereas the resulting harm is speculative, as the prey may not exit and, even if it does, the threat of new entry may induce the incumbent to maintain its aggressive strategy.[7] The welfare effects of predation are thus *a priori* ambiguous.[8]

Analyzing the role of incumbents and entrants' expectations, as well as assessing the overall welfare impact of predation, requires a fully dynamic framework. We therefore consider an infinite horizon, perfect information game in which an incumbent, I, faces a sequence of potential entrants. We impose only minimal assumptions on the firms' payoffs. In every period, the game starts in one of two states. In the *monopoly* state, I is initially alone in the market but, with positive probability, a potential entrant E is born and decides whether to enter. In the *competitive* state, I already faces a rival E and decides whether to predate, which reduces E's profit if it stays in the market; having observed I's decision, E decides whether to stay. In both states, E's decision affects I's profit (which is lower if E is active) and determines the state of the next period.

We first characterize the Markov Perfect equilibria (MPE) of this game and show that three types of equilibria can emerge: (i) *accommodation*, where there is no predation and the first newborn E enters and stays forever; (ii) *recurrent predation*, where every newborn E enters but immediately exits due to predation;[9] and (iii) *monopolization*, where every newborn E stays out because it expects entry to trigger predation and with it, its immediate exit. Which type of equilibrium emerges depends on three considerations. First, predation may be unsuccessful; indeed, I's predatory behavior may fail to induce an active E to exit, or a newborn E to stay out. Second, even if successful, predation may be too costly. As anticipated by Edlin (2012), this depends crucially on firms' expectations about their rivals' behavior,

[7] This view is summarized by Judge Breyer, who wrote: "[T]he antitrust laws very rarely reject such beneficial 'birds in hand' for the sake of more speculative (future low-price) 'birds in the bush". See *Barry Wright Corp. v. ITT Grinnell Corp.*, 724 F.2d 227, 234 (1st Cir. 1983).

[8] For instance, Scherer (1976) argues that the overall welfare effect of predation depends on considerations such as the relative costs of the dominant and fringe firms, the minimal scale of entry, the incumbent's behavior in case of exit, and whether fringe firms are driven out entirely.

[9] For an example of recurrent predation, see Scott-Morton (1997), who studies the British ocean shipping industry at the turn of the 20th century, and documents in Table V 14 cases where entry triggered predatory pricing, followed by exit in 6 cases.

which can give rise to multiple equilibria.[10] Indeed, if E expects accommodation in the future, it may not exit when I predates in the current period, which makes predation unprofitable. By contrast, if E expects predation in the future, it exits whenever I predates, which strengthens I's incentive to predate; as a result, a predatory equilibrium can exist regardless of the probability of future entry. Finally, the impact of predation on competition depends on whether hit-and-run entry (one period of entry, followed by one period of predation and exit) is profitable for E.

We then discuss the policy implications of our analysis. The U.S. and EU treatments of predation have been heavily influenced by Areeda and Turner (1975), who argue that below-cost pricing should be deemed predatory. Indeed, in *Matsushita* the U.S. Supreme Court defined predatory pricing as "either (i) pricing below the level necessary to sell their products, or (ii) pricing below some appropriate measure of cost."[11] In *Brooke Group*, however, the Court added a recoupment requirement and held that a plaintiff must also prove that "the competitor had a reasonable prospect of recouping its investment in below-cost prices."[12] In the EU, the Court of Justice held in *AKZO* that "Prices below average variable costs [...] by means of which a dominant undertaking seeks to eliminate a competitor must be regarded as abusive," and that "prices below average total costs [...], but above average variable costs, must be regarded as abusive if they are determined as part of a plan for eliminating a competitor."[13]

Our analysis does not support the emphasis on price-cost comparisons, as below-cost pricing is neither necessary nor sufficient for successful predation. If entry costs are high relative to I's cost, I can deter entry even by pricing above average cost. Conversely, pricing below marginal cost in the short-run may not enable I to drive E out of the market it if expects large enough profits in the long-run. By contrast, the "prospect for recoupment" plays a crucial role in our analysis, which shows how

[10] In particular, Edlin writes "Whether predation is a successful strategy depends very much on whether predator and prey believe it is a successful strategy." Our analysis confirms Edlin's intuition and identifies conditions under which multiple equilibria indeed arise. Importantly, since our game features sequential moves, the multiplicity of equilibria is rooted in the dynamics of the model and as in Besanko et al. (2010) and Besanko, Doraszelski, and Kryukov (2014), it is due to firms' expectations regarding the value of continued play and the fact that there may be more than one such play that is consistent with rational expectations.

[11] See *Matsushita* at 585, n. 8. The Court recalled this definition in *Cargill*, where it refers explicitly Areeda and Turner; see *Cargill, Inc. v. Monfort of Colorado, Inc.*, 479 U.S. 104, 117 (1986).

[12] See *Brooke Group Ltd. v. Brown & Williamson Tobacco Corp.*, 509 U.S. 209, 225–26 (1993). Although the *Brooke Group* test has proven difficult to meet (see e.g., Hemphill (2001)), numerous predatory pricing cases have survived summary judgment in U.S. courts, while others have survived dismissal, which suggests that predation cases may be successfully litigated in the U.S.; see Hemphill and Weiser (2018).

[13] Case C-62-86, *AZKO Chemie BV v Commission* [1991], ECR I-3359, at paragraphs 71-72 . At paragraph 44 of *Tetra-Pak II*, the Court further clarified that proof of recoupment was not needed (Case C-333/94 P, *Tetra Pak International SA v Commission* [1996], ECR I-5951).

it depends on the likelihood of exit and of future entry.

Our analysis also does not support a complete ban on predation, even if such a ban were enforceable. The reason is that the benefit of low prices during the predatory episode may outweigh the harm from monopoly incurred between exit and new entry, suggesting that legal rules intended to identify and mitigate predation should take into account dynamic considerations. This leads us to consider two rules that do so and are meant to be easier to enforce. The first rule, suggested by Williamson (1977) and Edlin (2002), curbs the incumbent's response to entry. The second rule, suggested by Baumol (1979), curbs instead the incumbent's response to exit. Either rule can be used to implement a ban on predation – the original intent of their proponents – and thus constitutes an alternative to the Areeda-Turner test. An adequate combination of the two rules, however, can do better when aggressive behavior is socially desirable, by fostering entry and extending the phases of aggressive behavior under recurrent predation. The latter can even provoke its social desirability.

In the rest of the paper, we proceed as follows. First, we relate our analysis to the literature on predatory behavior. We then present our model in Section 2 and characterize the equilibrium in Section 3. We discuss antitrust intervention in Section 4 and provide concluding remarks in Section 5. In Appendix A we illustrate the assumed payoff structure within a standard Stackelberg duopoly. All proofs are in Appendix B.

Related Literature

There is an extensive theoretical literature on predatory behavior. In an early survey, Ordover and Saloner (1989) distinguish three strands.[14] The first is the "deep pocket" or "long purse" theory, in which the predator seeks to deplete the resources of a financially constrained rival (see, e.g., Telser, 1966, and Bolton and Scharfstein, 1990). The second strand is "predation for reputation," in which the predator wishes to appear tough in order to deter future entrants (see, e.g., Kreps and Wilson, 1982, and Milgrom and Roberts, 1982). The third strand is based on signaling; there the predator's goal is to convince the entrant that staying in the market would be unprofitable, in order to induce it to exit (see, e.g., Roberts, 1986, and Fudenberg and Tirole, 1986) or acquire it at a low price (see, e.g., Saloner, 1987).

This early literature relies directly or indirectly on information problems: the deep pocket theory hinges on capital market imperfections that are typically based on some form of asymmetric information, and in the reputation and signalling theo-

[14]For a more recent survey, see, e.g., Kobayashi (2010).

ries, the prey is uninformed about market conditions. More recently, Fumagalli and Motta (2013) propose an alternative theory that relies on scale or scope economies: by supplying early buyers at a loss, an incumbent prevents a (possibly more efficient) rival from reaching a viable scale, which in turn enables the incumbent to exploit the remaining buyers.[15] As in much of the earlier literature, they focus on the interaction between an incumbent and a single entrant in a finite-horizon setting.

By contrast, our paper is closer to another strand of the predation literature, which also uses infinite-horizon, complete information settings but focuses instead on learning curve dynamics. Cabral and Riordan (1994) study a setting in which, in each period, two firms compete for a buyer. Winning the current competition lowers future costs due to a learning curve effect; this induces the firm to price aggressively, in order to lower its own future costs and prevent the rival from doing so. When a firm gains a sufficiently large cost advantage over the rival, the latter exits, which further encourages investments in cost-reduction. Their model, as ours, can give rise to multiple equilibria with and without predatory-like behavior, and below-cost pricing is neither a necessary nor sufficient indication of predatory behavior. They also find that predation has ambiguous welfare effects; in particular, by fostering learning and reducing costs, it may benefit consumers even in the long run.[16] An important difference between their paper and ours is that they do not allow for recurrent entry, which plays a key role in our setting.

Besanko, Doraszelski, and Kryukov (2014,2019) build on Cabral and Riordan (1994), using numerical simulations that allow for re-entry. They show that predatory motives constitute an important driver of competition and compare the equilibrium outcomes with that of a social planner. Their analysis also highlights the fact that predatory pricing can either harm or benefit consumers, and that blunt pricing conduct restrictions can lead to substantial welfare losses. Besanko, Doraszelski, and Kryukov (2020) adapt the definitions of predation from Ordover and Willig (1981) and Cabral and Riordan (1997) to a Markov-perfect industry-dynamics framework and construct sacrifice tests. These tests disentangle an illegitimate profit sacrifice stemming from predatory pricing from a legitimate effort to increase cost efficiency through aggressive pricing.

We focus instead on the debate about the plausibility of predation under persistent threat of entry and its implications for antitrust enforcement. We thus also abstract from learning curve effects (in addition to abstracting from asymmetric information, financial constraints, and scale economies) and show that firms' ex-

[15] A similar insight obtains when multiple buyers face some form of mis-coordination.

[16] Cabral and Riordan (1997) consider a two-period Cournot variant in which, conversely, predation may harm consumers in the short-run, as the predator's aggressive behavior may be offset by the prey's softer reaction.

pectations about the future behavior of rivals suffice to give rise to predation.[17] In essence, we adopt a similar approach to Asker and Bar-Isaac (2014) and use an infinite horizon, perfect information Markovian framework. Instead of studying exclusion within a vertical context as they do, we study exclusion within a horizontal context. Moreover, we adopt a sequential-move setting that minimizes the scope for multiple equilibria, as firms always make their decisions under complete information about their competitive environment. We characterize the conditions under which predation deters entry, thereby leading to monopolization, and the conditions under which newborn rivals keep entering and the incumbent fights them. Finally, we use our framework to assess the welfare effect of current and alternative legal rules.

2 The model

Consider an infinite-horizon, discrete time setting in which an incumbent I faces a sequence of potential entrants denoted by E. In each period, the game starts in one of two states: (i) a monopoly state, $\mathcal{M}$, in which I is initially the only firm in the market, but E may enter; or (ii) a competitive state, $\mathcal{C}$, in which I and E are both initially in the market, but E may exit. When a newborn E does not enter or an existing E exits, it dies but a new E (possibly an E that exited earlier) may be born in future periods. All firms face the same discount factor $\delta \in (0, 1)$.

The timing and profits are as follows:

• In state $\mathcal{M}$, a potential entrant E is born with probability β and decides whether to enter. If E was not born, or was born but decided not to enter, I obtains the monopoly profit π_I^m and the next period starts again in state $\mathcal{M}$. If instead E enters, it incurs a one-time entry cost $k > 0$, I and E obtain the competitive profits π_I^c and $\pi_E^c - k$, and the next period starts in state $\mathcal{C}$.[18]

• In state $\mathcal{C}$, I first decides whether to predate or to accommodate. Having observed I's decision, E decides whether to stay or to exit. If I predates and E exits, I's profit is π_I^p and the next period starts in state $\mathcal{M}$. If E stays despite being predated, the profits of I and E are $\underline{\pi}_I^p$ and π_E^p, and the game remains in state $\mathcal{C}$.

[17] For an early exploration, see Appendix A of Milgrom and Roberts (1982), where they consider an infinitely repeated version of Selten's chain store paradox. By assumption, the stage game in their model is infinitely repeated, and hence, their model features infinitely many markets, each is contested only once. They show that their game admits uncountably many pure-strategy equilibria, including equilibria in which predation prevents entry on arbitrary numbers of instances. By contrast, we consider a dynamic game with infinite horizon, where the stage game in each period depends on whether there was entry in previous periods and whether the entrant has stayed in the market or exited. In our setting, only three pure-strategy equilibria can arise. We characterize the conditions on the key drivers that determine the type of equilibrium (namely, monopolization, predation or accommodation) that can arise.

[18] An alternative interpretation of the stochastic process is that entry cost is either k with probability β, or is prohibitively costly with probability $1 - \beta$.

If I accommodates and E stays, I and E obtain the same competitive profits as in state $\mathcal{M}$, π_I^c and π_E^c, except that now E does not incur the entry cost, k, and the game remains in state $\mathcal{C}$. If instead E exits, I's profit is $\overline{\pi}_I^c$ and the next period starts in state $\mathcal{M}$.

Table 1 provides a summary of the firms' profits:

	E enters	E stays out
State $\mathcal{M}$	$\pi_I^c, \quad \pi_E^c - k$	$\pi_I^m, \quad 0$

		E stays	E exits
State $\mathcal{C}$	I accommodates	$\pi_I^c, \quad \pi_E^c$	$\overline{\pi}_I^c, \quad 0$
	I predates	$\underline{\pi}_I^p, \quad \pi_E^p$	$\pi_I^p, \quad 0$

Table 1: Profits

We naturally assume that $\pi_I^m > \pi_I^c > \max\{\pi_I^p, \underline{\pi}_I^p\}$: in state $\mathcal{M}$, I obtains a higher profit when it is alone in the market; and in state $\mathcal{C}$, I obtains a higher profit under accommodation than under predation.[19] Also, to rule out uninteresting cases, we make the following assumptions:

$$\pi_E^c > (1-\delta)\,k \text{ and } \pi_E^p < 0.$$

If the first assumption is violated, E's discounted sum of competitive profits falls short of the entry cost even if E is always accommodated. Hence, entry is blockaded. If the second assumption is violated, E never exits the market once it has already entered, so predating an existing entrant is impossible. These assumptions are quite natural. Moreover, our stylized approach is sufficiently flexible to allow for product differentiation, price and quantity competition, multi-product firms and (mixed) bundling, and so forth. A more special assumption we make is that I's profit in state $\mathcal{M}$ if entry occurs is equal to its profit in state $\mathcal{C}$. We make this assumption for expositional simplicity (it economizes on notation), but show in Appendix A that it holds in a classic Stackelberg model.[20] Furthermore, in that model we can either have $\pi_I^p > 0$ (in which case I's price is above average cost) or $\pi_I^p < 0$ (in which case I's price is below average cost) under predation.

[19] While one might assume realistically that I also obtains a higher profit when it operates alone in the market in state $\mathcal{C}$ ($\overline{\pi}_I^c > \pi_I^c$ and $\pi_I^p > \underline{\pi}_I^p$), the analysis does not rely on these assumptions.

[20] More generally, the assumption could also hold in a model in which I has only a limited number of options (e.g., build a new plant or not) and the same option turns out to be optimal under monopoly and under competition (which in our model is sequential as I chooses its strategy before E).

Our setting is very parsimonious. In particular, E must simply decide whether to be in the market or not, and I needs to make a decision only in state $\mathcal{C}$, namely, whether to predate or accommodate E; in state $\mathcal{M}$, I has no decision to make. The "length" of a period can be interpreted as the time lag before I can react to a change in its environment. Consider for instance a continuous time version, in which I can only choose to either behave unaggressively or aggressively, and cannot switch instantaneously. That is, if either entry or exit occurs at time t, I cannot adjust its behavior until time $t+\tau$.[21] Assuming that "fighting" is sufficiently costly, I will behave normally until entry occurs, and will then either stick to this behavior, or fight E as soon as possible, that is, after a time lag τ. Assuming that E, as a new entrant, is more agile and can react at once, E will exit as soon as predation occurs, and I will be able to revert to its pre-entry strategy after the time lag τ.

3 Equilibrium analysis

We focus on pure-strategy Markov Perfect equilibria (MPE). That is, firms adopt stationary Markovian strategies that depend only on payoff-relevant history.[22] A Markov strategy for I is the decision to either predate or accommodate in state $\mathcal{C}$. Likewise, a Markov strategy for a newborn E is the decision to either enter or stay out in state $\mathcal{M}$, and a mapping from I's action into the decision to either stay in the market or exit in state $\mathcal{C}$.[23]

Three possible types of equilibria may emerge. If I accommodates in state $\mathcal{C}$, we get an accommodation equilibrium, as the viability assumption $\pi_E^c > (1-\delta)\,k$ ensures that (i) in state $\mathcal{C}$, E stays forever, as its per-period profit, π_E^c, is positive, and (ii) in state M, the first newborn E enters the market, as the per-period profit

[21] The assumption that reacting to entry takes time is realistic. For example, when Icera entered the UMTS baseband chipsets in October 2008, Qualcomm reacted only in July 2009 (by offering certain quantities of three of its UMTS chipsets to "two of its key customers, Huawei and ZTE, below cost, with the intention of eliminating Icera"); see Case AT.39711 –Qualcomm (predation), 2019/C 375/07, Paragraph 1. Likewise, when Vanguard entered the Dallas-Forth Worth to Kansas City route at the end of January 1995, American Airlines responded only in June-July 1995 (by adding six daily non-stop flights into this route in order to "stand up against Vanguard's service in the market"); see United States of America v. AMR Corporation, American Airlines, Inc., and AMR Eagle Holding Corporation, (April 2001): Summary Judgement Decision No. 99-1180-JTM. A third example is Sierra Redi-Mix which, in response to D&S Redi-Mix entry into the concrete market in Sierra Vista, Arizona in December 1969, reacted only in August 1970 (when it "heavily subsidized" Cashway to compete with D&S Redi-Mix and cause D&S Redi-Mix to "suffer severe cash flow problems"); see D&S Redi-Mix v. Sierra Redi-Mix and Contracting Co., 692 F.2d 1245 (9th Cir. 1982).

[22] See Maskin and Tirole (1988).

[23] We focus on pure strategies to streamline the exposition. Allowing for mixed strategies would not change the qualitative insights. In particular, whenever a mixed-strategy equilibrium exists, there also exists a pure-strategy equilibrium that either yields the same equilibrium path or entails more exclusion.

covers the amortization of the entry cost. If instead I predates in state $\mathcal{C}$, the non-viability assumption $\pi_E^p < 0$ ensures that E exits at once in state $\mathcal{C}$.[24] In state $\mathcal{M}$, a newborn E then enters for one period if its one-period profit, π_E^c, covers the entry cost k, so we get an equilibrium with recurrent predation; otherwise a newborn E stays out of the market, so we get a monopolization equilibrium.

With our first proposition, we establish existence and show that the type of equilibrium depends on two key parameters: E's profit under accommodation, π_E^c, and I's "cost-benefit ratio" of predation,

$$\lambda \equiv \frac{\pi_I^c - \pi_I^p}{\pi_I^m - \pi_I^c}.$$

Its numerator reflects the profit sacrifice incurred in a predation period, $\pi_I^c - \pi_I^p$, and its denominator the monopolization benefit obtained in a subsequent period, $\pi_I^m - \pi_I^c$.

Specifically, using the thresholds

$$\hat{\pi}_E^c \equiv -\frac{1-\delta}{\delta}\pi_E^p (> 0), \quad \underline{\lambda} \equiv \frac{(1-\beta)\,\delta}{1-(1-\beta)\,\delta}\,(> 0) \quad \text{and} \quad \overline{\lambda} \equiv \frac{\delta}{1-\delta}\,(> \underline{\lambda}),$$

we have:

Proposition 1 (equilibrium outcomes) *The (pure-strategy) Markov perfect equilibrium outcomes are as follows:*

(i) ***Accommodation****: I accommodates entry, and the first newborn E enters and stays forever; such an equilibrium exists if and only if either $\pi_E^c \geq \hat{\pi}_E^c$ or $\lambda \geq \underline{\lambda}$.*

(ii) ***Recurrent predation****: I predates in case of entry, and newborn E's enter for only one period; such an equilibrium, which features hit-and-run entry, exists if and only if $\pi_E^c \geq k$ and $\lambda \leq \underline{\lambda}$.*

(iii) ***Monopolization****: I predates in case of entry, and newborn E's stay out; such an equilibrium exists if and only if $\pi_E^c \leq k$ and $\lambda \leq \overline{\lambda}$.*

Proof. See Appendix B.1. ■

When E expects accommodation in the future, it anticipates a gross profit of π_E^c from the next period onward. If this profit is large enough, namely $\pi_E^c \geq \hat{\pi}_E^c$, E

[24] Note that in and of itself, the assumption that $\pi_E^p < 0$ is not sufficient to ensure that predation is successful as E may stay in the market if it expects to be accommodated in future periods. But if I predates whenever in state $\mathcal{C}$, E cannot make profit in any period and is therefore better off exiting.

is willing to stay in the market even if I were to predate it in the current period.[25] Accommodation is then self-sustainable, as predation does not induce E to exit. If instead $\pi_E^c < \hat{\pi}_E^c$, deviating to predation would trigger exit, but is unprofitable if the cost-benefit ratio is too low, namely $\lambda \geq \underline{\lambda}$: as predation yields a monopolization benefit as long as no other entrant appears, the total expected discounted value of this benefit obtained from next period on is $\underline{\lambda}\,(\pi_I^m - \pi_I^c)$, which is then lower than the short-run sacrifice, $\pi_I^c - \pi_I^p$.

When E expects predation in the future, it exits as soon as possible to avoid losses. However, if $\pi_E^c \geq k$, a one-period profit covers the entry cost; the equilibrium thus features recurrent phases of hit-and-run entry followed by predation and exit.[26] For such an equilibrium to exist, I must be willing to predate, which amounts to $\lambda \leq \underline{\lambda}$, as the total expected discounted value of the monopolization benefit (between phases of hit-and-run entry) is again equal to $\underline{\lambda}\,(\pi_I^m - \pi_I^c)$.

Finally, when E expects predation but $\pi_E^c \leq k$, hit-and-run entry is unprofitable; predation is therefore more attractive for I, as it generates a monopolization benefit forever. As a result, the monopolization equilibrium arises for a larger range of the cost-benefit ratio, namely, $\lambda \leq \overline{\lambda}$.

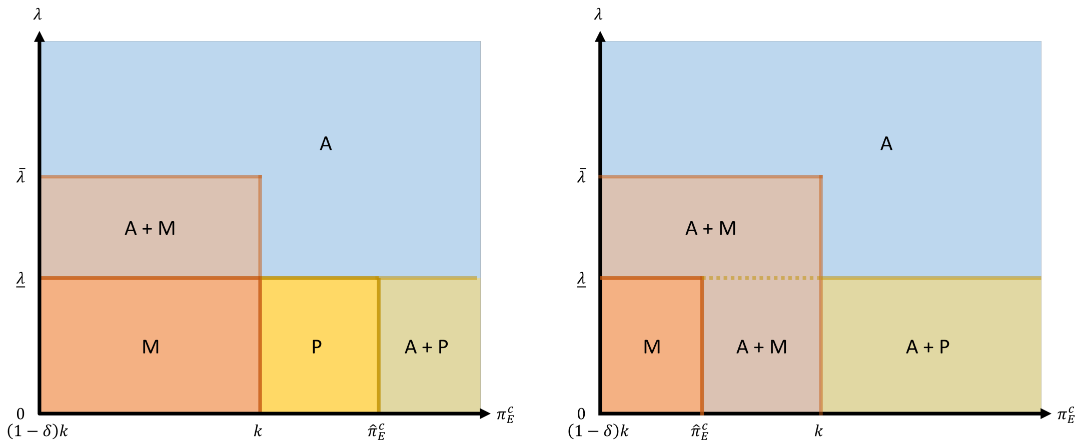
The above thresholds on the ratio λ can be regarded as recoupment tests, as they amount to assessing whether in equilibrium I's benefit from predation is less than, or exceeds its cost. The benefit depends critically on whether the dominant firm expects to become only a temporary monopoly until a new entrant is born, or a permanent one. Which threshold ($\underline{\lambda}$ for temporary monopoly or $\overline{\lambda}$ for permanent monopoly) becomes relevant depends on whether hit-and-run entry is profitable for the typical E. This challenges the recommendation adopted by the U.S. House Judiciary (2020) to override several decisions of the U.S. Supreme Court, and to clarify that "proof of recoupment is not necessary to prove predatory pricing or predatory buying".[27]

In Figure 1 we display the equilibrium outcomes as a function of E's profit π_E^c – in the relevant range $\pi_E^c > (1-\delta)k$ – and of I's cost-benefit ratio of predation λ. Accommodation is an equilibrium whenever predation is sufficiently costly for I

[25] To see why, note that $\pi_E^c \geq \hat{\pi}_E^c$ is equivalent to $\delta \frac{\pi_E^c}{1-\delta} \geq -\pi_E^p$, implying that the future gain from accommodation exceeds the current loss from predation.

[26] The existence of hit-and-run entry depends on our assumption that I cannot react immediately to entry – it can do so only in the next period, when the state changes from $\mathcal{M}$ to $\mathcal{C}$. As mentioned above, this assumption is consistent with real-life examples from predatory cases. The assumption is also consistent with Spence (1983), who argues that two assumptions are required for hit-and-run entry: (i) the incumbent's response time is longer than the time it takes the entrant to recover its sunk cost of entry, and (ii) demand responds instantaneously to price changes or to price differentials. Both of these assumptions are satisfied in our model.

[27] See U.S. House Judiciary (2020). The quoted decisions are *Matsushita* (cf. footnote 3), *Brooke Group* (cf. footnote 12), and *Weyerhaeuser Co. v. Ross-Simmons Hardwood Lumber Co.*, 549 U.S. 312 (2007).



(a) $\hat{\pi}_E^c > k$ (b) $\hat{\pi}_E^c < k$

Figure 1: Equilibrium outcomes
A: *Accommodation;* ***P:*** *Predation;* ***M:*** *Monopolization*

$(\lambda \geq \underline{\lambda})$ and/or entry is sufficiently profitable for E $(\pi_E^c \geq \hat{\pi}_E^c)$. Recurrent predation is instead an equilibrium when predating is sufficiently beneficial for I $(\lambda \leq \underline{\lambda})$ and hit-and-run entry is profitable for E $(\pi_E^c \geq k)$. Finally, monopolization is an equilibrium if predation is relatively beneficial for I $(\lambda \leq \overline{\lambda})$ and hit-and-run entry is unprofitable for E $(\pi_E^c \leq k)$. Interestingly, these findings tend to support the above-mentioned concerns of monopolization by Big Tech, as increasing exploitation of network effects and multi-sidedness, combined with the role of data, tend to boost the profit from predation (thus reducing λ) and raise entry barriers (thus increasing k).[28]

As mentioned in the Introduction, Bork and Easterbrook have expressed skepticism about predation, based on the argument that, once the prey exits, new entry would render predation unprofitable. Proposition 1 offers a more nuanced view. It does confirm the intuition that predation is less likely when entry is easy. In our model, this is the case when the likelihood that a new entrant is born, β, is high (i.e., close to 1) and the entry cost, k, is low. In terms of Figure 1, the horizontal line $\lambda = \underline{\lambda}$ shifts downward as β increases and the vertical line $\pi_E^c = k$ shifts inward as k decreases; as a result, accommodation arises for a wider set of parameters, and constitutes the unique equilibrium in the limit case where $\beta = 1$ (implying $\underline{\lambda} = 0$) and $k = 0$. However, outside this limit case, predation arises whenever it is not too costly (namely, when the cost-benefit ratio λ is sufficiently low): recurrent predation then constitutes an equilibrium whenever $\beta < 1$ (even if $k = 0$), and monopolization constitutes instead an equilibrium whenever $\pi_E^c \leq k$ (even if $\beta = 1$).

[28]Khan (2017) moreover notes that the particular high price of Amazon's stock (and the fact that it reported losses for the first seven years, as well as more recently) suggests that its investors are particularly patient (thus increasing δ).

This suggests that, although Bork's and Easterbrook's skepticism is justified in the limit, predation remains a valid concern in general.

Moreover, as anticipated by Edlin (2012), Proposition 1 shows that the role of firms' expectations about their rival's behavior can lead to a multiplicity of equilibria, in which accommodation may coexist with temporary or permanent exclusion. This occurs in two instances.[29] If $\lambda < \underline{\lambda}$, even temporary exclusion is profitable for I. In this case, exclusion (temporary if $\pi_E^c \geq k$, and permanent otherwise) can always arise, because if E expects predation in the future, then it exits whenever I predates, which in turn induces I to do so. Yet accommodation can also arise when $\pi_E^c \geq \hat{\pi}_E^c$, because if E expects accommodation in the future, then it would stay in the market even if I were to deviate to predation.

If instead $\lambda \in \left[\underline{\lambda}, \overline{\lambda}\right]$, exclusion is profitable for I only when it is permanent, that is, when hit-and-run entry is not profitable: $\pi_E^c \leq k$. In this case, monopolization can indeed arise, because if I expects future E's to exit in case of predation, it has an incentive to do so whenever a new E enters, which in turn deters entry. Yet accommodation can also arise, because if I anticipates entry in the future, then it does not find it profitable to predate, as the benefit of a temporary monopoly position does not compensate the short-run sacrifice. It is worth noting that, in the range where $\pi_E^c \leq k$ and $\lambda \leq \overline{\lambda}$, the monopolization equilibrium exists *regardless* of the probability β that a potential entrant arrives: I is willing to predate even when $\beta \to 1$, as potential entrants, anticipating predation, prefer to stay out. This challenges Bork's or Easterbrook's views that (potential) entry diminishes, if not nullifies the scope for predation.

We conclude this section by noting that the incumbent always prefers predatory equilibria:[30]

Proposition 2 (profitable predation) *I prefers the predatory equilibria whenever they coexist with the accommodation equilibrium, and the monopolization equilibrium whenever it coexists with the predation equilibrium.*

Proof. See Appendix B.2. ■

The intuition is straightforward and relies on the observation that, in any predatory equilibrium, I could always secure the accommodation payoff by never predating. Hence, by revealed preferences, predation must be more profitable for I whenever it arises in equilibrium.

[29] Another (non-generic) instance arises when $\pi_E^c = k$, implying that E is indifferent between staying or exiting when it expects predation in the future. The monopolization and predation equilibria then coexist if $\lambda \leq \underline{\lambda}$.

[30] In the boundary (and, thus, non-generic) case where $\lambda = \underline{\lambda}$ (resp., $\lambda = \overline{\lambda}$), I is indifferent between accommodation and monopolization (resp., recurrent predation). From here on, we focus on generic situations.

4 Policy implications

As mentioned in the Introduction, designing an appropriate policy for predation involves two main difficulties. The first difficulty is that the welfare effects of predatory behavior are in general ambiguous, because intense competition during the predatory phase may be pro-competitive and outweigh the anticompetitive effect when the prey exits. Hence, whether antitrust laws should outright prohibit predation is unclear. We address this issue in Subsection 4.1.

The second main difficulty is that in many, or even most, real-life cases it is unclear whether a given strategy is legitimate and reflects healthy competition, or is predatory and intended to induce a rival to exit. Recognizing this difficulty, several legal rules have been proposed to identify predatory behavior.[31] The most well-known legal rule, proposed by Areeda and Turner (1975), deems prices below average variable cost as predatory. Although the U.S. and EU antitrust approaches to predatory pricing build on it, this rule has been criticized on several grounds.

First, a static price-cost comparison may lead to substantial type I and type II errors. Type I errors (wrongly condemning the innocent) may arise because pricing below cost may be desirable regardless of the impact on rivals, for instance, to move down the learning curve, to signal high quality to consumers via an introductory offer, or to attract consumers and sell them other products. Conversely, type II errors (failing to convict the guilty) may arise because a price above average variable cost may suffice to induce a weaker – or financially fragile – rival to exit.[32] Second, even if at first glance the Areeda-Turner rule may appear simple to enforce, in reality average variable costs are often difficult to measure, especially when firms have large common costs. Third, the rule is static and overlooks the dynamic nature of predatory pricing.

Our analysis is consistent with these criticisms of the Areeda-Turner rule. In Proposition 1 we show that recurrent predation occurs if and only if $\pi_E^c \geq k$ and $\lambda \leq \underline{\lambda}$. The first condition is *independent* of I's profit, and the second can hold even if $\pi_I^p > 0$, that is, when I's price is *above* its average *total* cost, and thus, above average *variable* cost. As already noted, the second condition supports the use of appropriate recoupment tests, adequately accounting for the dynamic nature of predation; the caveat is that these tests suffer from measurement difficulties as well.

The controversy around the Areeda-Turner rule has led scholars to propose

[31]For an early overview and assessment of these rules, see, e.g., Joskow and Klevorick (1979).

[32]For instance, according to Edlin (2002), in the late 1990s American Airlines succeeded in driving Vanguard Airlines out of the Kansas City-Dallas Fort Worth route by lowering its fares by over twenty-five percent and increasing the frequency of its flights. The DOJ sued American Airlines for predatory pricing but lost because American Airlines' fares were found to be above cost. In our analysis, predatory behavior is consistent with either above-cost or below-cost pricing.

rules that avoid the difficulty of measuring the alleged predator's cost and examine instead its reaction to entry or exit, which is arguably easier to observe and measure. Another advantage of these rules is that they avoid the need to conduct recoupment tests which have proven hard to meet,[33] nor consider the expectations of the alleged predator and prey, which are often impossible to establish in court. Finally, as we show below, these rules can also be useful when predation is welfare-improving. We study two such rules in Subsections 4.2 and 4.3, and then a more general policy that combines the two rules in Subsection 4.4.

For the purpose of the analysis, we assume that regulators (e.g., competition agencies) rely on a given welfare criterion, and denote by w^m, w^c, and w^p the per-period welfare under monopoly, competition, and predation. It is natural to assume that $w^m < \min\{w^c, w^p\}$, so that in the short-term both competition and predation increase welfare relative to monopoly. The comparison between w^c and w^p is a priori less clear, as in the latter case I is alone in the market but behaves aggressively. Finally, we assume that in case of entry, welfare is $w^c - \alpha k$, where $\alpha \in [0, 1]$ denotes the share of the entry cost that regulators take into account in the welfare criterion.[34]

To assess the equilibrium level of welfare, we will assume that states $\mathcal{M}$ and $\mathcal{C}$ prevail according to their *long-run* probabilities of occurrence, which we denote by $\mu_{\mathcal{C}}$ and $\mu_{\mathcal{M}}$. In an accommodation equilibrium, state $\mathcal{C}$ eventually prevails with probability 1, so total discounted welfare is

$$W^A \equiv \frac{w^c}{1-\delta}. \tag{1}$$

In a monopolization equilibrium, state $\mathcal{M}$ eventually prevails with probability 1, so total discounted welfare is

$$W^M \equiv \frac{w^m}{1-\delta}. \tag{2}$$

Finally, in a recurrent predation equilibrium, expected welfare is $(1-\beta)\, w^m + \beta\,(w^c - \alpha k)$ in state $\mathcal{M}$ and w^p in state $\mathcal{C}$. As state $\mathcal{C}$ occurs if and only if a new E was born in the previous period, the long-run probabilities of states $\mathcal{M}$ and $\mathcal{C}$ satisfy

$$\mu_{\mathcal{C}} = \beta \mu_{\mathcal{M}},$$

[33] The U.S. House Judiciary (2020) notes that "Since the recoupment requirement was introduced, successful predatory pricing cases have plummeted."

[34] Many jurisdictions, including the U.S., the UK, and the EU, focus on consumer surplus (OECD, 2012, p. 27). In that case, $\alpha = 0$. Other countries, including Canada and Norway, pursue instead a total welfare standard that assigns an equal weight to consumer surplus and profits (OECD, 2012, p. 27), in which case $\alpha = 1$. Australia places a larger weight on consumer surplus than on profits (OECD, 2012, p. 66-67), which corresponds to $0 < \alpha < 1$.

which, using $\mu_{\mathcal{C}} + \mu_{\mathcal{M}} = 1$, yields:

$$\mu_{\mathcal{M}} = \frac{1}{1+\beta} \text{ and } \mu_{\mathcal{C}} = \frac{\beta}{1+\beta}.$$

Total expected discounted welfare in the long run is thus given by:

$$\begin{aligned} W^P &\equiv \frac{\mu_{\mathcal{M}}\left[(1-\beta)w^m + \beta(w^c - \alpha k)\right] + \mu_{\mathcal{C}} w^p}{1-\delta} \\ &= W^A + \frac{(1-\beta)\left(w^m - w^c\right) + \beta\left(w^p - w^c - \alpha k\right)}{(1+\beta)(1-\delta)}. \end{aligned} \tag{3}$$

As $w^m < w^c$, W^P can exceed W^A only if β is sufficiently large and $w^p > w^c + \alpha k$; that is, if new entrants are born with large enough probability and the per-period welfare under predation is sufficiently larger than that under accommodation, gross of (welfare relevant) fixed cost of entry.

A policy intervention may influence the equilibrium in three ways. First, it may affect the path of a given type of equilibrium –in particular the duration of the hit-and-run and predation phases. Second, it may affect the type of equilibrium that may arise. Third, when multiple types of equilibria exist with and without it, the rule could potentially, and somewhat artificially, serve as a coordination device, inducing a switch from one type of equilibrium (under laissez-faire) to another (under policy intervention). To avoid this latter effect, we shall adopt the following selection criterion:

Assumption A: *When multiple equilibria co-exist under a rule, the equilibrium most profitable for the incumbent is selected.*

From Proposition 2, this selection criterion amounts to favor predation over accommodation (and monopolisation over recurrent predation in the boundary cases where both types of predatory equilibria coexist). It can therefore be motivated in two ways. One motivation is simply that the equilibrium preferred by the incumbent, who acts as a leader in each period of competition, becomes focal.[35] Alternatively, and given the objective of studying policies designed to fight predation, this selection rule can be seen as precisely maximizing the scope for predation.

Under Assumption A, laissez-faire yields accommodation when this constitutes the unique equilibrium in the baseline setting, recurrent predation when this constitutes the unique predatory equilibrium in the baseline setting, and monopolization whenever there exists such an equilibrium in the baseline setting. From Propositions

[35] Cooper et al (1993) find experimental evidence that the outcome preferred by a first mover is focal and is played 90% of the time.

1 and 2, we thus have:[36]

Corollary 1 (equilibrium selection) *Laissez-faire yields* ***monopolization*** *if* $\pi_E^c \leq k$ *and* $\lambda \leq \overline{\lambda}$*,* ***recurrent predation*** *if* $\pi_E^c > k$ *and* $\lambda \leq \underline{\lambda}$*, and* ***accommodation*** *otherwise.*

Proof. Follows directly from Assumption A and Propositions 1 and 2. ■

The resulting equilibrium outcomes are shown in Figure 2.

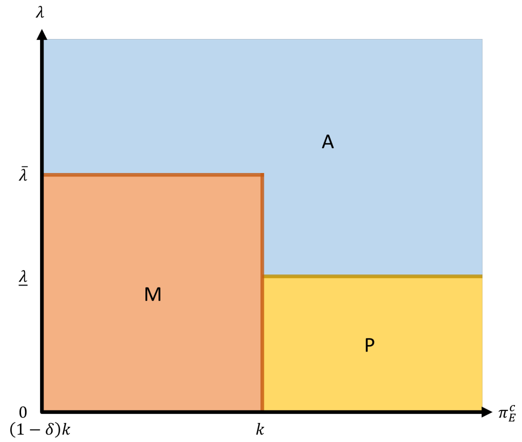


Figure 2: Equilibrium selection
A: *Accommodation;* ***P:*** *Predation;* ***M:*** *Monopolization*

4.1 Banning Predation

To assess the effect of a complete ban on predation, we compare the equilibrium welfare levels with those in a counterfactual where predation is no longer possible in state $\mathcal{C}$.[37] It follows that, on the equilibrium path, a newborn E eventually enters the market in state $\mathcal{M}$ and stays forever; total discounted welfare is therefore W^A.

When laissez-faire yields accommodation, predation is a non-issue, and a ban is therefore irrelevant. When instead laissez-faire yields a predatory equilibrium, a ban forces a switch to accommodation. Building on this, and comparing welfare under predation and accommodation, leads to:

[36] As already mentioned, allowing for mixed strategies never generates more exclusion – see Footnote 23. It follows that mixed-strategy equilibria could be selected under Assumption A only when featuring the same equilibrium path as the most predatory equilibrium in pure strategies (i.e., when differing from that equilibrium only by introducing randomization off the equilibrium path) – the only caveat is for the *non-generic* case $\lambda \leq \underline{\lambda}$, where I is indifferent between accommodation and predation; in that case, a mixed-strategy equilibrium, in which E always enters and I predates with some probability, could possibly be selected instead of the recurrent predation pure-strategy equilibrium.

[37] Under the current legal rules, a ban on predation is largely theoretical, given the practical difficulty to determine whether a given strategy is legitimate or predatory. The "dynamic" legal rules considered below may however help enforce a ban.

Proposition 3 (banning predation) *Compared with laissez-faire, a ban on predation:*

(i) is undesirable when laissez-faire yields recurrent predation and

$$(1-\beta)\,w^m+\beta\,(w^p-\alpha k)>w^c;$$

(ii) is otherwise desirable whenever relevant.

Proof. See Appendix B.3. ■

A ban has an effect only if a predatory equilibrium arises under laissez-faire. In case of monopolization, E never enters and I becomes a permanent monopolist. A ban on predation is then clearly socially desirable, as in each period it increases welfare from the monopoly to the competitive level.

In case of recurrent predation, " hit-and-run" phases (one period of entry, followed by one period of predation and exit) alternate with monopoly phases. Compared with accommodation, in hit-and-run phases a social entry cost αk is incurred in the first period, and welfare changes from w^c to w^p in the second period; in monopoly phases, welfare decreases from w^c to w^m. It follows that accommodation is strictly preferable so long as welfare under competition, w^c, exceeds a weighted average of welfare in monopolization periods, w^m, and in predatory periods, $w^p-\alpha k$, with weights reflecting the relative frequency of these periods. In particular, as entry occurs every time a new entrant is born in case of recurrent predation, and at most once in case of accommodation, a ban is more likely to be desirable when the entry cost k is large.

Proposition 3 is consistent with Cabral and Riordan (1997), who also show that a ban on predation may not be desirable.[38]. An important difference is that in their model, the incumbent's output expansion during the predatory phase lowers its cost due to a learning curve effect. As a result, consumers may benefit from predation even once the prey has exited. By contrast, in our model consumers benefit from predation only during the predatory phase.

Proposition 3 is also related to Atad and Yehezkel (2024). They consider an infinite-horizon model of platform competition between an incumbent platform and an entrant and examine the welfare effects of a ban on negative prices, which they interpret as predatory. They show that the ban decreases consumer surplus when imposed on both platforms, but raises consumers surplus when imposed only on the incumbent platform.[39]

[38] This is also indicated by Besanko *et al.* (2014)

[39] Proposition 3 is also related to the debate on "resale-below-cost" (RBC). See OECD (2007) for an overview of this debate, and Chen and Rey (2012, 2019) for analyses of the impact of RBC laws on competition and welfare.

4.2 Curbing the Response to Entry

In this section we consider a legal rule proposed by Williamson (1977) and Edlin (2002) to identify and mitigate predatory behavior. Unlike that of Areeda and Turner, this rule is not cost-based; rather, it is intended to limit temporarily the incumbent's ability to aggressively react to entry. Specifically, Williamson (1977) proposed an "output restriction rule" stipulating that "the dominant firm cannot increase output above the pre-entry level" for a period of $12 - 18$ months. Edlin (2002) proposed a closely related rule requiring that " if an entrant prices twenty percent below an incumbent monopoly, the incumbent's prices will be frozen for twelve to eighteen months," but added that "[T]he exact operationalization of the rule (twenty percent threshold and twelve to eighteen months duration) could vary by industry or be decided on a case-by-case basis." Although Edlin's proposal differs from that of Williamson in terms of specifics, in our parsimonious model the two are isomorphic.

To explore the implications of these proposals, we consider a *Williamson-Edlin* defined as follows: in the event of entry, I's strategy is " frozen" for T_{WE} periods. I and E thus obtain π_I^c and $\pi_E^c - \alpha k$ in the period of entry, and π_I^c and π_E^c in each of the ensuing freeze periods. Once the freeze is over, the state switches to $\mathcal{C}$, and I is free to predate if it wishes. In other words, the rule protects the entrant from predation for T_{WE} additional periods. Increasing T_{WE} progressively extends the entrant's protection from laissez-faire ($T_{WE} = 0$) to a complete ban on predation ($T_{WE} \to \infty$).

Under the Williamson-Edlin rule, a newborn entrant can secure a minimal discounted profit given by

$$(\pi_E^c - k) + \delta\pi_E^c + ... + \delta^{T_{WE}}\pi_E^c = \frac{\pi_E^c}{\psi\left(T_{WE}\right)} - k,$$

where

$$\psi\left(T\right) \equiv \frac{1-\delta}{1-\delta^{T+1}} \tag{4}$$

is strictly decreasing in T, from 1 for $T = 0$ to $1 - \delta$ for $T = \infty$. By expanding the duration of the hit-and-run phases, the Williamson-Edlin rule thus also enhances their profitability. Specifically, when $\pi_E^c \geq k$, entry is viable even without a freeze (i.e., for $T_{WE} = 0$). By contrast, if $\pi_E^c < k$, the minimal freeze duration that makes entry viable is positive and equal to

$$T_{WE}^M(\pi_E^c) \equiv \psi^{-1}(\frac{\pi_E^c}{k}).$$

Building on these observations leads to:

Proposition 4 (Williamson-Edlin rule) *The Williamson-Edlin rule affects the equilibrium outcome as follows:*

(i) If laissez-faire yields accommodation, the rule is irrelevant.

(ii) If laissez-faire yields recurrent predation, the rule modifies it by enabling E to stay in the market during the T_{WE} periods of the freeze before exiting.

(iii) If laissez-faire yields monopolization, the rule is ineffective unless $T_{WE} > T_{WE}^M(\pi_E^c)$, in which case it induces a switch to accommodation if $\lambda > \underline{\lambda}$, and to (modified) recurrent predation otherwise.

Proof. See Appendix B.4. ■

A first insight from Proposition 4 is that, as in the case of a ban on predation, the Williamson-Edlin rule is irrelevant when laissez-faire yields accommodation. Indeed, the rule has no bite on the equilibrium path as I never predates anyway, and it has no bite either on the continuation equilibrium path that follows a one-period deviation to predation by I in state $\mathcal{C}$. Hence, the rule does not affect the sustainability of accommodation, which remains self-sustainable whenever entry is sufficiently profitable for E (i.e., $\pi_E^c \geq \hat{\pi}_E^c$), and remains otherwise sustainable whenever predation is too costly for I (i.e., $\lambda \geq \underline{\lambda}$).

The Williamson-Edlin rule however increases the duration and profitability of hit-and-run phases for the entrant, which encourages entry and reduces the scope for monopolization.[40] Specifically, hit-and-run entry becomes viable for a larger range of parameters, namely, whenever $\pi_E^c \geq \psi(T_{WE}^M)k$. A long enough freeze induces E to enter even if it expects I to predate at the end of the freeze. Hence the equilibrium switches from monopolization to recurrent predation if inducing exit remains profitable (i.e., if $\lambda < \underline{\lambda}$), and to accommodation otherwise. In addition, by extending the length of the hit-and-run entry phases, the rule increases the frequency of the periods of competition. In particular, as $T_{WE} \to \infty$, the first newborn E enters and competes forever, and the rule thus *de facto* replicates a ban on predation.

By contrast, the rule does not affect I's incentive to predate. This is obvious in the case of monopolization: as I expects no future entry regardless of the rule, it is willing to predate whenever $\lambda \leq \overline{\lambda}$, as before. But this is also true in the face of recurrent entry, where I remains willing to predate whenever $\lambda \leq \underline{\lambda}$. This is because, in the limit case where predation is barely sustainable, the monopolization

[40] In a model in which I can choose between more than two actions, the rule may also induce I to choose a more competitive action in state $\mathcal{M}$ in order to be in a better competitive position following entry.

benefit is the same as in an accommodation equilibrium, where it is unaffected by the rule.

We illustrate these findings in Figure 3a below. The Williamson-Edlin rule leaves unchanged the horizontal boundaries below which the predatory equilibria exist (i.e., $\lambda = \overline{\lambda}$ for monopolization and $\lambda = \underline{\lambda}$ for recurrent predation), as well as the vertical boundary beyond which accommodation is self-sustainable (i.e., $\pi_E^c = \hat{\pi}_E^c$). By contrast, the rule shifts inward the vertical boundary beyond which hit-and-run entry is viable, which becomes $\pi_E^c = \psi(T_{WE})k$, with $\psi(T_{WE})k$ decreasing from k when $T_{WE} = 0$ to $(1-\delta)\,k$ as $T_{WE} \to \infty$. Thus the region where monopolization can arise shrinks, and disappears altogether as $T \to \infty$. Specifically, if monopolization arises under laissez-faire, it is progressively replaced by accommodation when $\lambda \in \left(\underline{\lambda}, \overline{\lambda}\right]$, and by recurrent predation when $\lambda \leq \underline{\lambda}$. In both cases welfare is enhanced, as it is lowest under monopolization.

4.3 Curbing the Response to Exit

Baumol (1979) proposed a legal rule intended to curb the incumbent's response to exit rather than to entry. The idea is to reduce the scope for recoupment, by forbidding the incumbent to increase its price or restrict its output once the prey exits. Although Baumol advocated a " quasi-permanent" constraint,[41] we allow for more flexibility and consider the following rule: if E exits, then I's strategy is frozen for T_B periods. As T_B increases, the rule becomes stricter, from laissez-faire (for $T_B = 0$) to Baumol's original proposal (for $T_B \to \infty$). As we shall see, although this rule does not formally nest a complete ban on predation as a special case, recoupment becomes impossible when $T_B \to \infty$, and thus I never predates in equilibrium; hence, the outcome is equivalent to that of a complete ban.

Extending the freeze increases I's cost of predation both by expanding the phase of aggressive action during which its profit is low, and by postponing the benefit of monopoly, i.e., the recoupment phase. We show in Appendix B.5 that, as a result, the cost-to-benefit ratio λ is multiplied by $1/\phi\,(T_B)$, where

$$\phi\,(T) \equiv \delta^T \frac{1-\delta}{1-\delta^{T+1}} \left(= \delta^T \psi\,(T)\right)$$

is strictly decreasing in T, from 1 for $T = 0$ to 0 for $T = \infty$. Hence, as T_B increases, predation is less likely to be profitable. Specifically, monopolization is no longer profitable when $T_B > T_B^M(\lambda)$ in case of monopolization and $T_B > T_B^P(\lambda)$

[41] Baumol explains his proposal as follows: "Under such an arrangement, the established firm would be put on notice that its decision to offer service at a low price is tantamount to a declaration that this price is compensatory, and thus, that it can be expected, in the absence of exogenous changes in costs or demands, to offer the service at this price for the indefinite future."

otherwise, where

$$T_B^P(\lambda) \equiv \phi^{-1}(\frac{\lambda}{\underline{\lambda}}) \qquad \text{and} \qquad T_B^M(\lambda) \equiv \phi^{-1}(\frac{\lambda}{\overline{\lambda}}).$$

Building on these observations leads to:

Proposition 5 (Baumol rule) *The Baumol rule affects the equilibrium outcome as follows:*

(i) If laissez-faire yields accommodation, the rule is irrelevant.

(ii) If laissez-faire yields recurrent predation, the rule induces a switch to accommodation if $T_B > T_B^P(\lambda)$, otherwise it only modifies the equilibrium by forcing I to predate for T_B additional periods in case of exit.

(iii) If laissez-faire yields monopolization, the rule induces a switch to accommodation if $T_B > T_B^M(\lambda)$, otherwise it is ineffective.

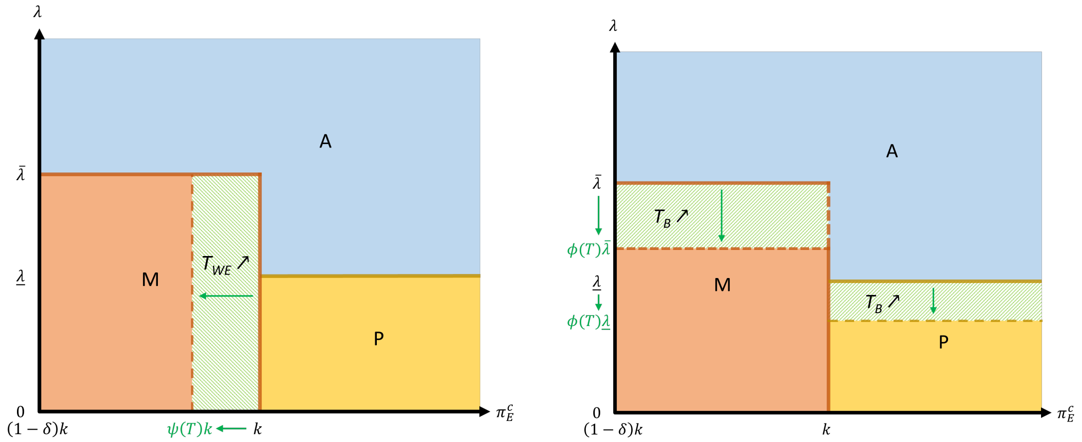
Proof. See Appendix B.5. ■

As the previous rules, the Baumol rule is again irrelevant when laissez-faire yields accommodation. Furthermore, following a deviation to predation by I in state $\mathcal{C}$, the rule either has no bite (if E stays), or it reduces the benefit of the deviation (if E exits), by forcing I to remain aggressive for T_B additional periods. Hence, accommodation remains self-sustainable whenever entry is sufficiently profitable (i.e., $\pi_E^c \geq \hat{\pi}_E^c$).

Extending the freeze under the Baumol rule discourages predation and can induce a switch to accommodation. Specifically, the rule induces a switch away from monopolization when $T_B > T_B^M(\lambda)$ and away from recurrent predation when $T_B > T_B^P(\lambda)$. Relatedly, however, when the recurrent predation equilibrium survives, the rule still affects welfare by the frequency of the predation periods.

By contrast, the Baumol rule does not affect the type of predatory equilibria that may arise. This is because the rule has no impact on the profitability of hit-and-run entry in either predatory equilibrium, as E expects immediate predation in state $\mathcal{C}$ anyway. This is in contrast to the Williamson-Edlin rule which, by extending the duration of hit-and-run entry phases, can induce a switch from monopolization to recurrent predation.

We illustrate these findings in Figure 3b below. Introducing the Baumol rule shifts down by a factor of $\phi(T_B)$ (≤ 1) the horizontal boundary $\lambda = \overline{\lambda}$ below which monopolization is profitable, and the horizontal boundary $\lambda = \underline{\lambda}$ below which recurrent predation is profitable. As a result, the equilibrium may switch from predation (namely, monopolization when $\pi_E^c < k$ and recurrent predation otherwise) to accommodation, as depicted by the horizontal dashed lines. In particular, as $T_B \to \infty$, $\phi(T_B) \to 0$ and accommodation becomes the unique equilibrium for all values of λ.



(a) Williamson-Edlin (b) Baumol

Figure 3: Impact of the Williamson-Edlin and Baumol rules
***A:** Accommodation; **P:** Predation; **M:** Monopolization*

4.4 Policy choice

Both the Williamson-Edlin and Baumol rules include laissez-faire as a special case (namely, $T_{WE} = T_B = 0$). Conversely, long enough freezes can *de facto* replicate a ban on predation. Specifically, if laissez-faire yields monopolization, a ban can be implemented with any $T_{WE} > T_{WE}^M(\pi_E^c)$ or $T_B > T_B^M(\lambda)$. If instead laissez-faire yields recurrent predation, a ban can be implemented with any $T_B > T_B^P(\lambda)$. Under the Williamson-Edlin rule, recurrent predation survives but, as $T_{WE} \to \infty$, the frequency of predatory episodes goes to 0, *de facto* replicating the effect of a ban.

We now consider a generalized freeze rule that includes the Williamson-Edlin and Baumol rules as special cases. By that rule, I's strategy is " frozen" for T_{WE} periods in the event of entry in state $\mathcal{M}$, and for T_B periods in the event of exit in state $\mathcal{C}$.

As expected welfare is lowest under monopolization, the relevant comparison is between accommodation (which may sometimes be achieved under laissez-faire, and always implementable by long enough freezes), and recurrent predation. In the former case, expected welfare is W^A, given by (1); in the latter case, we show in Appendix B.6 that it is given by (with the subscript F referring to the *freeze* rule):

$$W_F^P(T_{WE}, T_B) \equiv W^A + \frac{(1-\beta)(w^m - w^c) + \beta[(T_B + 1)(w^p - w^c) - \alpha k]}{[1 + \beta(1 + T_{WE} + T_B)](1-\delta)}. \qquad (5)$$

As $w^m < w^c$, recurrent predation can be socially desirable only if $w^p > w^c$. Its social value is then increasing in T_B and exceeds W^A if T_B is large enough, namely:

$$T_B > T_B^W \equiv \frac{(1-\beta)(w^c - w^m) - \beta(w^p - w^c - \alpha k)}{\beta(w^p - w^c)}. \tag{6}$$

Obviously, if recurrent predation is already desirable under laissez-faire (i.e., $W^P \geq W^A$), introducing a post-entry freeze $T_B > 0$ makes it further desirable – indeed, it follows from (3) and (6) that T_B^W is then negative; otherwise, a long enough post-exit freeze is warranted. By contrast, introducing a post-entry freeze $T_{WE} > 0$ cannot make recurrent predation socially desirable when it is not already so, and actually decreases welfare when recurrent predation is socially desirable.

Building on this and ignoring integer issues in the specification of freezes leads to the following:[42]

Proposition 6 (policy choice) *The optimal freeze policy is as follows:*

(i) If $w^c < w^p$, $\lambda \leq \underline{\lambda}$ and $T_B^P(\lambda) > T_B^W$, recurrent predation is socially desirable; the optimal freezes are then:

$$T_B = T_B^P(\lambda) \quad \textit{and} \quad T_{WE} = \begin{cases} 0 & \textit{if} \quad \pi_E^c > k, \\ T_{WE}^M(\pi_E^c)^+ & \textit{if} \quad \pi_E^c \leq k \end{cases}$$

(ii) Otherwise, a ban on predation (e.g., $T_{WE} = +\infty$ and/or $T_B = +\infty$) is socially optimal whenever relevant.

Proof. See Appendix B.6. ■

Both types of freezes can be used to *de facto* replicate a ban. Yet, their impact is different, and to some extent independent. A long enough post-entry freeze T_{WE} eventually allows E to profitably enter even if $\pi_E^c < k$, but has no impact on the profitability of predation for I. By contrast, a post-exit freeze T_B has no impact on E's decision to enter or to exit, but decreases the thresholds $\overline{\lambda}$, determining the boundary of the profitability of monopolization for I, and $\underline{\lambda}$, determining that of recurrent predation.[43] Together with Propositions 4 and 5, this implies in particular that any freeze policy is irrelevant when laissez-faire yields accommodation.

When $w^c \geq w^p$, accommodation is socially desirable – a ban is therefore optimal. When instead $w^p > w^c$, recurrent predation is socially desirable when the post-exit freeze T_B is long enough, namely, longer than T_B^W. Recurrent predation is profitable

[42]The notation T^+ stands for the "right-sided limit" of T.

[43]Both freezes reduce I's profit, however.

for I only if $\lambda \leq \underline{\lambda}$, however, in which case it remains profitable as long as the post-exit freeze is short enough, namely, $T_B \leq T_B^P(\lambda)$. Furthermore, if $\pi_E^c < k$, then the post-entry freeze must be long enough to encourage entry, namely, $T_{WE} > T_{WE}^M(\pi_E^c)$. As welfare $W_F^P(T_{WE}, T_B)$ is increasing in T_B for $T_B > T_B^W$ but decreasing in T_{WE}, the best policy for recurrent predation is to set T_B equal to $T_B^P(\lambda)$ and T_{WE} slightly above $T_{WE}^M(\pi_E^c)$, and that policy dominates a ban if and only if $T_B > T_B^P(\lambda)$.

Proposition 6 also shows that, other than to replicate a ban, the Williamson-Edlin rule is used only to ensure the profitability of entry, and only when recurrent predation generates higher welfare than accommodation. Furthermore, its use is always accompanied by the use of the Baumol rule. By contrast, the Baumol rule may have stand-alone value other than to replicate a ban. This can be the case in two situations. In the first, predation already arises under laissez-faire and is socially desirable (i.e., $W^P > W^A$). It is then optimal to extend the phase of aggressive play by the incumbent, subject to the constraint that predation remains profitable. In the second situation, predation is undesirable under laissez-faire (i.e., $W^P < W^A$), but becomes desirable *only* once to a long enough post-exit freeze is imposed.[44]

Edlin et al. (2019) assess the implications of legal rules for predatory behavior, by running a series of lab experiments in which an incumbent and an entrant interact over four periods – the incumbent is alone in the first period, but a competitor can enter the market and stay in the following periods. Specifically, they consider a ban on below-cost pricing, a Baumol rule forbidding the incumbent to raise its prices if the entrant exits, and an Edlin rule that allows the incumbent to lower its price by at most 20% in case of entry. In their setting, the entrant has a higher cost than the incumbent, so above-cost predation is feasible. They find that, as expected, a ban of below-cost pricing has little effect on market outcomes. By contrast, the Baumol and Edlin rules encourage entry, as in our model. Compared with laissez-faire, the Baumol rule induces incumbents to set higher prices in case of entry, whereas the Edlin rule induces them to set lower pre-entry prices, in order to retain their ability to compete effectively if entry occurs, albeit post-entry prices are higher than under laissez-faire.[45] These effects are not present in our parsimonious model, in which the incumbent cannot strategically tailor its price before or post-entry. Interestingly, Edlin *et al.* find that with this additional degree of freedom, the Edlin rule fosters entry more than the Baumol rule, and also generates highest consumer surplus

[44] This happens when $T_B^W \in (0, T_B^P(\lambda))$, in which case predation becomes desirable only for $T_B \in (T_B^W, T_B^P]$.

[45] Gilo and Spiegel (2018) consider excessive price regulation, where a low post-entry price may indicate that the incumbent was charging an excessive pre-entry price, in which case the incumbent pays a fine. They show that, similarly to the Williamson-Edlin rule, such regulation induces the incumbent to lower its pre-entry price.

(when a ban is included in the policy maker's choice set), with the Baumol rule being a close second. By contrast, overall welfare is lowest under the Edlin rule, and is similar under a ban on below-cost pricing and under the Baumol rule to that under laissez-faire.[46]

5 Conclusion

Following recent concerns about increasing concentration, raising markups, and the increasing power of big tech giants, there have been calls to reform antitrust laws, and in particular to have a more effective treatment of predation. Using a perfect information, infinite-horizon setting with persistent threat of entry, we show that the scope for predation depends not only on variables such as costs and revenues, or the probability of potential entry in the future, but also on mutual expectations about the rival's behavior.

Our analysis highlights the importance of adopting appropriate recoupment tests, properly accounting for dynamic considerations and, in particular, for the likelihood of *actual* entry in the future – which, in turn, depends on incumbents' reaction as expected by the entrant. Moreover, it highlights that predation does not hinge on whether the incumbent's profit is positive or negative. Thus the price-average cost comparisons that play a key role in antitrust policy in U.S. and EU may be misguided.

We use our framework to study the optimal design of "dynamic" legal rules, by which freezes are imposed on the incumbent's strategy following a rival's entry and/or exit. The informational requirements associated with their enforcement are minimal: it suffices to specify the period of time during which the incumbent is prevented from reacting to drastic changes in the competitive environment such as entry or exit. Finally, while the commonly discussed policy to ban predation does not account for the possibility that recurrent predation may be welfare improving, a suitable combination of these rules can allow and even bolster such an improvement.

[46]Welfare is lowest under the Edlin rule because entry leads to duplication of fixed costs and implies that some output is supplied by the higher-cost entrant.

Appendix

A Example: Stackelberg duopoly

To illustrate the assumed payoff structure, consider the following linear Stackelberg duopoly. I and E produce a homogeneous product and compete by setting quantities. The inverse demand function is $p = 1 - Q$, where $Q = q_I + q_E$ denotes the aggregate output. Both marginal costs are normalized to 0 and the fixed costs are $f_I < 1/8$ and $f_E < 1/16$.

In state $\mathcal{M}$, given I's output q_I, E's output, q_E, is given by the Cournot best-response:

$$R(q_I) \equiv \arg\max_{q_E} \{(1 - q_I - q_E) q_E - f_E\} = \frac{1 - q_I}{2}.$$

If in equilibrium a newborn E enters with probability $\eta \in [0, 1]$, the overall probability of entry is $\beta\eta$ and the resulting expected profit for I is

$$\beta\eta(1 - q_I - \frac{1 - q_I}{2})q_I + (1 - \beta\eta)(1 - q_I) q_I - f_I = \left(1 - \frac{\beta\eta}{2}\right)(1 - q_I) q_I - f_I.$$

This payoff is maximal at $q_I = q^m = 1/2$, regardless of the probability of entry.[47] If E does not enter, I earns the monopoly profit

$$\pi_I^m = \frac{1}{4} - f_I.$$

If E enters, it incurs an entry cost k and produces $q_E = R\left(q^l\right) = 1/4$; the resulting profits for I and E are then

$$\pi_I^c = \frac{1}{8} - f_I,$$

and $\pi_E^c - k$, where

$$\pi_E^c = \frac{1}{16} - f_E.$$

In state $\mathcal{C}$, if I accommodates entry, the Stackelberg equilibrium yields again the output levels $q_I = 1/2$ and $q_E = 1/4$. The resulting profits of I and E are thus given by π_I^c and π_E^c. Alternatively, I can predate by expanding its output to such an extent that E incurs a loss if it stays in the market. As our stylized model relies on a binary decision, to fix ideas suppose that I can only choose between using its existing plants with total output q^m, or activating an additional plant, thereby

[47] This comes from the fact that, in this linear model, the monopoly quantity coincides with the quantity chosen by a Stackelberg leader.

expanding its total output to some $q_I^p \in \left(\underline{q}_I^p\left(f_E\right), 1\right)$, where[48]

$$\underline{q}_I^p\left(f_E\right) \equiv \max\left\{1 - 2\sqrt{f_E}, \frac{1}{2} + \frac{\sqrt{2}}{4}\right\} \left(> q_I^m\right).$$

The condition $q_I^p < 1$ ensures that E's response is positive: $q_E^p = R\left(q_I^p\right) > 0$. If E stays, its profit is therefore

$$\pi_E^p = \left(\frac{1 - q_I^p}{2}\right)^2 - f_E < 0,$$

where the inequality follows from the condition $q_I^p > 1 - 2\sqrt{f_E}$. If E exits, I's profit is

$$\pi_I^p = \left(1 - q_I^p\right) q_I^p - f_I < \pi_I^c \left(< \pi_I^m\right),$$

where the first inequality follows from the condition $q_I^p > 1/2 + \sqrt{2}/4$. If instead E stays, I's profit is

$$\underline{\pi}_I^p = \left(1 - q_I^p - q_E^p\right) q_I^p - f_I < \pi_I^p,$$

where the inequality stems from $q_E^p = R\left(q_I^p\right) > 0$.

Per-period consumer surplus is $Q^2/2$, where Q denotes total output. Hence, consumer surplus under monopoly, competition and (successful) predation is thus given by:

$$CS^m = \frac{1}{8}, \qquad CS^c = \frac{9}{32}, \qquad CS^p = \frac{\left(q_I^p\right)^2}{2}.$$

In line with the spirit of our stylized model, let us assume that the welfare criterion W is of the form $W \equiv CS + \alpha\Pi$, where $\alpha \in [0,1]$ denotes the weight placed on the industry profit $\Pi \equiv \pi_I + \pi_E$. In state $\mathcal{C}$, per-period welfare is therefore given by:

$$w^m = CS^m + \alpha\pi_I^m = \frac{1 + 2\alpha}{8} - \alpha f_I,$$

$$w^c = CS^c + \alpha\left(\pi_I^c + \pi_E^c\right) = \frac{9 + 6\alpha}{32} - \alpha\left(f_I + f_E\right),$$

and

$$w^p = CS^p + \alpha\pi_I^p = \left(\frac{1}{2} - \alpha\right)\left(q_I^p\right)^2 + \alpha q_I^p - \alpha f_I.$$

The expressions for state $\mathcal{M}$ are similar, except that when entry occurs, welfare is $w^c - \alpha k$ rather than w^c.

By construction, welfare under predation coincides with that under monopoly

[48] The lower bound $\underline{q}_I^p\left(f_E\right)$ is decreasing in f_E and ranges from $1/2 + \sqrt{2}/4 \simeq 0.85$ (for $\left(3 - 2\sqrt{2}\right)/32 \simeq 0.005 \leq f_E < 1/16 = 0.0625$) to 1 (for $f_E = 0$).

for $q_I^p = q^m$:

$$w^p|_{q_I^p=q^m} = \frac{1+2\alpha}{8} - \alpha f_I = w^m.$$

Moreover, it increases with output:

$$\frac{\partial w^p}{\partial q_I^p} = q_I^p - 2\alpha\left(q_I^p - \frac{1}{2}\right) > 1 - q_I^p > 0,$$

where the first inequality stems from $\alpha \leq 1$ and the second from $q_I^p < 1$. It follows that welfare is higher under predation than under monopoly:

$$w^p > w^m. \tag{7}$$

As the assumption $f_E < 1/16$ ensures that $\pi_E^c > 0$, we have:

$$w^c - w^m = CS^c + \alpha\left(\pi_I^c + \pi_E^c\right) - w^m > CS^c + \alpha\pi_I^c - w^m = \frac{5-4a}{32} > 0, \tag{8}$$

where the last inequality stems from $\alpha < 1$. If in addition hit-and-run entry is profitable ($\pi_E^c \geq k$), then the same reasoning implies that it is socially desirable; indeed, we then have:

$$\frac{w^c + w^p - \alpha k}{2} - w^m \geq \frac{CS^c + \alpha\pi_I^c - w^m}{2} > 0,$$

where the first inequality stems from (7) and the working assumption $\pi_E^c \geq k$, and the second one from (8).

Summing-up, this linear Stackelberg duopoly model provides a micro-foundation for the profit and welfare values used in our stylized setting. Specifically, for any $(f_I, f_E) \in [0, 1/8) \times (0, 1/16)$ and any $q_I^p \in \left(\underline{q}_I^p(f_E), 1\right)$, the equilibrium profits satisfy the assumptions $\pi_I^m > \pi_I^c > \pi_I^p\,(> \underline{\pi}_I^p)$, $\min\{\pi_I^c, \pi_E^c\} > 0 > \pi_E^p$ and $w^m < \min\{w^c, w^p\}$. The two variables of interest used in Figures 1-3 (E's competitive profit, π_E, and the cost-benefit ratio, λ) are respectively driven by f_E and q_I^p:[49]

$$\pi_E^c = \frac{1}{16} - f_E \text{ and } \lambda = 1 - 8q_I^p\left(1 - q_I^p\right).$$

It follows that, through appropriate choices of $f_E \in (0, 1/16)$ and $q_I^p \in \left(\underline{q}_I^p(f_E), 1\right)$, π_E^c can take any value in $(0, 1/16)$ and λ can take any value in $\left(\hat{\lambda}(f_E), 1\right)$, where $\hat{\lambda}(f_E) \equiv \max\{1 - 16\sqrt{f_E}(1 - 2\sqrt{f_E}), 0\}$.[50]

[49] π_E^c is clearly strictly decreasing in f_E, whereas λ is strictly increasing in q_I^p in the relevant range $q_I^p > \underline{q}_I^p$: $d\lambda/dq_I^p = 16q_I^p - 8 > 0$, where the inequality stems from $q_I^p > \left(\underline{q}_I^p \geq q^m =\right) 1/2$.

[50] The lower bound $\hat{\lambda}(f_E)$ is decreasing in f_E for $f_E < 1/16$ and ranges from 0 (for $f_E \geq \left(3 - 2\sqrt{2}\right)/32$) to 1 (for $f_E = 0$).

This micro-foundation is sufficiently flexible to allow for arbitrary positions of the key boundaries determining the existence of the different types of equilibria. Regarding the horizontal boundaries, an appropriate choice of $\delta \in (0,1)$ can yield any positive value for $\overline{\lambda}(= \delta/(1-\delta))$ and, for any given $\overline{\lambda}$ and associated δ, an appropriate choice of $\beta \in (0,1)$ can generate any value for $\underline{\lambda}\,(= (1-\beta)\,\delta/[1-(1-\beta)\,\delta])$ between 0 and $\overline{\lambda}$. As for the vertical boundaries, any k between 0 and $\pi_E^c/(1-\delta)\,(> \pi_E^c)$ is admissible – k can thus lie either below or above π_E^c, implying that either type of predatory equilibrium can arise. Finally, we can either have $\pi_I^p > 0$ (for f_I small enough, for any given $q_I^p \in (\underline{q}_I^p, 1)$) or $\pi_I^p < 0$ (if q_I^p is large enough, for any $f_I > 0$);[51] hence, I's predatory price can either be above or below average cost.[52]

B Proofs

B.1 Proof of Proposition 1

We consider the three types of equilibria in turn.

B.1.1 Accommodation

Consider a candidate equilibrium in which I never predates. E then enters in state $\mathcal{M}$, as $\pi_E^c > (1-\delta)\,k$, and stays in the market in state $\mathcal{C}$, as $\pi_E^c > 0$. Therefore, I's equilibrium continuation values in states $\mathcal{M}$ and $\mathcal{C}$, $V_{\mathcal{M}}^A$ and $V_{\mathcal{C}}^A$, satisfy:

$$V_{\mathcal{M}}^A = (1-\beta)\left(\pi_I^m + \delta V_{\mathcal{M}}^A\right) + \beta\left(\pi_I^c + \delta V_{\mathcal{C}}^A\right) \quad \text{and} \quad V_{\mathcal{C}}^A = \pi_I^c + \delta V_{\mathcal{C}}^A,$$

which leads to:

$$V_{\mathcal{M}}^A = \frac{\beta \pi_I^c + (1-\beta)(1-\delta)\,\pi_I^m}{[1-(1-\beta)\,\delta]\,(1-\delta)} \quad \text{and} \quad V_{\mathcal{C}}^A = \frac{\pi_I^c}{1-\delta}. \tag{9}$$

To complete the characterization, it suffices to check that I has no incentive to deviate to predation in state $\mathcal{C}$. Following such a deviation, if E stays it obtains a profit of π_E^p in the current period and, anticipating accommodation in the future, it expects a profit of π_E^c in every following period. Hence, E's expected continuation value from staying is given by

$$\pi_E^p + \frac{\delta \pi_E^c}{1-\delta}.$$

[51]For example, if $f_I = 0$, then $\pi_I^P > 0$ for any $q_I^p < 1$; if instead $q_I^p = 1$, then $\pi_I^P < 0$ for any $f_I > 0$.

[52]In this simple example, in which predation takes the form of costless output expansion, predation is socially beneficial whenever it is costly for I (i.e., $\pi_I^p < \pi_I^c$ and $w^p > w^c$). Introducing an additional fixed cost f_I^p of expanding output from q_I^m to q_I^p would allow for $\pi_I^p < \pi_I^c$ and $w^p < w^c$ (proofs available upon request).

It follows that, if $\pi_E^c \geq \hat{\pi}_E^c$, the deviation does not induce E to exit and is therefore unprofitable for I, as $\pi_I^c > \underline{\pi}_I^p$. In other words, accommodation is self-sustainable in that case.

If instead $\pi_E^c < \hat{\pi}_E^c$, I's deviation to predation does induce E to exit. Using (9), the effect of the deviation on I's payoff is given by:

$$\underbrace{\left(\pi_I^p + \delta V_{\mathcal{M}}^A\right)}_{\text{Value following deviation}} - \underbrace{\left(\pi_I^c + \delta V_{\mathcal{C}}^A\right)}_{\text{Value on the equilibrium path}} = \pi_I^p - \pi_I^c + \frac{(1-\beta)\,\delta\,(\pi_I^m - \pi_I^c)}{1-(1-\beta)\,\delta}$$
$$= (\pi_I^m - \pi_I^c)\,(\underline{\lambda} - \lambda)\,,$$

where the last equality stems from the definitions of λ and $\underline{\lambda}$. As $\pi_I^m > \pi_I^c$, the deviation is unprofitable if and only if $\lambda \geq \underline{\lambda}$.

B.1.2 Predation

Now consider a candidate equilibrium in which I predates in state $\mathcal{C}$. E then exits in state $\mathcal{C}$, as $\pi_E^p < 0$, but a newborn E enters (for one period) in state $\mathcal{M}$ as long as $\pi_E^c \geq k$. I's continuation values, $V_{\mathcal{M}}^P$ and $V_{\mathcal{C}}^P$, therefore satisfy:

$$V_{\mathcal{M}}^P = (1-\beta)\left(\pi_I^m + \delta V_{\mathcal{M}}^P\right) + \beta\left(\pi_I^c + \delta V_{\mathcal{C}}^P\right) \quad \text{and} \quad V_{\mathcal{C}}^P = \pi_I^p + \delta V_{\mathcal{M}}^P.$$

Solving yields:

$$V_{\mathcal{M}}^P = \frac{(1-\beta)\,\pi_I^m + \beta\,(\pi_I^c + \delta\pi_I^p)}{(1+\beta\delta)\,(1-\delta)} \quad \text{and} \quad V_{\mathcal{C}}^P = \frac{(1-\beta)\,\delta\pi_I^m + \beta\delta\pi_I^c + [1-(1-\beta)\delta]\pi_I^p}{(1+\beta\delta)\,(1-\delta)}. \tag{10}$$

To check that this is indeed an equilibrium, consider a one-period deviation of I to accommodation in state $\mathcal{C}$. As $\pi_E^c > 0$, E stays in the market during the deviation period, but exits next period when I reverts to predation, as $\pi_E^p < 0$. Using (10), the effect of the deviation on I's payoff is:

$$\underbrace{\left(\pi_I^c + \delta V_{\mathcal{C}}^P\right)}_{\text{Value following deviation}} - \underbrace{\left(\pi_I^p + \delta V_{\mathcal{M}}^P\right)}_{\text{Value on the equilibrium path}} = \pi_I^c - \pi_I^p - \frac{\delta\left[(1-\beta)\,(\pi_I^m - \pi_I^c) + \pi_I^c - \pi_I^p\right]}{1+\beta\delta}$$
$$= \frac{[1-(1-\beta)\delta](\pi_I^m - \pi_I^c)}{1+\beta\delta}\,(\lambda - \underline{\lambda})\,.$$

The deviation is therefore unprofitable if and only if $\lambda \leq \underline{\lambda}$.

B.1.3 Monopolization

Finally, consider a candidate equilibrium in which I predates in state $\mathcal{C}$, and newborn E's do not enter in state $\mathcal{M}$, which requires that $\pi_E^c \leq k$. I's continuation values, $V_{\mathcal{M}}^{M}$ and $V_{\mathcal{C}}^{M}$, then satisfy:

$$V_{\mathcal{M}}^{M}=\pi_{I}^{m}+\delta V_{\mathcal{M}}^{M} \quad \text{and} \quad V_{\mathcal{C}}^{M}=\pi_{I}^{p}+\delta V_{\mathcal{M}}^{M}.$$

Solving yields:

$$V_{\mathcal{M}}^{M}=\frac{\pi_{I}^{m}}{1-\delta} \quad \text{and} \quad V_{\mathcal{C}}^{M}=\pi_{I}^{p}+\frac{\delta\pi_{I}^{m}}{1-\delta}. \tag{11}$$

Using these expressions, the net effect of a one-period deviation to accommodation in state $\mathcal{C}$ on I's payoff is:

$$\underbrace{\left(\pi_{I}^{c}+\delta V_{\mathcal{C}}^{M}\right)}_{\text{Value following deviation}}-\underbrace{\left(\pi_{I}^{p}+\delta V_{\mathcal{M}}^{M}\right)}_{\text{Value on the equilibrium path}}=\pi_{I}^{c}-\pi_{I}^{p}-\delta\left(\left(\pi_{I}^{m}-\pi_{I}^{c}\right)+\left(\pi_{I}^{c}-\pi_{I}^{p}\right)\right)$$
$$=\left(1-\delta\right)\left(\pi_{I}^{m}-\pi_{I}^{c}\right)\left(\lambda-\overline{\lambda}\right).$$

The deviation is therefore unprofitable if and only if $\lambda\leq\overline{\lambda}$.

B.2 Proof of Proposition 2

We show below that, whenever a predatory equilibrium coexists with the accommodation equilibrium, I obtains higher continuation values (in both states) in the predatory equilibrium. We first consider the case where predation is recurrent, before turning to the case where it leads to monopolization.

B.2.1 Predation vs. accommodation

First consider state $\mathcal{M}$. Using (9) and (10), we have:

$$\begin{aligned}V_{\mathcal{M}}^{P}-V_{\mathcal{M}}^{A}&=\frac{1}{1-\delta}\left[\frac{\left(1-\beta\right)\pi_{I}^{m}+\beta\left(\pi_{I}^{c}+\delta\pi_{I}^{p}\right)}{1+\beta\delta}-\frac{\beta\pi_{I}^{c}+\left(1-\beta\right)\left(1-\delta\right)\pi_{I}^{m}}{1-\left(1-\beta\right)\delta}\right]\\&=\frac{\beta\delta}{\left(1-\delta\right)\left(1+\beta\delta\right)}\frac{(1-\beta)\delta(\pi_{I}^{m}-\pi_{I}^{c})-[1-(1-\beta)\delta](\pi_{I}^{c}-\pi_{I}^{p})}{1-\left(1-\beta\right)\delta}\\&=\frac{\beta\delta\left(\pi_{I}^{m}-\pi_{I}^{c}\right)}{\left(1-\delta\right)\left(1+\beta\delta\right)}\left(\underline{\lambda}-\lambda\right)\geq0,\end{aligned}$$

where the inequality follows because a predation equilibrium exists only if $\lambda\leq\underline{\lambda}$.

Similarly, in state $\mathcal{C}$:

$$\begin{aligned}V_{\mathcal{C}}^{P}-V_{\mathcal{C}}^{A}&=\frac{1}{1-\delta}\left\{\frac{\left(1-\beta\right)\delta\pi_{I}^{m}+\beta\delta\pi_{I}^{c}+\left[1-\left(1-\beta\right)\delta\right]\pi_{I}^{p}}{1+\beta\delta}-\pi_{I}^{c}\right\}\\&=\frac{\left(1-\beta\right)\delta\left(\pi_{I}^{m}-\pi_{I}^{c}\right)-\left[1-\left(1-\beta\right)\delta\right]\left(\pi_{I}^{c}-\pi_{I}^{p}\right)}{\left(1-\delta\right)\left(1+\beta\delta\right)}\\&=\frac{\left[1-\left(1-\beta\right)\delta\right]\left(\pi_{I}^{m}-\pi_{I}^{c}\right)}{\left(1-\delta\right)\left(1+\beta\delta\right)}\left(\underline{\lambda}-\lambda\right)\geq0.\end{aligned}$$

Hence, in both states I prefers the recurrent predation equilibrium over the accommodation equilibrium whenever they coexist.

B.2.2 Monopolization vs. accommodation

Consider state $\mathcal{M}$. Using (9) and (11), and recalling that $\pi_I^m > \pi_I^c$, we have:

$$\begin{aligned} V_{\mathcal{M}}^M - V_{\mathcal{M}}^A &= \frac{1}{1-\delta}[\pi_I^m - \frac{\beta\pi_I^c + (1-\beta)(1-\delta)\pi_I^m}{1-(1-\beta)\delta}] \\ &= \frac{\beta(\pi_I^m - \pi_I^c)}{(1-\delta)[1-(1-\beta)\delta]} > 0. \end{aligned}$$

Similarly, in state $\mathcal{C}$:

$$\begin{aligned} V_{\mathcal{C}}^M - V_{\mathcal{C}}^A &= \frac{(1-\delta)\pi_I^p + \delta\pi_I^m - \pi_I^c}{1-\delta} \\ &= \frac{\delta(\pi_I^m - \pi_I^c) - (1-\delta)(\pi_I^c - \pi_I^p)}{1-\delta} \\ &= (\pi_I^m - \pi_I^c)\left(\overline{\lambda} - \lambda\right) \geq 0, \end{aligned}$$

where the inequality follows because a monopolization equilibrium exists only if $\lambda \leq \overline{\lambda}$.

Hence, in both states I prefers the monopolization equilibrium over the accommodation equilibrium whenever they coexist.

B.3 Proof of Proposition 3

By construction, a ban on predation has no effect when laissez-faire already yields accommodation (i.e., $\lambda > \overline{\lambda}$, or $\pi_E^c > k$ and $\lambda > \underline{\lambda}$). By contrast, a ban is always socially desirable when laissez-faire yields monopolization (i.e., $\lambda \leq \overline{\lambda}$ and $\pi_E^c \leq k$), as welfare is higher under competition than under monopoly (i.e., $w^c > w^m$).

Finally, when laissez-faire yields recurrent predation (i.e., $\lambda \leq \underline{\lambda}$ and $\pi_E^c > k$), a ban on predation changes total expected welfare from W^P to W^A. The conclusion then follows directly from (3).

B.4 Proof of Proposition 4

We first consider the three types of equilibria under the Williamson-Edlin rule, before drawing the implications for the impact of the rule.

B.4.1 Accommodation

In an accommodation equilibrium, I never predates in state $\mathcal{C}$. Hence, the Williamson-Edlin rule has no bite on the equilibrium path, and on any continuation equilibrium path that follows a one-period deviation by either firm. It has therefore no impact on E's incentives to enter, and no impact either on I's deviation incentives. Hence an accommodation equilibrium exists under the same condition as before.

B.4.2 Predation

Consider now a recurrent predation equilibrium. As before, when I predates in state $\mathcal{C}$, E exits as $\pi_E^p < 0$. For the equilibrium to exist, a newborn E must be willing to enter in state $\mathcal{M}$, which is the case if it covers its cost of entry during the entry period and the T_{WE} subsequent periods of freeze:

$$k \leq \left(1+\delta+...+\delta^{T_{WE}}\right)\pi_E^c = \frac{1-\delta^{T_{WE}+1}}{1-\delta}\pi_E^c \quad \Longleftrightarrow \quad \pi_E^c \geq \underbrace{\frac{1-\delta}{1-\delta^{T_{WE}+1}}}_{\psi(T_{WE})}k.$$

As $\psi\left(T\right)$ is strictly decreasing in T and tends to 0 as T goes to infinity, this inequality amounts to

$$T_{WE} \geq T_{WE}^M\left(\pi_E^c\right) \equiv \psi^{-1}\left(\frac{\pi_E^c}{k}\right).$$

As a newborn E enters and remains in the market during the T_{WE} periods of freeze, I's continuation values, $\hat{V}_{\mathcal{M}}^P$ and $\hat{V}_{\mathcal{C}}^P$, now satisfy:

$$\hat{V}_{\mathcal{M}}^P = (1-\beta)(\pi_I^m + \delta\hat{V}_{\mathcal{M}}^P) + \beta(\frac{1-\delta^{T_{WE}+1}}{1-\delta}\pi_I^c + \delta^{T_{WE}+1}\hat{V}_{\mathcal{C}}^P) \quad \text{and} \quad \hat{V}_{\mathcal{C}}^P = \pi_I^p + \delta\hat{V}_{\mathcal{M}}^P.$$

Solving yields:

$$\begin{aligned}
\hat{V}_{\mathcal{M}}^P &= \frac{(1-\beta)\pi_I^m + \beta\frac{1-\delta^{T_{WE}+1}}{1-\delta}\pi_I^c + \beta\delta^{T_{WE}+1}\pi_I^p}{1-\delta+\beta\delta(1-\delta^{T_{WE}+1})}, \\
\hat{V}_{\mathcal{C}}^P &= \frac{(1-\beta)\,\delta\pi_I^m + \beta\delta\frac{1-\delta^{T_{WE}+1}}{1-\delta}\pi_I^c + \left[1-(1-\beta)\,\delta\right]\pi_I^p}{1-\delta+\beta\delta(1-\delta^{T_{WE}+1})}.
\end{aligned}$$

To ensure that recurrent predation is an equilibrium, I's equilibrium payoff, $\pi_I^p + \delta\hat{V}_{\mathcal{M}}^P$, must exceed its corresponding payoff under a deviation to accommodation in state $\mathcal{C}$, $\pi_I^c + \delta\hat{V}_{\mathcal{C}}^P$, which amounts to:

$$\pi_I^c - \pi_I^p \leq \delta(\hat{V}_{\mathcal{M}}^P - \delta\hat{V}_{\mathcal{C}}^P) = \delta\frac{(1-\delta)(1-\beta)\left(\pi_I^m - \pi_I^c\right) + \left[1-\delta+\beta\delta(1-\beta\delta^{T_{WE}})\right]\left(\pi_I^c - \pi_I^p\right)}{1-\delta+\beta\delta(1-\delta^{T_{WE}+1})}.$$

Rearranging terms yields:

$$\lambda = \frac{\pi_I^c - \pi_I^p}{\pi_I^m - \pi_I^c} \leq \frac{(1-\beta)\delta}{1-(1-\beta)\delta} = \underline{\lambda}$$

as before. To see why, note that in the boundary case where I is indifferent between predating or not in state $\mathcal{C}$, the continuation values satisfy

$$\hat{V}_{\mathcal{C}}^P = \pi_I^c + \delta \hat{V}_{\mathcal{C}}^P = \frac{\pi_I^c}{1-\delta} \quad \text{and} \quad \hat{V}_{\mathcal{M}}^P = (1-\beta)(\pi_I^m + \delta \hat{V}_{\mathcal{M}}^P) + \beta \frac{\pi_I^c}{1-\delta}.$$

As T_{WE} affects none of these relations, it has also no impact on either the continuation values or the equilibrium conditions.

B.4.3 Monopolization

For a monopolization equilibrium to exist, a newborn E should not find it profitable to enter and stay in the market during the T_{WE} periods of freeze; hence, we must have $\pi_E^c \leq \psi(T_{WE})k$, or $T_{WE} \leq T_{WE}^M(\pi_E^c)$. As newborn E's do not enter, the Williamson-Edlin rule has no bite on the equilibrium path. Furthermore, following a one-period deviation to accommodation by I in state $\mathcal{C}$, the rule has again no bite on the continuation equilibrium path, as the deviation induces E to stay. Therefore, as before, the deviation is unprofitable if and only if $\lambda \leq \overline{\lambda}$.

B.5 Proof of Proposition 5

We first consider the various types of equilibria that arise under the Baumol rule, before drawing the implications for the impact of the rule.

B.5.1 Accommodation

In an accommodation equilibrium, I never predates and E thus never exits. Hence, the Baumol rule has no bite on the equilibrium path, and does not affect either E's incentive to enter (as E expects accommodation and thus plans to stay forever).

Suppose now that I deviates and predates in state $\mathcal{C}$. If E stays, the rule has again no bite and E thus expects accommodation in the future. It follows that E is willing to stay as long as $\pi_E^c \geq \hat{\pi}_E^c$, as before; in other words, the rule has no impact on the self-sustainability of accommodation.

If instead E exits, which always occurs when $\pi_E^c < \hat{\pi}_E^c$ and can also occur in the boundary case $\pi_E^c = \hat{\pi}_E^c$, the rule forces I to keep behaving aggressively for T_B periods. The net effect of the deviation on I's payoff is thus (using the fact that, along the equilibrium patch, the continuation values are $V^A_{\mathcal{M}}$ and $V^A_{\mathcal{C}}$, as before):

$$\underbrace{\left[\frac{(1-\delta^{T_B+1})\pi_I^p}{1-\delta}+\delta^{T_B+1}V^A_{\mathcal{M}}\right]}_{\text{Value following deviation}}-\underbrace{\left[\frac{(1-\delta^{T_B+1})\pi_I^c}{1-\delta}+\delta^{T_B+1}V^A_{\mathcal{C}}\right]}_{\text{Value on the equilibrium path}}$$
$$=\frac{(1-\beta)\delta^{T_B+1}(\pi_I^m-\pi_I^c)}{1-(1-\beta)\delta}-\frac{(1-\delta^{T_B+1})(\pi_I^c-\pi_I^p)}{1-\delta}$$
$$=\frac{(1-\delta^{T_B+1})(\pi_I^m-\pi_I^c)}{1-\delta}\left[\phi\left(T_B\right)\underline{\lambda}-\lambda\right],$$

where $\lambda=\frac{\pi_I^c-\pi_I^p}{\pi_I^m-\pi_I^c}$, $\underline{\lambda}=\frac{(1-\beta)\delta}{1-(1-\beta)\delta}$, and $\phi(T)=\delta^T\frac{1-\delta}{1-\delta^{T+1}}$ is lower than 1 and decreasing in T. Hence, the deviation is unprofitable, implying that the accommodation equilibrium survives if and only if $\lambda\geq\phi\left(T_B\right)\underline{\lambda}$; as $\phi(T)$ is decreasing in T, this amounts to

$$T_B\geq T_B^P\equiv\phi^{-1}(\frac{\lambda}{\underline{\lambda}}).$$

B.5.2 Predation

If in equilibrium I predates in state $\mathcal{C}$, then E exits, just as before. For recurrent predation to arise, a newborn E must be willing to enter the market for one period, which requires $\pi_E^c\geq k$. As the rule requires I to keep predating for T periods, I's continuation values, $\tilde{V}^P_{\mathcal{M}}$ and $\tilde{V}^P_{\mathcal{C}}$, are such that:

$$\tilde{V}^P_{\mathcal{M}}=(1-\beta)(\pi_I^m+\delta\tilde{V}^P_{\mathcal{M}})+\beta(\pi_I^c+\delta\tilde{V}^P_{\mathcal{C}})\quad\text{and}\quad\tilde{V}^P_{\mathcal{C}}=\frac{1-\delta^{T_B+1}}{1-\delta}\pi_I^p+\delta^{T_B+1}\tilde{V}^P_{\mathcal{M}}.$$

Solving yields:

$$\tilde{V}^P_{\mathcal{M}}=\frac{(1-\beta)(1-\delta)\pi_I^m+\beta(1-\delta)\pi_I^c+\beta\delta(1-\delta^{T_B+1})\pi_I^p}{[1-\delta+\beta\delta(1-\delta^{T_B+1})](1-\delta)},$$
$$\tilde{V}^P_{\mathcal{C}}=\frac{(1-\beta)(1-\delta)\delta^{T_B+1}\pi_I^m+\beta(1-\delta)\delta^{T_B+1}\pi_I^c+[1-(1-\beta)\delta](1-\delta^{T_B+1})\pi_I^p}{[1-\delta+\beta\delta(1-\delta^{T_B+1})](1-\delta)}.$$

Predation is an equilibrium if it is immune to I deviating for one period to accommodation in state $\mathcal{C}$. The effect of such a deviation on I's payoff is:

$$\underbrace{(\pi_I^c+\delta\tilde{V}^P_{\mathcal{C}})}_{\text{Value following deviation}}-\underbrace{\tilde{V}^P_{\mathcal{C}}}_{\text{Value on the equilibrium path}}$$
$$=\pi_I^c-\frac{\beta(1-\delta)\delta^{T_B+1}\pi_I^c}{1-\delta+\beta\delta(1-\delta^{T_B+1})}$$
$$-\frac{(1-\beta)(1-\delta)\delta^{T_B+1}\pi_I^m+[1-(1-\beta)\delta](1-\delta^{T_B+1})\pi_I^p}{1-\delta+\beta\delta(1-\delta^{T_B+1})}$$
$$=\frac{[1-(1-\beta)\delta](1-\delta^{T_B+1})\left(\pi_I^m-\pi_I^c\right)}{1-\delta+\beta\delta(1-\delta^{T_B+1})}$$

$$\times [\frac{\pi_I^c - \pi_I^p}{\pi_I^m - \pi_I^c} - \frac{(1-\delta)\delta^{T_B}}{1-\delta^{T_B+1}} \frac{(1-\beta)\delta}{1-(1-\beta)\delta}]$$
$$= \frac{[1-(1-\beta)\delta](1-\delta^{T_B+1})\left(\pi_I^m - \pi_I^c\right)}{1-\delta+\beta\delta(1-\delta^{T_B+1})} \left[\lambda - \phi\left(T_B\right)\underline{\lambda}\right].$$

Hence, the deviation is unprofitable if and only $\lambda \leq \phi\left(T_B\right)\underline{\lambda}$, which amounts to $T_B \leq T_B^P$.

B.5.3 Monopolization

For a monopolization equilibrium to exist, hit-and-run entry must be unprofitable: $\pi_E^c \leq k$. I's continuation values, $\tilde{V}_{\mathcal{M}}^M$ and $\tilde{V}_{\mathcal{C}}^M$, then satisfy:

$$\tilde{V}_{\mathcal{M}}^M = \pi_I^m + \delta \tilde{V}_{\mathcal{M}}^M \quad \text{and} \quad \tilde{V}_{\mathcal{C}}^M = \frac{1-\delta^{T_B+1}}{1-\delta}\pi_I^p + \delta^{T_B+1}\tilde{V}_{\mathcal{M}}^M.$$

Solving yields:

$$\tilde{V}_{\mathcal{M}}^M = \frac{\pi_I^m}{1-\delta} \quad \text{and} \quad \tilde{V}_{\mathcal{C}}^M = \frac{1-\delta^{T_B+1}}{1-\delta}\pi_I^p + \frac{\delta^{T_B+1}}{1-\delta}\pi_I^m.$$

By deviating to accommodation in state $\mathcal{C}$, I postpones predation by one period; the resulting effect on I's payoff is thus:

$$\underbrace{(\pi_I^c + \delta \tilde{V}_{\mathcal{C}}^M)}_{\text{Value following deviation}} - \underbrace{\tilde{V}_{\mathcal{C}}^M}_{\text{Value on the equilibrium path}} = \pi_I^c - (1-\delta)\left(\frac{1-\delta^{T_B+1}}{1-\delta}\pi_I^p + \frac{\delta^{T_B}+1}{1-\delta}\pi_I^m\right)$$
$$= (1-\delta^{T_B+1})(\pi_I^m - \pi_I^c)[\lambda - \phi\left(T_B\right)\overline{\lambda}],$$

where the second equality follows from $\lambda = \frac{\pi_I^c - \pi_I^p}{\pi_I^m - \pi_I^c}$, $\overline{\lambda} = \frac{\delta}{1-\delta}$, and $\phi(T) = \delta^T \frac{1-\delta}{1-\delta^{T+1}}$. Hence, the deviation is unprofitable if and only if $\lambda \leq \phi\left(T_B\right)\overline{\lambda}$. As $\phi\left(T_B\right)$ is strictly decreasing with T_B and tends to 0 as T_B goes to infinity, it follows that monopolization remains sustainable as long as

$$T_B \leq T_B^M \equiv \phi^{-1}(\frac{\lambda}{\overline{\lambda}}).$$

B.6 Proof of Proposition 6

We first compute total discounted expected welfare under the generalized freeze rule. As before, welfare is equal to $W^A = \frac{w^c}{1-\delta}$ under accommodation and equal to $W^M = \frac{w^m}{1-\delta}$ under monopolization. Turning to recurrent predation, let $\mathcal{F}_\tau^{WE}$, for $\tau \in \{1, ..., T_{WE}\}$, denote the state corresponding to period τ of the freeze following entry, and $\mathcal{F}_\tau^B$, for $\tau \in \{1, ..., T_B\}$, denote the state corresponding to period τ of the freeze following exit. The sequence of states upon entry is thus

$$\mathcal{M} \to \mathcal{F}_1^{WE} \to \ldots \to \mathcal{F}_T^{WE} \to \mathcal{C} \to \mathcal{F}_1^{B} \to \ldots \to \mathcal{F}_T^{B} \to \mathcal{M}.$$

Let $\mu_{\mathcal{M}}$ and $\mu_{\mathcal{C}}$ as before denote the long-run equilibrium probabilities of states $\mathcal{M}$ and $\mathcal{C}$. Noting that the freeze states have the same probability as state $\mathcal{C}$ (as they follow the same sequence), the long-run probabilities satisfy $\mu_{\mathcal{C}} = \mu_{\mathcal{M}}\beta$ and $(1 + T_{WE} + T_B)\mu_{\mathcal{C}} + \mu_{\mathcal{M}} = 1$, leading to:

$$\mu_{\mathcal{C}} = \frac{\beta}{1 + \beta(T_{WE} + T_B + 1)} \text{ and } \mu_{\mathcal{M}} = \frac{1}{1 + \beta(T_{WE} + T_B + 1)}. \tag{12}$$

Expected welfare is $(1-\beta)w^m + \beta(w^c - \alpha k)$ in state $\mathcal{M}$, w^c in states $\{\mathcal{F}_1^{WE}, \cdots, \mathcal{F}_{T_{WE}}^{WE}\}$, and w^p in states $\{\mathcal{C}, \mathcal{F}_1^B, \cdots, \mathcal{F}_{T_B}^B\}$. Hence, total expected discounted welfare can be expressed as:

$$\begin{aligned} W_F^P(T_{WE}, T_B) &\equiv \mu_{\mathcal{M}} \frac{(1-\beta)w^m + \beta(w^c - \alpha k)}{1-\delta} + \mu_{\mathcal{C}} \frac{T_{WE}w^c + (T_B + 1)w^p}{1-\delta} \\ &= \frac{(1-\beta)w^m + \beta[(T_{WE}+1)w^c + (T_B+1)w^p - \alpha k)]}{[1 + \beta(1 + T_{WE} + T_B)](1-\delta)} \\ &= W^A + \Delta(T_{WE}, T_B), \end{aligned}$$

where

$$\Delta(T_{WE}, T_B) \equiv \frac{(1-\beta)(w^m - w^c) + \beta[(T_B+1)(w^p - w^c) - \alpha k]}{[1 + \beta(T_{WE} + T_B + 1)](1-\delta)}.$$

The denominator of $\Delta(\cdot)$ is positive and increasing in both freezes, whereas its numerator may be positive or negative, and depends only on T_B. Hence, whether recurrent predation is socially desirable relative to accommodation is entirely driven by the sign of the numerator, and is independent of T_{WE}. Whenever recurrent predation is socially desirable (i.e., $\Delta > 0$), however, the level of welfare it generates is decreasing in T_{WE}. Therefore, T_{WE} should be kept as low as possible.

Moreover, recalling that $w^c > w^m$, closer inspection of the numerator reveals that accommodation dominates recurrent predation whenever $w^c \geq w^p$. In that case, a ban on predation is optimal and can be achieved by setting T_{WE} and/or T_B large enough.

From now on, we focus on the case where $w^p > w^c$. The numerator of $\Delta(\cdot)$ is then increasing in T_B and positive if T_B is large enough, namely, if and only if $T_B > T_B^W$, where T_B^W is given by (6). Furthermore, this positive impact more than offsets that on the denominator. Indeed,

$$\frac{\partial\Delta(T_{WE},T_B)}{\partial T_B}=\beta\frac{(1+\beta T_{WE})(w^p-w^c)+(1-\beta)(w^c-w^m)+\beta\alpha k}{[1+\beta(T_{WE}+T_B+1)]^2(1-\delta)}>0,$$

implying that it is then socially desirable to increase T_B as much as possible.

The freezes must ensure, however, that a newborn E enters in state $\mathcal{M}$, and that I predates in state $\mathcal{C}$. In state $\mathcal{M}$, a newborn E is willing to enter if and only if $k\leq\left(1+\delta+...+\delta^{T_{WE}}\right)\pi_E^c$, which amounts to:

$$\pi_E^c\geq\psi\left(T_{WE}\right)k,$$

where $\psi\left(T\right)=\frac{1-\delta}{1-\delta^{T+1}}$ decreases from 1 to $1-\delta$ as T increases from 0 to $+\infty$. As $\pi_E^c>(1-\delta)\,k$ by assumption, it follows that E is willing to enter if T_{WE} is large enough. In particular, if $\pi_E^c\geq k$, then E is always willing to enter, so $T_{WE}=0$ (i.e., no freeze after entry) ensures entry and maximizes $W_F^P\left(T_{WE},T_B\right)$ whenever recurrent predation is socially desirable. If instead $\pi_E^c<k$, then conditionally on recurrent predation being desirable, the optimal duration of freeze following entry is the smallest T_{WE} for which E is willing to enter, namely, $T_{WE}=T_{WE}^M\left(\pi_E^c\right)=\psi^{-1}\left(\pi_E^c/k\right)$.

In state $\mathcal{C}$, I's continuation values, $\bar{V}_{\mathcal{M}}$ and $\bar{V}_{\mathcal{C}}$, satisfy:

$$\begin{aligned}\bar{V}_{\mathcal{M}}&=(1-\beta)\left(\pi_I^m+\delta\bar{V}_{\mathcal{M}}\right)+\beta\Big(\frac{1-\delta^{T_{WE}+1}}{1-\delta}\pi_I^c+\delta^{T_{WE}+1}\bar{V}_{\mathcal{C}}\Big),\\ \bar{V}_{\mathcal{C}}&=\frac{1-\delta^{T_B+1}}{1-\delta}\pi_I^p+\delta^{T_B+1}\bar{V}_{\mathcal{M}}.\end{aligned}$$

Solving yields:

$$\begin{aligned}\bar{V}_{\mathcal{M}}&=\frac{(1-\beta)(1-\delta)\pi_I^m+\beta(1-\delta^{T_{WE}+1})\pi_I^c+\beta\delta^{T_{WE}+1}(1-\delta^{T_B+1})\pi_I^p}{[1-\delta+\beta\delta(1-\delta^{T_{WE}+T_B+1})](1-\delta)},\\ \bar{V}_{\mathcal{C}}&=\frac{(1-\beta)(1-\delta)\delta^{T_B+1}\pi_I^m+\beta(1-\delta^{T_{WE}+1})\delta^{T_B+1}\pi_I^c+[1-(1-\beta)\delta](1-\delta^{T_B+1})\pi_I^p}{[1-\delta+\beta\delta(1-\delta^{T_{WE}+T_B+1})](1-\delta)}.\end{aligned}$$

I is willing to predate if and only if $\bar{V}_{\mathcal{C}}\geq\pi_I^c+\delta\bar{V}_{\mathcal{C}}$, or:

$$\begin{aligned}0&\leq(1-\delta)\bar{V}_{\mathcal{C}}-\pi_I^c\\ &=\frac{(1-\beta)(1-\delta)\delta^{T_B+1}(\pi_I^m-\pi_I^c)+[1-(1-\beta)\delta](1-\delta^{T_B+1})(\pi_I^p-\pi_I^c)}{1-\delta+\beta\delta(1-\delta^{T_{WE}+T_B+1})},\end{aligned}$$

which amounts to $\lambda\leq\phi\left(T_B\right)\underline{\lambda}$, as before.[53] Recalling that $\phi(T)$ decreases from 1

[53] In particular, this incentive condition does not depend on T_{WE}. This is because, as already noted in Section B.4.2, in the boundary case where I is indifferent between predating or not in state $\mathcal{C}$, T_{WE} affects neither I's continuation values nor the equilibrium conditions.

to 0 as increases from 0 to $+\infty$, it follows that I is never willing to predate if $\lambda > \underline{\lambda}$; if instead $\lambda \leq \underline{\lambda}$, then I would be willing to predate under laissez-faire, and remains willing to do so as long as $T_B \leq T_B^P(\lambda) = \phi^{-1}(\lambda/\underline{\lambda})(\geq 1)$. As we have seen, T_B should be set as large as possible when recurrent predation is socially desirable; it follows that recurrent predation is socially optimal if and only if $T_B^P(\lambda) > T_B^W$, in which case it is optimal to set $T_B = T_B^P(\lambda)$.

Summing-up, the optimal policy is a ban on predation (e.g., $T_{WE} = +\infty$ and/or $T_B = +\infty$) and laissez-faire, if it yields accommodation –unless $w^p > w^c$ together with $\lambda \leq \overline{\lambda}$ and $T_B^P(\lambda) > T_B^W$, in which case it is optimal to impose a freeze after exit of $T_B = T_B^P(\lambda)$ periods, together with a freeze after entry of $T_{WE}^M(\pi_E^c)$ periods if $\pi_E^c < k$, and no freeze after entry otherwise.

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