Market Competition and Political Influence: An Integrated Approach*

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Abstract

The operation of markets and of politics are in practice deeply intertwined. Political decisions set the rules of the game for market competition and, conversely, market competitors participate in and influence political decisions. We develop an integrated model to capture the circularity between the two domains. We show that a positive feedback loop emerges such that market power begets political power in a positive feedback loop, but that this feedback loop is bounded. With too much market power, the balance between politics and markets itself becomes lopsided and this drives a wedge between the interests of a policymaker and the dominant firm. Although such a wedge would seem pro-competitive, we show how it can exacerbate the static and dynamic inefficiency of market outcomes. More generally, our model demonstrates that intuitions about market competition can be upended when competition is intermediated by a strategic policymaker.

Keywords: market and political power, political influence, market competition, Arrow effect.

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1 Introduction

The operation of markets and of politics are in practice deeply intertwined. Political decisions set the rules of the game for market competition and, conversely, market competitors participate in and influence political decisions. Since at least the time of Stigler (1971), the connection between the two domains has been formalized in economics, and the flourishing literature that emerged has deepened our understanding of how special interests can distort political outcomes and how political decisions shape market outcomes.

What has been less explored is the circularity of this connection. If political decisions affect market structure, and that market structure, in turn, determines the power of firms to participate in and influence political decisions, a circularity develops in which market and political outcomes are codetermined. The endogeneity of both market and political outcomes leads to sharp questions about the origins, persistence, and welfare effects of market power.

These questions have come to the forefront of debate in recent years in both academic writing and the public forum. Recent evidence establishes that market power has increased in the US in the past few decades (De Loecker et al. 2020). An open question is why. Was the increase due to efficiency gains by some firms that were rewarded with market leadership, or did it derive from anti-competitive practices and, in particular, the wielding of political power to handicap market rivals?[1]

In this paper we develop a model to explore and analyze the circularity between markets and politics. Two firms engage in imperfect competition repeatedly without end. The essential element of the model is that firms can obtain market power from two distinct sources. Market power can come from a competitive advantage that firms invest in, be it through R&D and technological superiority, from higher managerial competence, or some combination thereof. This *capability*-based market power builds a competitive advantage that makes the market as a whole more efficient.

The second source of market power is political protection. We endow a self-interested policymaker with the ability to intervene in the market to advantage one firm over its competitors. For concreteness, we model this power via a minimum technology standard, a regulatory tool common in practice. The policymaker can impose a standard to separate the firms, choosing a level that only the leader can

[1] Covarrubias et al. (2019) refer to these as "good concentration" and "bad concentration" respectively. See also Zingales (2017).

meet and excluding the follower firm from the market. The protected firm benefits from the removal of competition and passes along a share of the surplus that is gained as payment to the policymaker.[2] This *political*-based market power enables a competitive advantage by disabling competition, which, in contrast to capability-based market power, comes at the expense of efficiency.

We study this model dynamically. We show that a positive feedback loop emerges between the two sources of market power—that a capability advantage begets a political advantage and so on in a reinforcing cycle. In this way, an initial capability advantage can be parlayed over time into a larger advantage and a dominant market position.

We show, however, that this feedback loop is bounded and conditional on market power itself. We identify a threshold in capability-based advantage beyond which the feedback loop reverses. Beyond this threshold, therefore, greater capability-based market power leads to the removal of protection and less politically-based market power. This removal restores a degree of competition and bounds the ability of firms to dominate the market through political protection.

The core insight driving this result is that the interests of the market leading firm and the policymaker are aligned but not perfectly aligned. Within each period their interests are aligned on political protection—monopoly power maximizes the surplus available for them to share. Across periods, however, the degree of market power changes, and so too does the balance of power in their relationship. If the market leader gains a large capability-based advantage over its competitor, the need for, and thus the value of, political protection declines, and as this declines, the ability of the policymaker to extract rents from the market leader declines. Capability-based and politically-based market power are substitutes, in effect, such that the more the market leader has of one, the less it needs of the other.

This generates dynamic incentives for the policymaker that are very different from her static incentives. Dynamically, the policymaker seeks to "manage competition." She wants to protect the leading firm so that she can extract rents, but she doesn't want the leader to get so far ahead technologically that political protection becomes obsolete. It is her desire to remain relevant that causes her to stop protecting the leader and encourage competition, hoping that this allows the follower firm to catch

[2]This tool can only separate firms that have a technological difference. The tool(s) available to the policymaker are fundamental to the outcome of market and political interaction. We return to this point later in the paper.

up and make her protection valuable once more.

At first blush, managed competition appears promising as it bounds political intervention in the market and restores a semblance of competition. We show, however, that this is not the case. In an otherwise standard model of duopolistic competition, we show that managed competition can lead to the worst of both worlds. We characterize the unique renegotiation-proof subgame perfect equilibrium and show that play eventually stabilizes at a configuration in which technology stagnates and the policymaker protects the leading firm. The steady state is inefficient both because the leading firm is a protected monopolist and because investment stops at a low level. In fact, the capability level at the steady state is never greater, and typically lower, than if the policymaker always protected the leading firm. Investment with political interventions is lower, therefore, than even if monopoly were guaranteed.

This result shares a deep connection with Arrow's (1962) famous "replacement effect" from markets. Arrow observed that investment in technology will be higher with competition than in monopoly. The reason is that a monopolist obtains only an efficiency gain from investment whereas a duopolist has the additional benefit of capturing greater market share.[3]

The connection of Arrow to politics is that, by intervening in the market, the policymaker affects the degree of competition and, thus, the firms' incentive to invest. Our result shows that political intervention turns Arrow's conclusion around, creating what we refer to as a *reverse Arrow effect*. Precisely because the policymaker wants to manage competition—to remove protection should the leading firm's advantage exceed a threshold—the leading firm is incentivized to stop investing early. At the threshold, investment will not decrease competition, as Arrow suggests, rather it will increase as the policymaker removes protection, allowing the follower firm to enter the market. With Arrow's argument reversed, the leading firm stops investing at the precipice of the threshold, and as the policymaker protects at this point, the market stabilizes at a steady state with no competition and low investment.

A general lesson from this analysis is that the impact of political intervention on markets is a function of the structure of market competition itself. The insight from managed competition is that a self-interested policymaker seeks market competition not for its own sake, but so that the threat of even more competition increases the value of protection to the leading firm. This implies that a standard market

[3] A duopolist "escapes competition" in the terminology of Aghion et al. (2005). We discuss this idea in more detail in Section 2.

intuition—that competitive pressure translates into more efficient markets—need not hold when that competition is intermediated by a strategic policymaker.

To explore this idea, we consider a market in which competitive pressure is reduced. Specifically, we suppose that a firm will give up and leave the market permanently if it has been excluded by political protection for some period of time. This change nominally reduces competitive pressure on the leading firm as exit by the follower firm removes competition altogether. However, to understand the impact of this change on a market intermediated by a policymaker, we must understand how it changes the incentives of the policymaker.

We show that this reduction in competition pressure weakens the leverage of the policymaker and improves market outcomes. In fact, we show that investment is higher in the steady state than it is in monopoly and even duopoly. The reason for this reversal and efficiency gain again comes back to Arrow. The reverse Arrow effect still emerges in this setting, although now only temporarily, and the problem of underinvestment that it causes is eventually, albeit slowly, overcome. As the policymaker can only extract rents when competitive pressure is there, a weakening of that pressure reduces her influence on the market, enabling investment to reemerge.

On top of this, we show that a separate, distinct variant of the Arrow effect emerges—what we refer to as the *politically enhanced Arrow effect*—in which political protection serves as a reward to investment rather than a punishment. In this way political intervention enhances investment and is able to correct, in part, the standard market failure in which firms underinvest. Ultimately, however, political protection causes the trailing firm to exit the market and monopoly prevails.

These results illuminate a novel economic mechanism when markets and politics intersect and provides a structure through which to understand current debates. The mechanism we identify goes beyond the truism that politics affect markets. Rather, it lays out a specific channel through which the structure of market competition links to the degree of political influence. We show how the power of this mechanism rests on the substitutability of the two sources of market power, that the value of political power varies inversely with the technological state of the market. Tracing through the logic of this mechanism, we see how heightened competitive pressure can generate political inefficiency, and to such a degree that it overshadows the standard benefits of more competition, leaving society worse off. This result poses a challenge to the standard benchmark of a competitive market. If more competition only provides fertile ground for a self-interested policymaker to extract rents, there is little reason to expect that overall efficiency will increase. As Lerner (1972, p.259) observed, "An economic transaction is a solved political problem." When politics is itself a live variable—a yet unsolved problem—the market transaction must be viewed through a broader lens.

1.1 Connections to the Literature

Competition within the market and the dynamics of market structure have been extensively analyzed in the economics literature. While government intervention to affect market structure has been a core element of economic models, for instance in analyzing the effects of antitrust policies (e.g., Segal & Whinston 2007, Asker & Bar-Isaac 2020), most of these analyses assume a benevolent social planner or simply exogenous government interventions. Our contribution is to introduce politically motivated strategic market interventions into the standard model of firm competition.

Similarly, firms and industries have been at the core of political economy models, as actors who lobby for favored policies. Yet their interests and capabilities have been generally taken as given without accounting for how they coevolve dynamically with policy (e.g., Grossman & Helpman 1994).[4] Our paper is a small step toward bringing these literatures closer together and exploring their interdependence.[5]

Our model is closest in spirit to Coate & Morris (1999). They explicitly connect lobbying and political influence to private sector investment, showing how political choices influence private sector decisions that, in turn, influence politics. In their model there is a single firm that decides which of two sectors to operate in. We differ in emphasizing competition between firms and the dynamics of competition within a single market, showing the importance to a policymaker of deciding when and not just whether to extract rents.

In modeling the dynamic interaction of market competition and a regulator, we share a focus with a recent literature in antitrust that considers the dynamic effects of mergers through the eyes of a socially-minded regulator (Nocke & Whinston 2010, Mermelstein et al. 2020). We develop the connection with this literature and its

[4] Baldwin & Robert-Nicoud (2007) allow for market entry post-lobbying and show how market structure determines how this feeds back into the lobbying decision.

[5] A more distant connection is to the literature that combines industrial organization with organizational economics (Barron & Powell (2018) provide an overview). In particular, Powell (2019) focuses on commitment and how the interplay of current and future rents affects market performance.

application to current antitrust debates in the discussion section.

The feedback loop between politics and markets has recently come into focus in the empirical literature, as most clearly and forcefully articulated in Zingales (2017) (see Philippon (2019) and Wu (2018) for related book-length treatments). We develop a formal model of market and political competition that complements Zingales' discussion and we identify a novel channel through which the feedback loop operates that focuses on the strategic self-interest of the policymaker.[6]

2 The Model

The environment consists of two firms and a policymaker, P. In each period $t = 1, 2, ...$ the firms compete in the market and lobby the policymaker for protection.

The Market. Each firm that operates in the market has a technology level which determines its marginal cost of production. Higher technology leads to a lower marginal cost of production. We refer to the firm with the higher technology level as the leader (L), and the firm with the lower technology as the follower (F). The technology levels take non-negative integer-values and are denoted by l and f for the leader and follower, respectively, and they therefore satisfy $l \geq f$.

When both firms operate in the market, competition between them is imperfect. We have in mind Cournot competition and similar settings. Market demand is assumed constant across periods. For clarity and generality, we formulate the problem with firm profits as the primitives, given the state of the market (l, f), and work with continuous functions even though the technology levels are discrete. Within-period profits in the competitive market are given by twice-continuously differentiable functions $\pi^L(l, f) : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$ and $\pi^F(l, f) : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$, for the leader and the follower, respectively, such that the following conditions are satisfied.

Assumption 1 (Duopoly Profit) *The leader's duopoly profit $\pi^L(l, f)$ satisfies the following conditions, $\forall l \geq f \geq 0$:*

[6] Zingales's (2017) identifies six factors that may drive a positive feedback loop: the main source of political power, the conditions of the media market, the independence of the prosecutorial and judiciary power, the campaign finance laws, and the dominant ideology. These are distinct from the mechanism we identify. At a more abstract level, the insights from our model reinforce and put structure to Zingales's (2017) argument that a 'goldilocks' balance is required between the power embedded in politics and in markets for the system to have any hope of efficient and fair progress.

1. Monotonicity:

$$\frac{\partial}{\partial l}\pi^L(l,f) \geq 0, \qquad \frac{\partial}{\partial f}\pi^L(l,f) \leq 0. \tag{1}$$

2. Regularity:

$$\frac{\partial^2}{\partial l^2}\pi^L(l,f) \leq 0, \qquad \frac{\partial^2}{\partial f^2}\pi^L(l,f) \geq 0, \qquad \frac{\partial^2}{\partial l \partial f}\pi^L(l,f) \leq 0. \tag{2}$$

The first requirement is straightforward: the leader benefits from advances in its own technology and loses from advances in the competitor's technology. The second requirement is a regularity condition. It says that the leader's profit is concave in own technology, that it is convex in the follower's technology, and that an increase in the follower's technology reduces the leader's marginal profit gain from increases in its own technology.

The conditions of Assumption 1 obtain under the classical Cournot competition model with either linear or CES market demand for a nontrivial region of the parameter space, as we show formally in the Supplementary Appendix.

If one firm does not compete in the market, we have a monopoly. The monopolist's profit at technology level l is denoted $\hat{\pi}^M(l)$.

Assumption 2 (Monopoly Profit) *The monopoly profit* $\hat{\pi}^M(l)$ *satisfies*

$$\frac{\partial}{\partial l}\hat{\pi}^M(l) \geq 0, \qquad \frac{\partial^2}{\partial l^2}\hat{\pi}^M(l) \leq 0. \tag{3}$$

We require that the monopoly profit is increasing and concave in technology. These conditions can be immediately obtained, for instance, when the marginal cost of production is decreasing and convex in the firm's technology.

The firms can improve their technology level through investment every period in which they are in the market. Investment by the leader incurs a fixed cost $c(l) > 0$ that is increasing in l such that $\lim_{l\to\infty} c(l) \to \infty$. This condition on the cost function insures that there exists a level of technology, which we denote $l^{\max}$, at which investment stops, regardless of market structure. Technological advancement is deterministic and one-step per investment.[7] The step sizes in technology are small in the following sense:

[7]Step-by-step advancement is standard in the literature; see Aghion et al. (2005). It is straightforward to prove that our results are robust to stochastic advances in technology.

Assumption 3 (Small step size)

$$\hat{\pi}^M(l) > \pi^L(l+1, f) - c(l), \forall l \geq f \geq 0. \tag{4}$$

That is, the leader prefers to be a monopolist at technology level l than to advance one step and have to compete. The follower can also advance one step each period in which it competes in the market. Its advancement comes at a lower cost compared to the leader. The follower firm can more easily imitate the leading firm than the leader can come up with new ideas. We take the follower's advancement cost to be zero.[8] We generally consider the situation in which both firms begin at technology level 0, although the analysis holds should the market begin at any state of technology. Indeed, one can view a different starting state as resulting from a disruptive innovation, with the model describing incremental competition thereafter.

Political Influence. The policymaker can intervene in the market and impose a minimum technology standard. The standard can be adjusted from period to period. It is outcome relevant only if it separates the firms. When a standard is imposed, the follower firm is excluded from the market, earning zero profit, and the leader obtains monopoly power.[9]

The protected firm pays rents to the policymaker, which we assume to be a fixed share of the value of protection. The value is the difference between monopoly and duopoly profits, which for the policymaker's share $\rho \in (0, 1)$ and technology levels l and f, gives a payoff for the policymaker of

$$\pi^P(l, f) = \rho \cdot \left[\hat{\pi}^M(l) - \pi^L(l, f)\right]. \tag{5}$$

The protected firm's profit is then monopoly profit less policymaker rents:

$$\pi^M(l, f) = \hat{\pi}^M(l) - \pi^P(l, f), \tag{6}$$

[8] A version of this assumption appears in many other models of competition and innovation, such as in the influential work by Aghion et al. (2005) and Bessen & Maskin (2009).

[9] Formally, investment in our model is a cost reduction and so we model the regulatory intervention as a technology or capability standard. Modeling investment as a quality improvement on the final goods would permit an analogous application to quality floor regulations. As Tirole (1997, p. 389) points out, "a product innovation can generally be regarded as a process innovation—imagine that the new product existed prior to the innovation, and that the innovation simply reduced its production cost."

which, by construction, exceeds the duopoly profit. Note that the policymaker and leading firm cannot commit to a rent-sharing agreement beyond the present period. Lack of commitment is assumed throughout the model.

The rent-sharing rule we consider encapsulates the tension between the policymaker and the leading firm within and across periods. The parameter ρ reflects the relative bargaining power between them within a period, representing in reduced form the effect of various institutional features, including the willingness of the policymaker to accept rents or of the firm to share them, the cost to the policymaker of protection, as well as the degree of political competition.[10]

That the value of protection to the leading firm varies in its market position across periods captures the idea that capability-based and political-based market power are, to some extent, substitutes. The particular sharing rule we chose is sufficiently simple to allow for a clean characterization of the dynamics between market and political power. However, it is not the unique sharing rule that delivers our insights. Other rules develop similar effects. All that is required, as we show in the Supplementary Appendix, is that rents are proportional to the market gains from political intervention, and they decrease as the technology gap between firms widens.

Timing: The timing of the play within each period is as follows. For $l_t > f_t$:

1. *Investment.* The leading firm invests ($i_t = 1$) or not ($i_t = 0$) and the interim state is $(l_t + i_t, f_t)$.

2. *Protection.* The policymaker imposes a technology standard ($a_t = 1$) or not ($a_t = 0$).

3. *Market competition.* The firms compete (if $a_t = 0$) or firm L is a monopolist (if $a_t = 1$).

4. *Transition.* The state in period $t + 1$ will begin at $(l_t + i_t, f_t + 1 - a_t)$.

When the firms are equal technologically and $l_t = f_t$, nature selects in step 1 one of the firms to invest, and play proceeds identically otherwise.[11] This is a simple tie-

[10] In Stigler's (1971) original view, it was the industry cartel that held all of the bargaining power, making demands of policymakers and extracting all of the benefit of political protection. McChesney (1987) shows that if instead policymakers are proactive and can make demands of the firms, then they extract all of the surplus. Reality lies somewhere between these extremes.

[11] With the exception that only the selected firm can push the technological frontier; i.e., if the selected firm does not invest and protection is not offered, the follower firm does not advance technologically in step 4.

breaking rule that creates the opportunity for technology gaps to open up between the firms.

The transition in stage 4 reflects the two ways in which political protection impacts the market in our model: It removes competition *and* it restrains technological catch-up by the follower firm. Both aspects will play a role in our analysis.

Competition and the Incentive to Invest: The incentives of firms to invest depend on market structure and political intervention. In a purely market setting, Arrow (1962) argues that the incentive to invest is lower in monopoly than with competition. This has come to be known as the Arrow replacement effect (Tirole 1997) and led to an enormous amount of research on the impact of competition on investment and innovation. In our model, as in Arrow (1962), only a single firm has the opportunity to invest and, by so doing, it lessens the degree of competition with the follower firm, thereby "escaping competition" (Aghion et al. 2005). Empirical evidence strongly points to competition increasing the incentive to invest and innovate when the comparison is between monopoly and duopoly, as it is here (Shapiro 2012, Holmes & Schmitz 2010).[12]

Arrow's effect is intuitive although that it holds for all technology levels does not follow directly from a standard model of competition like Cournot. We impose the following condition on relative profits.

Assumption 4 (Arrow Effect) *The monopoly profit and the leader's profit in duopoly satisfy,* $\forall l \geq f + 1 \geq 1$*:*

$$\frac{\partial}{\partial l}\hat{\pi}^M(l) < \frac{\partial}{\partial l}\pi^L(l, f).$$

The condition states simply that, for a technology level l, the marginal gain from increasing technology is higher for the duopolist than the monopolist. The duopolist improves efficiency *and* gains market share from its competitor, whereas the monopolist only improves efficiency albeit from a larger base quantity. The Arrow effect requires that the market share gain dominates the larger quantity for the monopolist.

Arrow's effect implies that the gap between profits in monopoly and duopoly is narrowing. That as the leader's technology level grows, competition restrains its

[12] Schmutzler (2009) provides a thorough theoretical treatment of the connection between competition and innovation.

profits to a lesser degree.[13] This property is important as it is the gap in profit between monopoly and duopoly that determines the rents paid to the policymaker. The policymaker receives a share of the value of protection, which is exactly this difference in profit. That this gap declines in the leader's technology level implies, therefore, that the policymaker's rents also decline in leading firm's technology level.

Assumption 4 is for a duopolist and a pure monopolist. The case of a protected monopolist—who shares rents with the policymaker—lies between these cases. The fixed proportion rent sharing rule we assume implies, immediately from Assumption 4, that the incentive to invest of a protected monopolist satisfies: $\hat{\pi}^M(l+1) - \hat{\pi}^M(l) \leq \pi^M(l+1, f) - \pi^M(l, f) \leq \pi^L(l+1, f) - \pi^L(l, f)$ for each $l \geq f + 1 \geq 1$. The incentive of the protected monopolist equals that of the pure monopolist at $\rho = 0$, that of the duopolist at $\rho = 1$, and is strictly increasing in ρ.

Planning Horizons: The policymaker and the firms discount utility at rates, δ and β, respectively. Throughout our analysis the policymaker is far-sighted with $\delta \in (0, 1)$. For simplicity, we present the model when the firms are short-sighted ($\beta = 0$). In Section 5 we establish the robustness of the results for any $\beta \in (0, 1)$. Note that the firms receive the benefit of investment within a period, so even when myopic, investment can have a positive return.

Equilibrium Concept: We identify a renegotiation proof Subgame Perfect Equilibrium (SPE) of the following form: after each history, if at the timing of the leader's investment decision or at the timing of the policymaker's protection decision there are two equilibria that are Pareto ranked for the policymaker and the leader, then we pick the Pareto efficient one. As the ensuing analysis will show, the SPE is derived using backwards induction from $l^{\max}$ at which the leader never invests. This ensures uniqueness up to the state (l, f) at which the leader's optimal investment decision depends on the policymaker's protection decision after the leader does not invest (her decision after the leader's investment is determined by backwards induction since the leader's technology goes up by one step). In the states when the policymaker's optimal decision also depends on the leader's investment decision,[14] this circularity

[13] To the extent that competition is relaxed completely for a large enough technology gap (if, for example, the monopoly price for the leading firm is below the follower firm's cost of production), then the Arrow effect *must* hold for at least large parts of the technology range.

[14] To see why, if the policymaker does not protect after no investment, then the next state will again be (l, f) and the policymaker's payoff depends on what the leader will do in that state.

may cause multiplicity, and renegotiation proofness is necessary to guarantee uniqueness. We prove in the Supplementary Appendix that the outcome of the Subgame Perfect Equilibrium satisfying renegotiation proofness exists and is unique. We fully characterize this equilibrium and show that it has the structure of a Markov Perfect Equilibrium. We refer to it as the equilibrium throughout the paper.

3 Market Incentives

To illuminate the market incentives in the model we begin by shutting down the policymaker as a strategic actor. We consider two benchmarks. One in which the policymaker does not exist or, equivalently, never intervenes in the market, and a second in which the policymaker always intervenes to protect the leading firm.

The Policymaker Never Intervenes: Without political intervention, both firms compete in each period and the market is a duopoly. A firm invests if the improvement in technology increases profit enough to justify the cost. For firms with a single period horizon, investment is profitable if:

$$\pi^L(l+1, f) - c(l) \geq \pi^L(l, f). \tag{7}$$

The decision to invest depends on the technology level of the leader as well as the follower. This generates a threshold level of technology for the follower at which equality holds in (7) and the leader is indifferent between investing and not. We denote this threshold by $IC_D(l)$ to represent the duopolist's incentive compatibility constraint. We then have the following result.

Lemma 1 *The leader invests if and only if $f < IC_D(l)$, where the threshold satisfies $IC_D(l+1) \leq IC_D(l), \forall l \geq 0$.*

The leading firm's willingness to invest is decreasing in its own technology level. The higher is the firm's own technology, the higher is the cost of further advancement and the lower is the increase in profit that it produces.

The leading firm's willingness to invest is also decreasing in the technology of the follower firm. As the follower catches up to the leader, competition is more intense. This means that the inframarginal benefit to the leader of investment—less intense competition and a higher price—is lower. The leader does benefit from

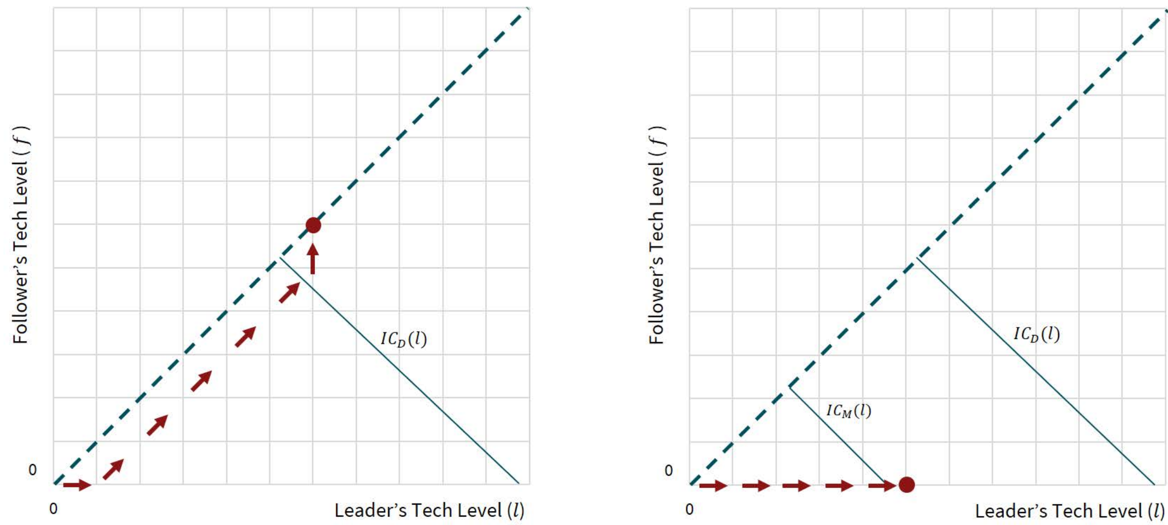

Figure 1: Market Incentives. The red arrows illustrate the equilibtrium transitional path and the red dot the equilibrium steady state. The left panel shows the case when the policymaker never intervenes. The leader invests as long as f is below the threshold IC_D. The right panel shows the case where the policymaker always intervenes. The leader invests as long as f is below the threshold IC_M.

capturing market share from the follower, but this effect does not dominate. This property holds in Cournot competition when both firms are active in the market. In our model, it follows from $\frac{\partial^2}{\partial l \partial f}\pi^L(l, f) \leq 0$ in Assumption 1. This implies that the $IC_D(l)$ threshold is decreasing in the leader's technology l, as depicted in the left panel of Figure 1, where each point in the positive quadrant corresponds to a state (l, f).[15]

Figure 1 also depicts the dynamic path of the market when starting at the origin. One firm invests in the first period, becoming the market leader. In every subsequent period that firm invests, advancing one level, and the follower firm also advances while remaining one step behind. This continues until the state reaches the $IC_D(l)$ threshold, at which point the leader no longer finds it worthwhile to invest and stops. The follower catches up one final step and the market stabilizes at equal technology levels, as marked by the dot.

The Policymaker Always Intervenes: In this case the leading firm benefits

[15]This does not violate Assumption 4 as instead of comparing a duopolist to a monopolist, we are comparing duopolists to each other when both firms produce positive quantities, which is the case throughout our model. Only if the follower were to drop out of the market would the leader's incentive to invest weaken.

from political protection in every period and operates as a monopolist. Investing at technology level l is profitable if:

$$\pi^M (l+1, f) - c(l) \geq \pi^M (l, f). \tag{8}$$

Although the leader is a monopolist whether it invests or not, the profitability of investment depends on the follower's technology level. This is because we are considering a protected monopolist. The leader pays rents to the policymaker proportional to the value of protection, and this depends on profitability should the leader have to compete. As in the duopoly case, this leads to a threshold in investment at which equality holds in (8). This threshold is denoted by $IC_M(l)$, for monopoly.

Lemma 2 *The leader invests if and only if $f < IC_M(l)$, where the threshold satisfies $IC_M(l+1) \leq IC_M(l)$ and $IC_M(l) \leq IC_D(l), \forall l \geq 0$.*

This is depicted in the right-side panel of Figure 1. The threshold is downward sloping, as it is for duopoly. This is due to the increasing marginal cost of investment and the decreasing marginal benefit of investment as l or f increase (given Assumption 1). The leader is more willing to invest the further behind is the follower firm as it then pays smaller rents to the policymaker and captures more of the efficiency gains of investment. The leader's willingness to invest is lower than in duopoly, as implied by Arrow's effect, and the protected monopolist stops investing earlier than does the duopolist.

The dynamic path of the market moves only horizontally (as the follower is never in the market and never catches up). Starting at the origin, the market moves along the l-axis and stabilizes at $\lceil IC_M^{-1}(0) \rceil$, the first technology level beyond the IC_M threshold, as marked by the dot.

4 Market & Political Equilibrium

To market competition we now add the strategic policymaker. The policymaker will choose to protect only when it is in her interest. Protection delivers rents today, but it also excludes the follower firm from the market and this gives the leading firm an opportunity to advance its technology advantage, which lowers the policymaker's rents in future periods. The policymaker's optimal strategy depends, therefore, on the investment decisions of the firms which, in turn, depend on the policymaker's decision to protect or not. The equilibrium is the balance between these different incentives.

The Policymaker's Incentive Compatibility Constraint.

We will show that the policymaker's incentives enter the equilibrium in the form of a simple indifference condition on the rate at which her rents increase when the follower is allowed to catch up technologically. As we will argue below, this condition distills down to a one-period trade-off even though she is far-sighted. It is given by:

$$\pi^P(l,f) = \delta\pi^P(l,f+1). \tag{9}$$

This defines, for each l, the level of f at which the policymaker is indifferent between the rents available today from protection and the higher rents available tomorrow should she not protect and the follower catches up one step. Denote this critical value of f by $IC_P(l)$, reflecting that this is the policymaker's indifference condition.[16] For f above $IC_P(l)$, the policymaker will intervene in the market, and for f below it, she will not.

The equilibrium depends on the slope of the $IC_P(l)$ curve and where it intersects the edges of the state space. The following single-crossing condition ensures that the slope of $IC_P(l)$ is between 0 and 1.

Definition 1 *We say that $IC_P(l)$ satisfies single-crossing if for each l for which $IC_P(l)$ is well-defined, (i) $IC_P(l')$ is also well-defined for $l' > l$, and (ii) we have $0 \leq IC_P(l+1) - IC_P(l) \leq 1$.*

The conditions required for single-crossing to hold are given by the following lemma. We show in the Supplementary Appendix that these conditions are consistent with competition under Cournot with either linear or CES market demand.

Lemma 3 *For each $(l,f) \in \mathbb{R}_+ \times \mathbb{R}_+$ such that $l^{\max} \geq l \geq f+1$, constraint IC_P*

[16]Formally, let $\underline{l}$ be the smallest l such that $\pi^P(l,l-1) \geq \delta\pi^P(l,l)$ with $\pi^P(l,l) = \rho\left(\hat{\pi}^M(l) - \pi^L(l,l)\right)$. For $l \geq \underline{l}$, define $IC_P(l)$ as follows: if $\pi^P(l,f) \geq \delta\pi^P(l,f+1)$ for $f=0$, then $IC_P(l)=0$; otherwise, $IC_P(l)$ is the follower's technology level f that satisfies $\pi^P(l,f) = \delta\pi^P(l,f+1)$.

satisfies single-crossing if the following conditions hold:

$$(1-\delta)\left[\frac{\partial}{\partial l}\hat{\pi}^{M}(l)-\frac{\partial}{\partial l}\pi^{L}(l,f)\right]+\delta\max_{s\in[0,1]}\left\{\frac{\partial^2}{\partial l\partial f}\pi^{L}(l,f+s)\right\}\leq 0, \tag{10}$$

$$(1-\delta)\left[\frac{\partial}{\partial l}\hat{\pi}^{M}(l)-\frac{\partial}{\partial l}\pi^{L}(l,f)-\frac{\partial}{\partial f}\pi^{L}(l,f)\right] +\delta\min_{s\in[0,1]}\left\{\frac{\partial^2}{\partial l\partial f}\pi^{L}(l,f+s)+\frac{\partial^2}{\partial f^2}\pi^{L}(l,f+s)\right\}\geq 0. \tag{11}$$

Condition (10) immediately follows from Assumptions 1 (part 2) and 4. It ensures that the $IC_P(l)$ curve is not downward sloping: $\pi^P(l,f)-\delta\pi^P(l,f+1)$ is non-increasing in l.[17] Condition (11) imposes that the slope of $IC_P(l)$ is no more than one: $\pi^P(l+t,f+t)-\delta\pi^P(l+t,f+t+1)$ is non-increasing in t.

The Equilibrium.

Our main result is that in equilibrium the balance between market and political incentives leads to the worst of both worlds. The policymaker's effort to extract rents from the leading firm causes that firm to stop investing when it is at a low technology level, often at a level strictly lower than in duopoly and even monopoly. Moreover, the policymaker protects the leader in every period. The equilibrium path is inefficient both within period and across periods. When the policymaker protects and the leader does not invest, the market stabilizes and remains in a steady state thereafter.

The level of distortion in equilibrium depends on where and whether the $IC_P(l)$ and $IC_M(l)$ thresholds intersect and where $IC_P(l)$ meets the l-axis. Let the intersection of the curves, should it occur, be at the point $\left(l^I,f^I\right)$ and the intersection of $IC_P(l)$ with the l-axis be at $\hat{l}$. When $\hat{l}\geq 1$ we have the following.[18]

Proposition 1 *For $\hat{l}\geq 1$ and IC_P satisfying single-crossing, the steady state beginning from the origin is $(l^*,0)$ where $l^*\leq l^I-f^I$ if the IC_P and IC_M curves intersect, and $l^*=\lceil IC_M^{-1}(0)\rceil$ otherwise.*

[17] Since $\pi^P(l,f)-\delta\pi(l,f+1)=(1-\delta)\pi^P(l,f)-\delta(\pi^P(l,f+1)-\pi^P(l,f))\approx(1-\delta)\pi^P(l,f)-\delta\frac{\partial}{\partial f}\pi^P(l,f)$, and given that $\pi^P(l,f)$ is proportional to the difference between $\hat{\pi}^M(l)$ and $\pi^L(l,f)$, (10) guarantees that $\pi^P(l,f)-\delta\pi^P(l,f+1)$ is decreasing in l. We have the max operator in (10) to precisely evaluate $\approx$.

[18] The alternative case of $\hat{l}<1$ implies that the state is below the IC_P threshold after a first period of investment. When this holds, there may be periods of competition as the policymaker allows the follower to catch up. Nevertheless, in the steady state, as in Proposition 1, protection is applied and investment is suppressed. We provide complete details in the Supplementary Appendix.

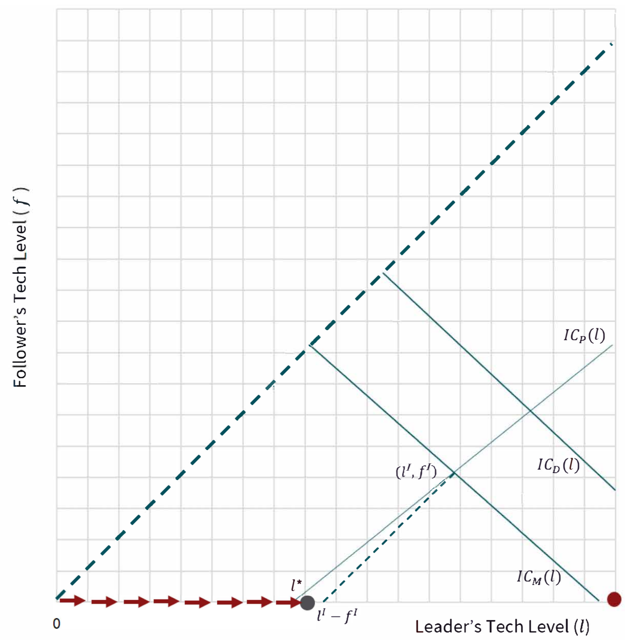

Figure 2: Market and political equilibrium. The red arrows illustrate the transitional path and the gray dot shows the equilibrium steady state. The red dot shows the steady state under the benchmark where the policymaker always intervenes.

The equilibrium steady state and dynamic path starting at the origin are depicted in Figure 2. The proposition establishes that the steady state is at or lower than the investment level under protected monopoly, given by the red dot. As is evident in the figure, when the IC_P and IC_M curves intersect, the steady state is strictly lower than in monopoly and the underinvestment caused by political intervention can be severe. Only if the IC_M and IC_P curves do not intersect does the monopoly level $\lceil IC_M^{-1}(0) \rceil$ provide the upper bound on equilibrium investment.

The equilibrium path represents a mutual reinforcement between capability-based and politically-based market power. At each state up until $(l^*, 0)$ the leader invests and is protected by the policymaker. Competition never occurs on the equilibrium path. One firm gains an initial technology advantage and uses that advantage to obtain political protection that it parlays into a larger technology advantage. The entire market outcome, including the steady state, is preordained once the identity of the firm with the initial advantage is realized.

Managed Competition & the Reverse Arrow Effect.
This raises the question of why investment stops at such a low technology level. If

a monopolist invests at this technology level, why wouldn't a protected monopolist invest? The reason is that the positive reinforcement stops. A crucial feature of the equilibrium is that at state $(l^* + 1, 0)$ the equilibrium calls for the policymaker to not protect. Therefore, if at state $(l^*, 0)$ the leader increases its capability-based market power, its political-based market power will be removed.

It is at this state that the policymaker tries to "manage competition." At this state she decides that forgoing rents today is worth the benefit of allowing the follower firm to stay in touch with the leader. By not protecting, the policymaker ensures a higher degree of potential competition tomorrow that allows her to extract higher rents. The policymaker manages competition not for competition's sake but to ensure her own relevance.

Managed competition undermines investment by generating the reverse Arrow effect. Because the policymaker will remove protection at state $(l^* + 1, 0)$, the leading firm anticipates at state $(l^*, 0)$ that investment will cause it to lose protection and switch from a protected monopolist to a duopolist. This takes Arrow's logic to the opposite conclusion. In this setting, investment does not reduce competition—it does not allow the firm to "escape competition"—rather it increases competition. This pro-competition effect suppresses investment and induces market stagnation at a low level of firm technology.

Backward Inducting to the Reverse Arrow Effect.
To this point we have explained why the steady state exists given the equilibrium behavior at higher states, but we haven't yet explained why that equilibrium behavior is what it is. For this, we must look at the full structure of the equilibrium, which we derive from backward induction. The details of the argument are provided in the Appendix. We focus here on the key trade-offs that generate the path in Proposition 1.

The game is solvable by backward induction as the increasing and convex cost of investment ensures the existence of technology level $l^{\max}$ at which investment stops, regardless of the policymaker's action. This implies that the state space is effectively finite and that a steady state exists. The state $(l^{\max}, f)$ is stable at $f = l^{\max}$ as the policymaker cannot protect when the technology levels are equal and neither firm invests, and stable for $f < l^{\max}$ if the policymaker protects (as otherwise the follower would move up in technology when $f < l$, negating the idea of a steady state).

It is straightforward to then characterize equilibrium behavior when $f \geq IC_P(l)$ and $f \geq IC_M(l)$. Consider the $IC_P(l)$ threshold. It follows from Assumption 1 that

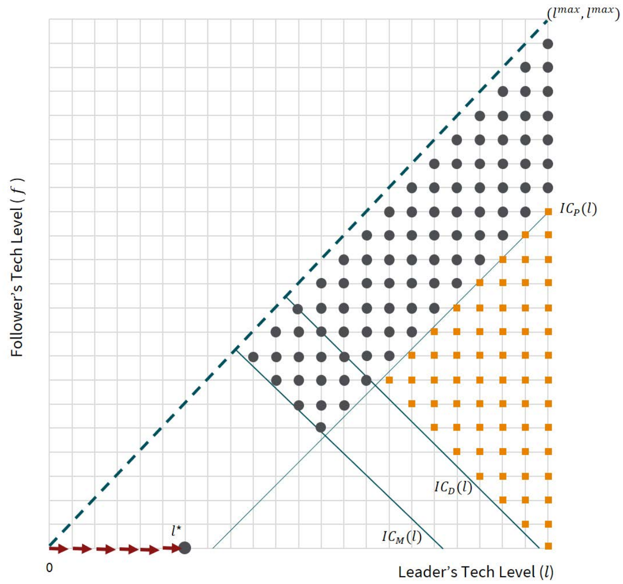

Figure 3: Equilibrium behavior for high technology states. The dark blue dots are steady states as above both IC_P and IC_M the policymaker protects and the leader does not invest. At the orange squares below IC_P and above IC_D the leader does not invest and policymaker does not protect, and the state progresses upwards.

the left-hand side of (9) is higher than the right-hand side whenever $f > IC_P(l)$. In this region, the cost of investment is too high for the monopolist to invest and the policymaker would prefer to take rents today than wait until tomorrow. Therefore, in equilibrium the leader does not invest and the policymaker protects, and every state in this region is stable. This region is represented by dark circles in Figure 3.

Similarly, if $f \leq IC_P(l)$ and $f \geq IC_D(l)$, the cost of investment is too high for a monopolist or a duopolist to invest, yet the policymaker prefers to let the follower catch up and reap higher rents tomorrow. Thus, every state in this region is unstable, as the follower advances technologically each period until a steady state is reached above IC_P. This region is represented by light squares in Figure 3.

The dynamics become more interesting in the remaining regions of the state space. The core of the argument focuses on the states around the intersection of the IC_P and IC_M curves, which are depicted in Figure 4. It will be helpful to distinguish the state depending on who is making a decision. We say we are in the "ex ante state" when the leading firm makes its investment decision, and in the "interim state" when the policymaker decides on protection.

Three observations drive backward induction from here on. First, if the policymaker protects the leader at interim state (l, f), then protection will be offered forever on the equilibrium path starting from that interim state. To see why, note that this implies the policymaker will protect the leader should it not invest at ex ante state (l, f). As it can ensure protection by not investing, the leader will only invest, by Assumption 3, if the policymaker protects at interim state $(l + 1, f)$. Recursively, protection will be always offered on path.

The second observation is on the policymaker's incentives. Suppose the equilibrium outcome at (l, f) is "no investment and protection" and consider the interim state $(l, f - 1)$. If $(l, f - 1)$ is below the IC_P curve, the policymaker will not offer protection. To see why, suppose that she did. The first observation implies that protection will be offered thereafter in equilibrium. Since an investment by the leader decreases the policymaker's payoff given Assumption 4, her payoff is no more than $\pi^P(l, f - 1)/(1 - \delta)$. By contrast, if she does not protect, the state transitions to (l, f) and her payoff is $\delta\pi^P(l, f)/(1 - \delta)$. Since $(l, f - 1)$ is below the IC_P curve, not protecting is the better choice.

The third observation combines the incentives of the policymaker and the leader. Suppose the policymaker does not protect the leader at interim state (l, f). Then either the equilibrium outcome at $(l - 1, f)$ is "no investment and protection" or the policymaker does not protect the leader at the interim state $(l - 1, f)$. If the policymaker does protect at the interim state $(l - 1, f)$ the leader will not invest, by Assumption 3, as doing so will cause it to lose protection. Moreover, if $(l - 1, f)$ is above the IC_P curve, then the equilibrium outcome is "no investment and protection." This is optimal for the leader and it is the best feasible outcome for the policymaker. Holding l fixed, the policymaker wants to stay at $(l-1, f)$, and Assumption 4 implies that higher l reduces the policymaker's payoff. Thus, our renegotiation proofness requirement selects "no investment and protection" as the equilibrium.

We now apply these observations inductively, beginning at state $(l, f + 1)$ in Figure 4. This state is stable as the leader doesn't invest and the policymaker protects. The second observation above implies that the policymaker does not protect at interim state (l, f) as it is below the IC_P curve. From here, we apply the third observation recursively until we obtain an $l' < l$ exists such that the equilibrium outcome at (l', f) is "no investment and protection." The value of l' is no less than the first crossing point of the IC_P curve; specifically, it is no less than the largest $l'' < l$ such that (l'', f) is above the IC_P curve. It is also no larger than $l - 1$ and, thus, to the left of

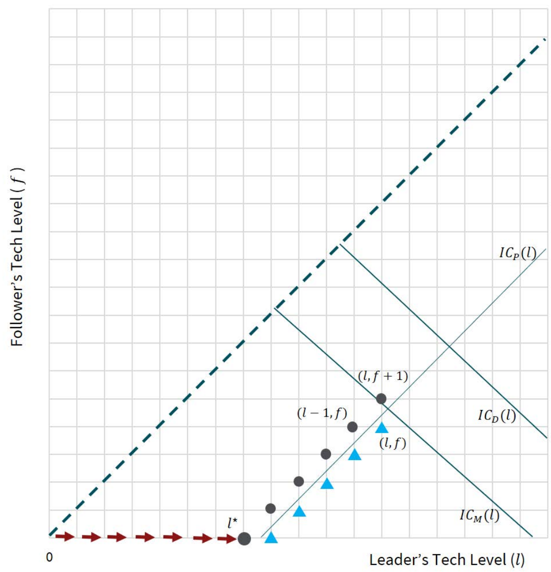

Figure 4: Backwards induction. The unravelling logic is shown given states on either side of the policymaker's incentive constraint IC_P. The gray dark blue dots are steady states where the policymaker protects and the leader does not invest. The blue triangles are states at which the policymaker does not protect and the market is a duopoly. For simplicity, we illustrate the case where the slope of IC_P equals 1.

the line of slope one connecting (l, f) to $(l^I - f^I, 0)$. In Figure 4 this is depicted as state $(l - 1, f)$.

This establishes the reverse Arrow effect. Note what it implies. At state (l', f), the leader stops investing despite being below the IC_M curve and the IC_D curve. Thus, the incentive to invest at this state for a protected monopolist is lower than for a duopolist and even a monopolist.

This behavior is interesting by itself, yet its true importance lay in how it affects behavior at preceding states. Starting now at state (l', f), we know that even if (l', f) is above the $IC_P(l)$ curve, state $(l', f - 1)$ is below it as the slope of the $IC_P(l)$ curve is less than one, under the single-crossing conditions of Lemma 3. Thus, by the same argument as above, the policymaker will not protect at $(l', f - 1)$ and the logic of the reverse Arrow effect recurs.

This begins an unraveling that continues all the way to the l-axis where the follower firm has a technology level of zero. The unraveling proceeds between a line of slope 1 and states immediately to the left of the IC_P curve. This generates a steady state on the l-axis no greater than $(l^I - f^I, 0)$ at which the leader doesn't invest and the policymaker protects. This provides an upper bound on investment in equilibrium. Therefore, whenever the IC_P and IC_M curves intersect, the investment level is strictly below that of a monopolist.

A striking feature of this bound is how it varies in the policymaker's patience. If δ decreases, future rents are less valuable and managing competition less urgent. Thus, the policymaker is more willing to protect and take rents today and the IC_P curve shifts to the right. Thus, if the policymaker's grip on power is weaker—a lower δ—there is more scope for investment by the leading firm in equilibrium. Conversely, if the policymaker is entrenched in power and δ is high, the upper bound on investment is lower. This resonates with the idea that the less competition there is in politics, the more inefficient is policymaking.

4.1 Relaxing Competitive Pressure

The insight of 'managed competition' is that the policymaker seeks market competition purely for the threat value. She allows competition only because it enables the follower firm to catch up and increase the threat of further competition. In this sense, competitive pressure translates not into more efficient markets, but into leverage for the policymaker to extract rents. This induces the reverse Arrow effect that undermines market efficiency.

The lesson from this is that standard intuitions about market competition need not hold when markets and politics are intertwined. Counter-intuitively, therefore, it may be that outcomes are improved if the degree of competition is relaxed. We explore this possibility in this section.

One dimension of competitive pressure is the willingness of the follower firm to enter into the market and compete if political protection is removed. It is a striking feature of the equilibrium in Proposition 1 that the follower firm never competes in the market yet nevertheless stands ever ready to do so. Although this is a reasonable description of some markets (e.g., foreign competitors and trade barriers), it is less appropriate in other markets, and one might think that the follower firm will, at some point, give up and abandon the market altogether.

To formalize this idea, we amend the model as follows. We suppose that a firm that has been *excluded* from the market for κ consecutive periods will permanently *exit* the market. That is to say, if a firm has not been allowed to compete for κ periods it gives up and pursues opportunities elsewhere.

Although this is a simple variant, it complicates the analysis considerably. The state space is now the technology levels of the firms plus the number of periods of consecutive protection. As it is possible for the firms to remain at technology levels for multiple periods before advancing, we say a state is a steady state only if the technology levels have not changed for κ periods and are permanently stable. For this environment we characterize the steady states of market competition but do not provide a full description of the equilibrium path.

A market with potential exit changes the incentives of the policymaker. The policymaker must now remove protection at least once every κ periods else she loses her leverage. We focus on situations in which the policymaker wants to keep the follower in the market, even if that means forgoing rents for one period. Specifically, for each (l, f) with $l \geq f$, we consider the case when δ and κ are sufficiently large and the leader's advancement does not reduce the policymaker's payoff too rapidly such that the following holds:

$$\sum_{t=1}^{\kappa} \delta^t \min_{l \leq l' \leq l+t} \pi^P \left(l', f+1\right) > \pi^P \left(l, f\right). \tag{12}$$

The benefit of the policymaker being patient is clear when the follower is more than two steps behind the leader. In this case, after protecting for $(\kappa - 1)$ periods, the policymaker faces a simple trade-off: Protect and receive rents for a final period or forgo rents today, allow competition, and renew a fresh stream of rents for κ periods. Indeed, if the leader doesn't invest while protection is removed, tomorrow's rents are certain to be higher.[19] This implies that the market cannot stabilize unless the firms' technology levels are close or equal.

Lemma 4 *When competitive pressure is relaxed and (12) holds, the firm technology pair (l, f) is not a steady state if $f < l - 1$.*

The logic of this result does not necessarily hold when the follower is only one step behind the leader. The difference is that, if the leader doesn't invest when protection is removed, the follower will catch up and the state will transition to $l = f$ on the 45 degree line. This matters because on the 45 degree line the minimum standard has no bite and the policymaker cannot extract rents. The optimal behavior of the

[19]Similar forces are at work for κ small or δ small, although the analysis is more complicated and identifying steady states would require the full characterization of the equilibrium path.

policymaker in this case depends, then, on the strategy of the firm that is given the opportunity to invest when on the 45 degree line.

The need for the policymaker to refresh competition also changes the incentives of the firms. Because in some periods the leader knows that protection will be removed *regardless* of whether it invests or not, the reverse Arrow effect is relaxed in those periods. In those periods, the leader invests knowing it will have to compete and, therefore, the relevant threshold is that of duopoly, $IC_D(l)$. This is not to say the reverse Arrow effect does not bind in other periods when protection is a choice for the policymaker, only that in some periods it is relaxed, and that is enough to ensure that eventually technology advances to the duopoly level.

Lemma 5 *When competitive pressure is relaxed and* (12) *holds, the firm technology pair* (l, f) *is not a steady state if* $f < IC_D(l)$*.*

Combining the two lemmas provides a broader picture of equilibrium behavior. Lemma 4 shows that a steady state must be either on or adjacent to the 45 degree line where firm capabilities are equal, and Lemma 5 shows that a steady state cannot exist below the duopoly threshold.

A reasonable conjecture is that investment stops as soon as the duopoly threshold is passed. Were this true, the policymaker would, upon first reaching a state $(l, l-1)$ beyond the duopoly threshold, take the κ^{th} period of rents and let the follower exit the market, as the alternative is moving to the 45 degree line and stagnation.

We show that this conjecture is not true. The firms are willing to invest beyond the duopoly threshold, although only when the state is on the 45 degree line and their technology levels are equal. The reason for this willingness comes from Arrow once again. In this context, however, the logic of Arrow is enhanced rather than reversed. The firms are willing to invest on the 45 degree line because investment is the only way they can obtain protection.

To see this, observe that although the policymaker cannot protect when the firms' capabilities are equal, she can protect if one firm were to invest and obtain a technological advantage. She will protect, therefore, if and only if the leader invests. This enhances the firm's incentive to invest and the standard Arrow effect as not only is competition reduced by investment, it is entirely eliminated and the investing firm becomes a monopolist. We refer to this as the *politically enhanced Arrow effect.*

In this situation investment is profitable for a firm on the 45 degree line if:

$$\pi^{M}(l+1,l) - c(l) \geq \pi^{L}(l,l). \tag{13}$$

This is similar to the conditions for duopoly and monopoly in Equations (7) and (8), respectively. The difference here is that the firm receives the profit of a protected monopolist when it invests but the duopoly profit otherwise. Thus, the smallest l with which (13) holds with equality, which we denote by IC_{EA} for 'enhanced Arrow,' is higher than even duopoly.

The enhanced Arrow effect applies only on the 45 degree line and, thus, the IC_{EA} threshold is defined only in that case. With firms willing to invest on the 45 degree line, it implies that the logic of Lemma 4 holds one step away from the 45 degree line as long as condition (13) holds. This delivers the following result.

Proposition 2 *When competitive pressure is relaxed and (12) holds, every steady state is given by* $(l^{**}, l^{**} - 1)$ *for some* $l^{**} \geq IC_{EA}$*, and the follower firm exits the market.*

This result can be seen in Figure 5. It depicts a potential dynamic path for the equilibrium in which investment passes the duopoly threshold with the leading firm holding a large technology advantage. Beyond the duopoly threshold the equilibrium behavior becomes clear. The leader no longer finds it profitable to invest and the state transitions vertically until reaching the 45 degree line. Progress to this point is staggered, with stretches of protection and temporary stability interspersed with periods of competition as the policymaker renews her leverage. As this path intersects the 45 degree line below the threshold IC_{EA}, the policymaker is happy to let the follower firm fully catch up. She knows, through the enhanced Arrow effect, that the firms will invest on the 45 degree line when given the opportunity. This creates a ratchet effect as the state moves off the 45 degree line and back to it repeatedly, with investment increasing along the path. This sequence finally ends once the IC_{EA} threshold is crossed. The steady state, $(l^{**}, l^{**} - 1)$, is off the diagonal and the follower firm permanently exits the market. At this state the policymaker protects the leader for a full κ periods and accepts the exit of the follower firm as she knows that, should she remove protection and let the follower catch up, neither firm will invest any more, the technology standard will not have any bite, and she wouldn't be able to extract any more rents.

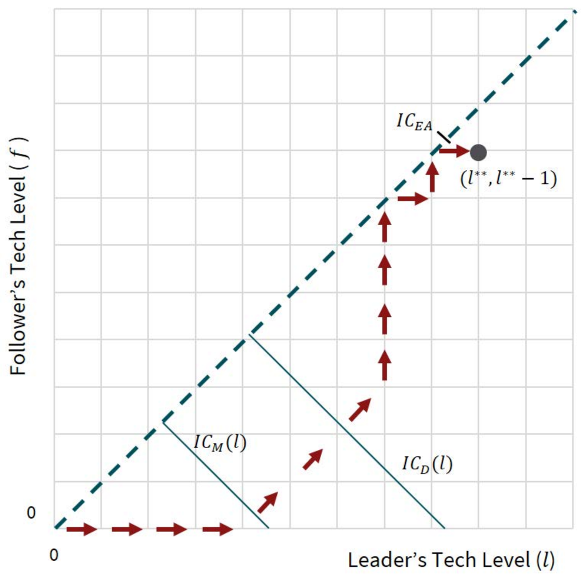

Figure 5: The steady state under relaxed competitive pressure and a potential equilibrium path. Threshold IC_{EA} is such that above it investment is no longer profitable at state (l, l) if protection will be offered at state $(l + 1, l)$. The red arrows illustrate the equilibrium transitional path. The gray dot at $(l^{**}, l^{**} - 1)$ represents the steady state. The policymaker protects and the follower eventually permanently exits.

The steady state is striking for what it implies about competition and protection. In contrast to Proposition 1, the leading firm is not protected in the steady state. Moreover, it faces no competition—as the follower firm exits the market—and it has attained a high level of technology. To an observer, this outcome would suggest a firm has earned market dominance through high technological performance. However, the full equilibrium path belies this interpretation. Political intervention is a mainstay along the equilibrium path and the final outcome is predetermined once the initial advantage is obtained even when, as in our model, it is determined by luck.[20] This is not to deny the high technology level of the final steady state, but it does imply that fairness had little to do with it.

[20]With myopic firms this conclusion depends on the tie-breaking rule when the state returns to the 45 degree line. If tie-breaking is random then the crucial stroke of luck for the firms is the final random selection of a firm to invest rather than the first. Our preferred tie-breaking rule is that the firm that was leading previously is given the opportunity to invest. This ensures the importance of the stroke of luck at the origin of the market. We prefer this rule as it reflects the market outcome when firms are forward-looking. If the tie-breaking rule at the 45 degree line were random, a leading firm that is forward-looking would invest preemptively to always maintain its lead and avoid being subject to that randomization.

4.2 Welfare

In the steady states of both Propositions 1 and 2 there is no competition and the leading firm operates as a monopolist; in Proposition 1 because the leader is protected politically, and in Proposition 2 because the follower firm has exited the market. Therefore, a comparison of consumer welfare between these states depends only on the level of investment by the leading firm.

We establish that a sufficient condition for the steady state in Proposition 2 to strictly dominate that in Proposition 1 is that the share of surplus going to the policymaker is sufficiently small. In this case, weaker competitive pressure leads to strictly greater market efficiency.

The logic for this result follows from the original Arrow effect. Assumption 4 requires that a monopolist has a lower incentive to invest than a duopolist, regardless of the follower firm's technology level. As the protected monopolist's profit can be rearranged as $\pi^M(l, f) = (1 - \rho)\hat{\pi}^M(l) + \rho\pi^L(l, f)$, it has a lower incentive to invest than the duopolist for any combination of follower technology levels as long as ρ is small.

Lemma 6 *There is a $\rho' \geq 0$ such that for all $\rho \in [0, \rho']$ and $l^{\max} \geq l \geq f+1, f'+1 \geq 1$, we have*

$$\pi^M(l+1, f) - \pi^M(l, f) \leq \pi^L(l+1, f') - \pi^L(l, f').$$

The protected monopolist's profit converges to that of the unconstrained monopolist as ρ decreases and the rents of the policymaker disappear. For sufficiently small ρ, therefore, the steady state in Lemma 2 with guaranteed protection involves a lower investment level than the steady state of Lemma 1 under duopoly.

As these investment levels provide the upper and lower bounds, respectively, on the steady states in the propositions, it follows that a sufficient (though not necessary) condition for investment in the steady state in Proposition 1 to be dominated by that in Proposition 2 is that $\rho \leq \rho'$. Recall that the leader's steady state technology level is l^* in Proposition 1 and l^{**} in Proposition 2.

Proposition 3 *Suppose the premises of Propositions 1 and 2 hold. A sufficient condition for $l^{**} > l^*$ is $\rho \leq \rho'$.*

Proposition 3 implies that relaxing competitive pressure can improve market efficiency when that market is intermediated by a strategic policymaker. This ordering reflects a balance of distortions. When competitive pressure is reduced there is a direct negative effect on welfare through the standard economic forces (if the competitor disappears the market switches from competitive to monopoly). In addition, there is an indirect political effect, which is that the power of the policymaker is weakened. Both forces affect market efficiency, with the economic effect decreasing efficiency whereas the political effect increases it. Proposition 3 establishes that the latter effect dominates for sure when the policymaker's ability to extract rents is not too great.

Proposition 3 compares the steady states but not the path to reach these points. A welfare analysis that includes the path only strengthens the ranking in Proposition 3. Along the path the market is competitive for many periods with the relaxed competition of Proposition 2, whereas the market is never competitive on the path of Proposition 1.

5 Discussion

5.1 The Distortions of Politics.

The policymaking side of the model combines two standard elements of political environments. First, the policymaker is self-interested. Second, she lacks commitment power. Both elements play an important role in the mechanism. To disentangle the role of each, we discuss briefly the resulting behavior when one or both of these elements does not hold. We focus on the specification of the model in which the follower never exits the market and keep the discussion informal (formal statements and proofs are contained in the Supplementary Appendix).

Full commitment power. Commitment power better enables the policymaker to reward or punish investment. As she is far-sighted, this means a self-interested policymaker has more ability to maneuver the market to her preferred steady state. This does not negate the reverse Arrow effect, rather it magnifies it, and causes market inefficiency to increase.

To see why, observe that the policymaker's rents decrease in the leading firm's technology level and increase in the tightness of market competition, conditional on a difference existing such that protection remains effective. Thus, the optimal state for the self-interested policymaker is $(1, 0)$. The policymaker is able to ensure this state is reached and never left by committing to remove protection should the leader invest beyond it. Thus, by committing to the reverse Arrow effect early, the policymaker can use it to her own advantage.

Commitment power increases market inefficiency because it doesn't solve the bargaining problem between the policymaker and the leading firm. Their joint surplus is maximized by the level of investment a monopolist would undertake, yet with a sharing rule dependant on the value of protection, the monopoly outcome is not optimal for the policymaker. Thus, commitment power does not remove the wedge between the interests of the two players, rather it allows the policymaker to leverage her response to that wedge even at the expense of overall market efficiency.

Benevolent social planner. A social-welfare maximizing policymaker wishes to leverage Arrow as well, although in this case it is the enhanced Arrow effect that she can use to her advantage. The enhanced Arrow effect can increase investment beyond the duopoly level and, therefore, correct the classic underinvestment that results from firms not internalizing the social benefit of innovation. To a benevolent and patient policymaker, the short-term cost of monopoly is worth the long-term benefit of higher technological levels.

The difficulty for the policymaker is in implementing this effect. Once the investment is undertaken, the policymaker would prefer to renege and not protect to avoid the cost of monopoly. Anticipating this, firms do not invest beyond the duopoly threshold and the logic of enhanced Arrow breaks down. It follows that protection never occurs in equilibrium, and the equilibrium trajectory and steady state is simply that given by duopoly in Lemma 1.

Benevolent social planner with commitment. Commitment power allows the policymaker to solve her time-inconsistency problem and leverage the enhanced Arrow effect to her benefit. By committing to reward investment with protection, the policymaker can incentivize investment beyond the duopoly threshold and up to the IC_{EA} level. This is not the first best as the cost of this incentive is temporary monopoly power, yet in the steady state the policymaker restores competition and, as long as she is sufficiently patient, the net effect is positive.[21]

The dual political distortions. The reverse and the enhanced Arrow effects represent two distortions in markets caused by political intervention. The reverse Arrow

[21] This is logically equivalent to a patent mechanism. This shows how the logic of patents may be more widespread throughout policymaking than the narrow confines of the formal patent system.

effect follows from the self-interest of the policymaker and plays no role without it. In contrast, the enhanced Arrow effect follows from a combination of social-mindedness and commitment, playing an important role when both or neither are present.

The combination of self-interest and lack of commitment are mainstays of political economy models. An important result is that an inability to commit to who holds political power—and, therefore, the inability to commit to the sharing of future surplus—can distort economic outcomes away from efficiency (Acemoglu & Robinson 2000, Acemoglu 2006, Acemoglu et al. 2008). Our model shows inefficiency can arise even when political power is not contested. In our model political power is held throughout by the same policymaker. What changes instead is the value of policy making power itself. By explicitly modeling competition within the market, we show how changes in the nature of competition can change the balance between markets and politics and how that can undermine efficiency.

5.2 Model Robustness.

Our model provides a simple framework to illustrate a mechanism through which market and political outcomes are linked. For clarity and tractability, we make several strong assumptions. In this section, we relax the assumption of short-sighted firms and show that our core insight is robust. We develop this extension formally in the Supplementary Appendix, along with a second extension that adds an investment cost for the follower.

Suppose the firms discount the future at rate $\beta > 0$. This does not challenge the conditions of Assumptions 1 or 3, though the firms do now internalize the long-run benefit and have a stronger incentive to invest. This increases the investment thresholds for both duopoly and monopoly, which now become:

$$f = IC_D^{\beta}(l): \qquad \frac{1}{1-\beta}\pi^L(l+1,f) - c(l) = \frac{1}{1-\beta}\pi^L(l,f) \tag{14}$$

$$f = IC_M^{\beta}(l): \qquad \frac{1}{1-\beta}\pi^M(l+1,f) - c(l) = \frac{1}{1-\beta}\pi^M(l,f). \tag{15}$$

The threshold IC_P for the policymaker does not change from the main model, as the policymaker's preferences are unchanged.

Far-sighted firms does imply that the reverse Arrow effect no longer follows from Assumption 3: even if the policymaker lifts protection following investment, the leader might still invest in order to increase his expected continuation payoff. Though the logic of the reverse Arrow effect may not hold globally, we can still show that it holds near the indifference curve IC_M^β. This implies less investment and lower technology in equilibrium compared to the guaranteed monopoly case.

To see why the reverse Arrow effect eventually holds, note that near the IC_M^β curve the leader is close to indifferent between no investment and investment given guaranteed protection. Thus, if protection is offered strategically, the leader will stop investing earlier if doing so causes the removal of protection. The loss in continuation payoff even from a one-period loss in protection is sufficient to discourage further investment. The higher is the value of political protection, the less inclined is the leader to invest through periods without protection, and the more binding is the reverse Arrow effect.

5.3 Connections to Practice

The model is highly stylized and meant to highlight a mechanism through which politics and markets interact. The core mechanism is not particular to the specific details of the model, and similar forces should emerge from other regulatory barriers to entry, like permitting or import restrictions. In this section we explore touch-points between our model and practice. At a high level, it is uncontroversial that lobbying is important in practice, and that government policies can block entry to the market or inhibit competition in some other way. In this discussion, we focus on the features and predictions that are novel to our model.

The novelty in our model is that influence activities and government protection are related to the technology levels of the firms. In the equilibrium of Proposition 1, the firm initially invests in technology to increase its capability-based market power, begins to lobby for political protection only after it has obtained a technology lead, and then shuts down investment and relies only on political protection once that lead is sufficiently large. This pattern of resource allocation is evident in recent work by Akcigit et al. (2021) on Italian firms. They show that as firms increase their market share, they decrease their use of productive, innovation-based growth strategies and increase their reliance on non-productive strategies to hold onto their dominant market positions, including investments in political connections.[22]

[22]A related prediction is that lobbying and protection is positively related to market concentration. Bombardini & Trebbi (2012) and Kim (2017) provide evidence from trade consistent with this

The equilibrium of Proposition 2 predicts a more subtle relationship between technology levels and government protection, generating a non-monotonicity in which the leader stops lobbying and loses political protection at its maximum technology level, albeit precisely when competition has disappeared and political protection is no longer valuable. This steady state offers an intriguing resolution to the long-standing puzzle of why there is so little money in American politics relative to the value that is at stake (Ansolabehere et al. 2003). By explicitly tying lobbying to market structure, and showing that capability-based and politically-based market power are substitutes, our model shows that there may be little money in politics because, given the state of market competition, it is simply not needed. This argument relies on the policymaker holding limited tools to either restrain or enhance competition. It is interesting that the dramatic increase in lobbying expenditures by big tech companies in the US is correlated with the increasing prominence of calls for antitrust action against them and the strengthening of regulatory tools.

The model also makes predictions on investment levels in technology and protection. The striking feature of Proposition 1 is that, because of the reverse Arrow effect, the investment level in the presence of a strategic policymaker is below what would arise if the leader were always protected. In practice it is difficult to determine whether an investment level is consistent with this prediction as the counterfactual is not observed. The best evidence, albeit suggestive, comes from market transitions during episodes of regulation and deregulation.

The classic example of AT&T is illustrative.[23] Following the expiration of its key telephone patents in 1893 and 1894, AT&T faced an explosion in competition. AT&T responded by aggressively rolling out its network nationwide and by buying up competitors. The prospect of a market leader unchallenged by competition was too much for policymakers and the government threatened antitrust action. This action ended when the two parties settled with the "Kingsbury Commitment" in 1913.

Although nominally meant to restrain AT&T's market power, the Kingsbury Commitment only served to remove competition and institutionalize AT&T's monopoly.[24]

prediction.

[23] In what follows we do not seek to match AT&T's long history literally to the path of equilibrium in Proposition 1. Instead we match eras and behaviors in AT&T's history to incentives within our model.

[24] As Kellogg et al. (1992, p. 17) attest, "To judge by actions, then, rather than words, government officials had no strong objection to monopoly telephone service. It was just that the Bell empire had been getting too big and wealthy."

The agreement erected barriers to further entry, and protected AT&T from the competition that did remain by allowing the company and the remaining independent operators to swap customers so that each held a monopoly in its region (Brock 1981). The difference being that now AT&T's monopoly was under the protection, and close supervision, of local and federal regulators.

At the time of regulation, AT&T had a cutting-edge network. Over the fifty-plus years of regulation, however, AT&T underinvested in its network. By the 1970's there was a series of high-profile network failures in New York and other large cities, and the quality of the network was well behind what was possible, and what an unconstrained firm would have achieved (Coll 1986, Temin 1987, Olley & Pakes 1996, Wu 2018). Moreover, despite the technological marvel of Bell Labs, many technological innovations were not implemented or, at best, were delayed by a decade or more (Hausman 1997).

One new technology that AT&T hoped would open up a new market was cell phones. Despite the technology being ready to roll out in the early 1970's, it wasn't approved by the FCC until 1983. Throughout that period, AT&T argued that, given its investment and network efficiencies, it should be the monopoly provider of service in each MSA. Nevertheless, the FCC decided, after much hesitation, that there should be two cellular providers in each MSA. As Hausman (1997, p.18) observes: "This duopoly situation was a departure for the commission, which previously had not allowed competition." This dynamic resonates with the reverse Arrow effect that is core to our model. AT&T's deviated by investing beyond the steady state, only to be rewarded for its investment, to its chagrin, by the removal of monopoly protection and an increase in competition.

The AT&T monopoly on telephones ended in 1982 with the signing of the consent decree with the government.[25] It is telling that, after a brief period of competition, monopoly power in many segments of the market was soon restored with the reconsolidation of the "baby bells" and SBC's eventual acquisition of the AT&T parent company. Although many forces were at work in the economy and society more broadly, this period of investment, competitor catch-up, and restoration of monopoly in a still-heavily regulated industry resonates with the dynamic in our model should the leader invest beyond the equilibrium level.

[25] Traces of the reverse Arrow effect are evident here also, as the break-up of AT&T coincided with the appointment of John deButts as Chairman and his vow to "Reawaken the spirit of AT&T's declining empire" (Coll 1986, p.10) (see also Temin (1987)).

5.4 Market Power and Antitrust

The rise in market power of recent decades is notable in that it is heterogeneous within industries. As Eeckhout (2021, p. 1345) puts it, "Rather than business as a whole dominating the economy, it is more accurate to state that some large firms dominate the vast majority of other firms." This is consistent with the dynamic in our model applied broadly across the economy.

One reason put forward to explain the systematic growth in market power has been lax antitrust enforcement, particularly in the United States (Philippon 2019). This has led to calls to not only tighten enforcement, but also to rethink the purpose of antitrust, and its appropriate goals, in what has come to be known as the *New Brandesian* movement (Wu 2018).

The New Brandesians argue that antitrust should focus on the level of competition per se rather than the outcome measure of consumer surplus. A possible interpretation and formalization of this position can be seen through the lens of our model, in particular the equilibrium of Proposition 1.

In the context of regulating markets, an important distinction lies between the level of an individual market and the economy as a whole. Our model describes an individual market, with firms interacting with a regulator or elected official best thought of as possessing power over competition within that market.

Should the level of inefficiency grow too large, however, an economy-wide level policymaker may intervene. This is a reasonable description of the end of AT&T's monopoly, the deregulation of trucking and airlines, Teddy Roosevelt's trust-busting, and the attempted break-up of Microsoft. Indeed, avoiding this fate by compartmentalizing AT&T's business was a key motivation for the initial Kingsbury Commitment of 1913. Kellogg et al. (1992, p. 17) argue, "This was especially true for state regulators. For them, a local telephone monopoly was both welcome and convenient. The problem with the burgeoning Bell System was that it had been growing larger than local politics."[26]

An interpretation of the New Brandesian argument is that dominant firms, particularly the big tech firms, have grown so large as to overwhelm politics at a system-wide level. When this happens, as argued 80 years ago by Franklin Roosevelt's head of

[26]Further cementing local control of the AT&T protected monopoly, the Willis-Graham Act of 1921 exempted telephone mergers from antitrust review if approved by the regulators (Brock 1981, p.156). Similarly, toward the end of AT&T's era of monopoly, state regulators were aligned with AT&T against the pro-competitive policies of the FCC (Brock 1994, p.150).

the Antitrust Division in the Department of Justice, Thurman Arnold (1943), big business subsumes powers of the state:

> "Monopolies enter into politics using money and economic coercion to maintain themselves in power, making alliances with other powerful groups against the interests of consumers and independent producers. In short, they will become a sort of independent state within a state, ... dealing on equal terms with the executive and legislative branches of the government and defying governmental authority if necessary with the self-righteousness of an independent sovereign."

A corrective to this outcome is to create new tools for policymakers or change how existing tools are used. This motivates a refocus of antitrust from the narrow economic measure of consumer surplus within a market to an aggregate outcome that preserves the power of the state.

This interpretation of the New Brandesians reflects a melding of the ideas in our model and those in recent work on the dynamics of antitrust. Nocke & Whinston (2010) and Mermelstein et al. (2020) develop models in which an antitrust regulator must anticipate how a merger will affect subsequent investments by firms, future mergers, and the resulting competitive effects. Our model suggests that antitrust regulators must also allow for the subsequent behavior of other policymakers.

For instance, if a merger leads to a clear market leader that wins protection from an industry regulator, that prospect of monopoly power should be factored into merger reviews by the antitrust authority. And if the resulting market dominance should grow so large as to overwhelm the antitrust regulator itself, then the evaluation of the merger must go well beyond a narrow measure of consumer surplus. Adopting this perspective is to acknowledge that the guardrails on market competition are endogenous, determined by policymakers today and in the future, and that anticipating these effects is essential to achieving efficient market outcomes.

6 Conclusion

The focus of the political economy literature is on the choice of a policy, in which political power varies in the design of institutions and the identity of those who make the decisions. We have shown in this paper that the value of political power—the power of politics itself—varies as the market environment varies. For a fixed set of political tools, the command of policymakers over the economy and society changes as market conditions change. This, in turn, alters the impact of business on society.

The core insight is that when markets and politics co-evolve, the interests of firms and the policymaker are aligned but not perfectly aligned. This has ramifications for the outcomes in both domains. We build a model to capture these incentives and characterize the outcomes they produce. The policymaker cares about rents and the firms care about market power, and the market and political outcomes reflect how these forces balance out. Many practical details are left out or included in a reduced form. Adding richness to the model will affect this balance and add nuance to the predictions, to be sure, but not fundamentally change the logic for how markets and politics interact.

There are many natural ways to extend our model beyond those discussed in the previous section. On the market side, the number of firms and the structure of market competition are promising directions to explore. On the policy side, the natural extension is to multiple policymakers and instituting a degree of political competition. Political institutions are often structured hierarchically, from legislator down to regulator. Incorporating this into the model not only adds an agency problem, it opens up the question of where and not just how much firms lobby and transfer rents.

The motivations of policymakers also offers scope to broaden the applicability of the underlying insights. In addition to rents and consumer welfare, policymakers care about their careers, about policy itself, or building bureaucratic empires. These motivations can generate the same incentive to 'manage competition' as emerges for a rent-seeking policymaker. For example, a regulator will be out of a job if she solves the underlying policy issue. To avoid rendering herself obsolete, a career-minded policymaker may 'manage the policy issue' in the same way that the self-interested policymaker here manages competition.

A particularly intriguing extension is to explore a balance between political and economic goals. In our model, political power is the means to the end of market power. Some important political goals stand aside from economic outcomes, and market power may be the means toward those ends. Exploring the interdependence of politics and markets more deeply is of considerable importance.

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Appendix

A Proofs from Section 3

A.1 Preliminaries

Let $l^{\max}$ be the smallest l such that there does not exist $f \in [0,l]$ for which

$$\hat{\pi}^{M}(l+1) - c(l) \geq \pi^{L}(l,f). \tag{A.1}$$

The myopic leader never invests if $l \geq l^{\max}$. Hence, we will focus on $(l,f) \in \mathscr{L}^{*} := \left\{(l',f') \in \mathbb{Z}_{+}^{2} : l^{\max} \geq l' \geq f'\right\}$. We write $l \in \mathscr{L}_{1}^{*} := \{l' \in \mathbb{Z}_{+} : \exists f \geq 0 \text{ such that } l^{\max} \geq l' \geq f\} = \{l' \in \mathbb{Z}_{+} : l' \leq l^{\max}\}$, and $f \in \mathscr{L}_{2}^{*} := \{f' \in \mathbb{Z}_{+} : \exists l \text{ such that } l^{\max} \geq l \geq f'\} = \{f' \in \mathbb{Z}_{+} : f \leq l^{\max}\}$. As mentioned in the main text, we define $\pi(l,f)$ for non-integer values. Thus, it is useful to also define $\bar{\mathscr{L}}^{*} := \left\{(l,f) \in \mathbb{R}_{+}^{2} : l^{\max} \geq l \geq f\right\}$ by replacing $\mathbb{Z}$ with $\mathbb{R}$. $\bar{\mathscr{L}}_{1}^{*}$ and $\bar{\mathscr{L}}_{2}^{*}$ are similarly defined.

As stated in footnote 15 in the main text, we define $\pi^{P}(l,l) = \rho\left(\hat{\pi}^{M}(l) - \pi^{L}(l,l)\right)$. Although protection is not feasible at (l,l), defining π^{P} for (l,l) eases the notation.

A.2 Proof of Lemma 1

For each $l \in \mathscr{L}_{1}^{*}$, we define $\hat{IC}_{D}(l)$ as the largest $f \in [0,l]$ such that

$$\pi^{L}(l+1,f) - c(l) \geq \pi^{L}(l,f). \tag{A.2}$$

If such f does not exist (that is, investment is always unprofitable), define $\hat{IC}_{D}(l) = -1$. Then, if $\hat{IC}_{D}(l) = l$ (that is, investment is always profitable), we define $IC_{D}(l) = l^{\max}$. Otherwise, we define $IC_{D}(l) = \hat{IC}_{D}(l)$

Then, Assumption 1 and inequality (A.2) imply that the leader invests if $f < IC_{D}(l)$ and only if $f \leq IC_{D}(l)$. In addition, for each $(l,f) \in \mathscr{L}^{*}$, $\pi^{L}(l+2,f) - c(l+1) \geq \pi^{L}(l+1,f)$ implies $\pi^{L}(l+1,f) - c(l) \geq \pi^{L}(l,f)$ given increasing $c(l)$ and condition (2) of Assumption 1. Thus, for each $l \in \mathscr{L}_{1}^{*}$,

$$IC_{D}(l+1) - IC_{D}(l) \leq 0. \tag{A.3}$$

A.3 Proof of Lemma 2

Given $\pi^P(l,f) = \rho\left(\hat{\pi}^M(l) - \pi^L(l,f)\right)$ and hence $\pi^M(l,f) = (1-\rho)\hat{\pi}^M(l) + \rho\pi^L(l,f)$, Assumptions 1 and 2 imply that, for each $l \geq f \geq 0$, we have

$$\frac{\partial^2}{\partial l \partial f}\pi^M(l,f) \leq 0 \text{ and } \frac{\partial^2}{\partial l^2}\pi^M(l,f) \leq 0. \tag{A.4}$$

We define $\hat{IC}_M(l)$ as the largest $f \in [0,l]$ such that

$$\pi^M(l+1,f) - c(l) \geq \pi^M(l,f). \tag{A.5}$$

If such f does not exist (that is, investment is always unprofitable), then define $\hat{IC}_M(l) = -1$. Then, if $\hat{IC}_M(l) = l$ (that is, investment is always profitable), we define $IC_M(l) = l^{\max}$. Otherwise, we define $IC_M(l) = \hat{IC}_M(l)$.

Conditions (A.4) and (A.5) imply that the leader invests if $f < IC_M(l)$ and only if $f \leq IC_M(l)$. In addition, for each $(l,f) \in \mathscr{L}^*$, $\pi^M(l+2,f) - c(l+1) \geq \pi^M(l+1,f)$ implies $\pi^M(l+1,f) - c(l) \geq \pi^M(l,f)$ given increasing $c(l)$ and (A.4). Thus, for each $l \in \mathscr{L}_1^*$,

$$IC_M(l+1) - IC_M(l) \leq 0. \tag{A.6}$$

B Proof from Section 4

B.1 Proof of Lemma 3

Note that conditions (10) and (11) are equivalent to

$$(1-\delta)\frac{\partial}{\partial l}\pi^P(l,f) - \delta \min_{s\in[0,1]}\left(\frac{\partial^2}{\partial l \partial f}\pi^P(l,f+s)\right) \leq 0. \tag{B.1}$$

$$(1-\delta)\left[\frac{\partial}{\partial l}\pi^P(l,f) + \frac{\partial}{\partial f}\pi^P(l,f)\right] - \delta \max_{s\in[0,1]}\left[\frac{\partial^2}{\partial l \partial f}\pi^P(l,f+s) + \frac{\partial^2}{\partial f^2}\pi^P(l,f+s)\right] \geq 0. \tag{B.2}$$

First, we derive the following two inequalities: For each $(l+t,f) \in \bar{\mathscr{L}}^*$ with $l+t > f+1$, we have

$$\frac{d}{dt}\left(\pi^P(l+t,f) - \delta\pi^P(l+t,f+1)\right) \leq 0, \tag{B.3}$$

and, for each $(l+t, f+t) \in \bar{\mathscr{L}}^*$ with $l+t > f+1+t$, we have

$$\frac{d}{dt}\left(\pi^P(l+t, f+t) - \delta\pi^P(l+t, f+1+t)\right) \geq 0. \tag{B.4}$$

Note that the derivative is well-defined. Then, (B.3) can be written as

$$(1-\delta)\frac{\partial}{\partial l}\pi^P(l+t, f) - \delta\left(\frac{\partial}{\partial l}\pi^P(l+t, f+1) - \frac{\partial}{\partial l}\pi^P(l+t, f)\right) \leq 0.$$

By the intermediate value theorem,

$$\frac{\partial}{\partial l}\pi^P(l+t, f+1) - \frac{\partial}{\partial l}\pi^P(l+t, f) \geq \min_{s\in[0,1]}\left(\frac{\partial^2}{\partial l \partial f}\pi^P(l+t, f+s)\right).$$

Hence (B.1) implies the result; similarly, (B.4) can be written as

$$\begin{aligned}(1-\delta)&\left(\frac{\partial}{\partial l}\pi^P(l+t, f+t) + \frac{\partial}{\partial f}\pi^P(l+t, f+t)\right)\\ &+\delta\left(\frac{\partial}{\partial l}\pi^P(l+t, f+t) + \frac{\partial}{\partial f}\pi^P(l+t, f+t) - \frac{\partial}{\partial l}\pi^P(l+t, f+1+t)\right.\\ &\left.\qquad - \frac{\partial}{\partial f}\pi^P(l+t, f+1+t)\right) \geq 0.\end{aligned} \tag{B.5}$$

By the intermediate value theorem,

$$\begin{aligned}&\frac{\partial}{\partial l}\pi^P(l+t, f+t) + \frac{\partial}{\partial f}\pi^P(l+t, f+t)\\ &\qquad - \frac{\partial}{\partial l}\pi^P(l+t, f+1+t) - \frac{\partial}{\partial f}\pi^P(l+t, f+1+t)\\ &\qquad \geq \min_{s\in[0,1]} -\left(\frac{\partial^2}{\partial l \partial f}\pi^P(l, f+s) + \frac{\partial^2}{\partial f^2}\pi^P(l, f+s)\right)\\ &\qquad = -\max_{s\in[0,1]}\left(\frac{\partial^2}{\partial l \partial f}\pi^P(l, f+s) + \frac{\partial^2}{\partial f^2}\pi^P(l, f+s)\right).\end{aligned} \tag{B.6}$$

Thus, (B.2) implies the result.

Second, we prove that, for each $l \geq \underline{l}$, both $IC_P(l)$ and $IC_P(l+1)$ are well-defined. To see why, it suffices to show that (i) $\pi^P(l, l-1) \geq \delta\pi^P(l, l)$ and (ii) if there exists $f \in [0, l-1]$ satisfying $\pi^P(l, f) = \delta\pi^P(l, f+1)$, then such f is unique.

To show (i), for each $\hat{l} \geq l$, we calculate (B.4) given $(\underline{l}+t, \underline{l}+t-1)$ for each t and then integrate it over $t \in \left[0, \hat{l} - \underline{l}\right]$ to yield

$$0 \leq \pi^P\left(\hat{l}, \hat{l} - 1\right) - \delta\pi^P\left(\hat{l}, \hat{l}\right) - \left(\pi^P\left(\underline{l}, \underline{l} - 1\right) - \delta\pi^P\left(\underline{l}, \underline{l}\right)\right)$$
$$= \pi^P\left(\hat{l}, \hat{l} - 1\right) - \delta\pi^P\left(\hat{l}, \hat{l}\right).$$

For (ii), it suffices to show that $\pi^P(l, f) - \delta\pi^P(l, f+1)$ is increasing in f, which follows from

$$\frac{\partial}{\partial f}\left(\pi^P(l, f) - \delta\pi^P(l, f+1)\right) = \frac{\partial}{\partial f}\left((1-\delta)\pi^P(l, f) - \delta\pi^P(l, f+1) - \pi^P(l, f)\right)$$
$$= (1-\delta)\frac{\partial}{\partial f}\pi^P(l, f) - \delta\frac{\partial}{\partial f}\left(\pi^P(l, f+1) - \pi^P(l, f)\right), \quad \text{(B.7)}$$

which is non-negative given Assumption 1.

Third, we prove $IC_P(l+1) - IC_P(l) \geq 0$. Integrating (B.3) over $t \in [0, 1]$ implies that $\left(\pi^P(l+1, f) - \delta\pi^P(l+1, f+1)\right) - \left(\pi^P(l, f) - \delta\pi^P(l, f+1)\right) \leq 0$, and hence

$$\pi^P(l+1, f) - \delta\pi^P(l+1, f+1) \geq 0 \Rightarrow \pi^P(l, f) - \delta\pi^P(l, f+1) \geq 0. \quad \text{(B.8)}$$

Thus, if $(l+1, f)$ is above the IC_P curve, then (l, f) is also above the IC_P curve (and hence the slope of $IC_P(l)$ is no less than zero).

Finally, we prove $IC_P(l+1) - IC_P(l) \leq 1$. Integrating (B.4) over $t \in [0, 1]$ implies that $\left(\pi^P(l+1, f+1) - \delta\pi^P(l+1, f+2)\right) - \left(\pi^P(l, f) - \delta\pi^P(l, f+1)\right) \geq 0$, and hence

$$\pi^P(l, f) \geq \delta\pi^P(l, f+1) \Rightarrow \pi^P(l+1, f+1) \geq \delta\pi^P(l+1, f+2). \quad \text{(B.9)}$$

Thus, if (l, f) is above the IC_P curve, then $(l+1, f+1)$ is also above the IC_P curve (and hence the slope of $IC_P(l)$ is no more than one).

B.2 Proof of Proposition 1

Below, we summarize the argument for the proof, using auxiliary results that we prove in auxiliary lemmas provided in the Supplementary Appendix, Section 2.

To simplify notation, we henceforth call the technology level profile at the beginning of the period (that is, at the timing of the leader's decision) "*the ex ante state*," and we call the technology level profile after the leader's investment (that is, at the timing of the policymaker's decision) "*the interim state*."

Policymaker Threshold. For each l, we define $IC_P(l)$ as the smallest $f \in \mathscr{L}_2^*$ such that $f \leq l$ and

$$\pi^P(l, f) \geq \delta \pi^P(l, f+1). \tag{B.10}$$

If such f does not exist, then define $IC_P(l) = -1$. We derive the two results about $IC_P(l)$. First, by Auxiliary Lemma 2.1, $IC_P(l)$ is a proper threshold (the above inequality is satisfied if and only if $f \geq IC_P(l)$) and by Lemma 3 has a slope less than one.

Second, by Auxiliary Lemma 2.2, if the current state (l, f) satisfies $l \geq f + 1$ and $f \geq IC_P(l)$, then the policymaker prefers to stay in the current state: that is, for each t and each $(l', f') \in \mathscr{L}^*$ such that there exists a feasible path from (l, f) to (l', f') spending t periods, we have

$$\pi^P(l, f) > 1_{\{l' > f'\}} \delta^t \pi^P(l', f'). \tag{B.11}$$

Denote by $V(l, f)$ the policymaker's value function given the ex ante state (l, f). In particular, since no protection is feasible if $f = l$, (B.11) implies that, for each Markov perfect equilibrium and each $(l, f) \in \mathscr{L}^*$ with $l \geq f + 1$ and $f \geq IC_P(l)$,

$$\frac{\pi^P(l, f)}{1 - \delta} \geq \max\{V(l+1, f), \delta V(l, f+1)\}. \tag{B.12}$$

Regions. The ex ante state $(l, f) \in \mathscr{L}^*$ may fall into one of the three regions:

1. Region 1: $f \leq IC_P(l)$ and $f \geq IC_D(l)$. In this region, as will be seen, the leader does not invest (NI) and the policymaker does not protect (NP), except near the 45-degree line.

2. Region 2: $f \geq IC_P(l)$ and $f \geq IC_M(l)$. In this region, as will be seen, the leader does not invest (NI) and the policymaker protects (P) whenever $l > f$.

3. Region 3: $f \leq IC_P(l)$ and $f \leq IC_D(l)$ or $f \geq IC_P(l)$ and $f \leq IC_M(l)$.

Investment Threshold. Given Lemma 3, the IC_P curve intersects the 45-degree line at most once. Thus, depending on the location of the IC_P and IC_M curves, the following two cases are possible:

Case 1. The IC_P curve intersects with the l-axis at $(\hat{l}, 0)$ with $\hat{l} \geq 1$:

(a) IC_P and IC_M intersect in $\mathscr{L}^*$. In this case, let l_0 be the smallest l such that there exists $f \leq l-1$ for which (l, f) is in Region 2 and $(l, f-1)$ is below the IC_P curve: $f \geq IC_P(l)$, $f \geq IC_M(l)$, and $f - 1 \leq IC_P(l)$. Then, take f_0 satisfying $l_0 \geq f_0 + 1$, $f_0 \geq IC_P(l_0)$, $f_0 \geq IC_M(l_0)$, and $f_0 - 1 \leq IC_P(l_0)$. By definition, $(l_0, f_0 - 1)$ is *below* the IC_P curve and (l_0, f_0) is *above* the IC_P curve.

(b) IC_P and IC_M do not intersect in $\mathscr{L}^*$. Since the slope of the IC_P curve is less than one by Lemma 3, it means that $IC_M^{-1}(0) \leq \hat{l}$. Therefore, $\left(\lceil IC_M^{-1}(0) \rceil, 0\right)$ is in Region 2.

Case 2. The IC_P curve intersects with the l-axis at $(\hat{l}, 0)$ with $\hat{l} < 1$:

(a) IC_P and IC_M intersect in $\mathscr{L}^*$. In this case, let l_0 be the smallest l such that there exists $f \leq l-1$ so that (l, f) is in Region 2 and $(l, f-1)$ is below the IC_P curve: $f \geq IC_P(l)$, $f \geq IC_M(l)$, and $f - 1 \leq IC_P(l)$. Then, take f_0 satisfying $l_0 \geq f_0 + 1$, $f_0 \geq IC_P(l_0)$, $f_0 \geq IC_M(l_0)$, and $f_0 - 1 \leq IC_P(l_0)$. By definition, $(l_0, f_0 - 1)$ is *below* the IC_P curve and (l_0, f_0) is *above* the IC_P curve.

(b) IC_P and IC_M do not intersect in $\mathscr{L}^*$. In this case, let f_0 be the smallest f_0 such that $f_0 \geq IC_P(f_0 + 1)$. Define $l_0 = f_0 + 1$. Again, (l_0, f_0) is *above* the IC_P curve.

Given (l_0, f_0), for each f, define $L^*(f) = l_0 - (f_0 - f)$. In addition, let $\underline{f} \in \mathbb{Z}_+$ be the smallest $f \geq 0$ such that $(f+1, f)$ is above the IC_P curve. In Case 1, $\underline{f} = 0$, and in Case 2, $\underline{f} \geq 1$. In Proposition 1, we focus on Case 1. In Case 1(a), we define $\left(l^I, f^I\right) = (l_0, f_0)$. In the Supplementary Appendix we also cover Case 2. All the lemmas without reference to a specific case hold for all cases.

Equilibrium Uniqueness. The following lemma establishes equilibrium uniqueness given the form of renegotiation proofness described in the main text.

Lemma B.1 *The set of subgame perfect equilibrium (SPE) payoffs that satisfy renegotiation proofness exits and is unique at each ex ante state $(l, f) \in \mathscr{L}^*$ and also at each interim state $(l, f) \in \mathscr{L}^*$. In this renegotiation-proof subgame perfect equilibrium, the strategy is Markov: the leader's investment decision depends only on the* *ex ante state, and the policymaker's protection decision depends only on the interim state. Moreover, at each ex ante state $(l, f) \in \mathscr{L}^*$, if (NI, P) is incentive compatible, then (NI, P) is the equilibrium outcome.*

For $l \geq l^{\max}$, since the policymaker is a single decision maker, the result holds. By backward induction, we can also show that, except for (NI, P), the dynamic-game payoff profile of taking a certain action profile is determined, since the state transits to another state with higher l or f. For the action profile (NI, P), the next state will be the same as the current one, and so the payoff profile depends on the expectation of the continuation play. We apply Pareto criteria to select the equilibrium.

Given this result, in what follows, we refer to "equilibrium" as the unique renegotiation proof SPE. Let $\text{eqm}\,(l, f) \in \{I, NI\} \times \{P, NP\}$ be the equilibrium outcome given the ex ante state $(l, f) \in \mathscr{L}^*$.

Equilibrium Characterization. For simplicity, we assume that there is no $(l, f) \in \mathscr{L}^*$ such that $\pi^P(l, f) = \delta\pi^P(l, f + 1)$, $\pi^L(l + 1, f) - \pi^L(l, f) = c(l)$, or $\pi^M(l + 1, f) - \pi^M(l, f) = c(l)$.[1]

First, in Region 2, $\text{eqm}\,(l, f) = (NI, P)$ (Auxiliary Lemma 2.7). This follows from (B.12) and renegotiation proofness (note that the myopic leader always prefers P).

Next, in Region 1, $\text{eqm}\,(l, f) = (NI, NP)$, except near the 45-degree line (Auxiliary Lemma 2.8). Given that $f \geq IC_D(l)$, the leader does not invest if protection is not offered. Combined with the inductive argument, this implies that the policymaker does not protect the leader, without worrying about the effect of her current action on the leader's future investment decision.

Lastly, we analyze Region 3. In this region, we first show that, if the policymaker does not protect the leader at the interim state (l, f), then, for $(l - 1, f)$, either $\text{eqm}\,(l - 1, f) = (NI, P)$ or the policymaker does not protect the leader at the interim state $(l - 1, f)$ (Auxiliary Lemma 2.9). The result follows from Assumption 3. This implies that, at ex ante state (l, f), if $f \geq IC_P(l)$ and the policymaker does not protect the leader at the interim state $(l + 1, f)$, then the equilibrium outcome at (l, f) is (NI, P) (Auxiliary Lemma 2.10).

Next, we show that, once the leader invests at the ex ante state (l, f) and the policymaker protects the leader at the interim state $(l + 1, f)$, then protection will always be offered in the on-path continuation play. Specfically, for each $(l, f) \in \mathscr{L}^*$,

[1] Without this assumption, all the proofs go through with more tedious tie-breaking analysis based on renegotiation proofness.

suppose either the policymaker protects the leader at the interim state $(l+1, f)$ and $f \leq IC_M(l)$, or $\text{eqm}(l, f) = (I, P)$. Then, Auxiliary Lemma 2.3 shows that there exists $l' \geq l+1$ such that $\text{eqm}\left(\tilde{l}, f\right) = (I, P)$ for all $l \leq \tilde{l} \leq l'-1$ and $\text{eqm}(l', f) = (NI, P)$. The result holds because Assumption 3 implies that the leader stops investing as soon as protection is not expected after investment. This in particular implies that, if the policymaker protects the leader at the interim state (l, f), then her payoff is bounded by $\frac{\pi^P(l,f)}{1-\delta}$ (Auxiliary Lemma 2.11) since Assumption 4 implies that higher technology level for the leader reduces the policymaker's payoff.

We say *Condition (*) holds* for (l, f) if (i) $\text{eqm}(l, f) = (NI, P)$ and (ii) $(l, f-1)$ is below IC_P curve. By definition, (l_0, f_0) satisfies Condition (*) in Cases 1(a) and 2(a).[2] Define $L(f_0) = l_0$. The following lemma establishes the key inductive argument.

Lemma B.2 *In Cases 1(a) and 2(a), for each* $f \in \{f_0-1, f_0-2, ..., \underline{f}\}$*, there exists* $L(f) \leq L(f+1) - 1$ *such that Condition (*) holds for* $(L(f), f)$*.*

Proof. Since Condition (*) holds for (l_0, f_0), it suffices to prove that, for each $f \in \{\underline{f}+1, ..., f_0\}$, if there exists $L(f)$ such that Condition (*) holds for $(L(f), f)$, then there exists $L(f-1) \leq L(f) - 1$ such that Condition (*) holds for $(L(f-1), f-1)$.

First, note that no protection is offered at the interim state $(L(f), f-1)$. Suppose otherwise: protection is offered at the interim state $(L(f), f-1)$. Then Auxiliary Lemma 2.11 implies $V(L(f), f-1) \leq \frac{\pi^P(L(f), f-1)}{1-\delta}$. Since $(L(f), f-1)$ is below IC_P and $V(L(f), f) = \frac{\pi(L(f), f)}{1-\delta}$, protection is suboptimal.

Second, there exists $L(f-1) \leq L(f) - 1$ such that $\text{eqm}(L(f-1), f-1) = (NI, P)$ and $(L(f-1), f-2)$ is below IC_P —that is, (i) and (ii) of Condition (*) hold for $(L(f-1), f-1)$.

To see why, let $\tilde{L}(f-1)$ be the smallest $l \geq f$ such that $(l, f-1)$ is below the IC_P curve. We make the following three observations: (a) such l exists since we have assumed that $f - 1 \geq \underline{f}$; (b) we have $\tilde{L}(f-1) \leq L(f)$ since $(L(f), f-1)$ is below IC_P curve by (ii) of Condition (*) for f (inductive hypothesis); (c) since $\left(\tilde{L}(f-1), f-1\right)$ is below the IC_P curve and Lemma 3 implies that the slope of the IC_P curve is less than one, $\left(\tilde{L}(f-1)-1, f-2\right)$ is below the IC_P curve. Therefore, it remains to show that there exists $\tilde{l}$ such that $L(f) - 1 \geq \tilde{l} \geq \tilde{L}(f-1) - 1$ and the equilibrium outcome at $(\tilde{l}, f-1)$ is (NI, P) (once we show this, we can take $L(f-1)$ equal to such $\tilde{l}$).

[2] Although Proposition 1 considers Case 1 only, we cover Case 2 in the Supplementary Appendix, so it is useful to include Case 2(a) here.

Consider the following three cases:

(1) If $\tilde{L}(f-1) = L(f)$, since no protection is offered at interim state $(L(f), f-1)$, Auxiliary Lemma 2.10 implies eqm $\left(\tilde{L}(f-1)-1, f-1\right) = (NI, P)$. To see this, note that $\tilde{L}$ is defined as the smallest l such that $(l-1, f)$ is below the IC_P curve; hence, $\left(\tilde{L}(f-1)-1, f-1\right)$ is above IC_P, and $\tilde{l} = \tilde{L}(f-1)-1$ satisfies the claim.

(2) If $\tilde{L}(f-1) \leq L(f)-1$ and eqm $(l, f-1) = (NI, P)$ for some $l = \tilde{L}(f-1)-1, ..., L(f)-1$, then we can take $\tilde{l}$ equal to such l.

(3) If $\tilde{L}(f-1) \leq L(f)-1$ and eqm $(l, f-1) \neq (NI, P)$ for each $l = \tilde{L}(f-1)-1, ..., L(f)-1$, then by Auxiliary Lemma 2.9, no protection is offered at the interim state $\left(\tilde{L}(f-1), f-1\right)$. Since $\left(\tilde{L}(f-1)-1, f-1\right)$ is above the IC_P curve, Auxiliary Lemma 2.10 implies that eqm $\left(\tilde{L}(f-1)-1, f-1\right) = (NI, P)$, which is a contradiction. ■

In Cases 1(a) and 2(a), for each $f \geq \underline{f}$, let $L^{**}(f)$ be the smallest l with eqm $(l, f) = (NI, P)$. For $f \in \{\underline{f}, ..., f_0\}$, such l exists and $L^{**}(f) \leq L(f)$ by Lemma B.2. For $f \geq f_0$, since (l_0, f_0) is in Region 2, for each $f \geq f_0$, there exists l such that (l, f) is in Region 2 and hence eqm $(l, f) = (NI, P)$. Thus, for each $f \geq \underline{f}$, the cutoff $L^{**}(f)$ is well-defined.

Finally, Auxiliary Lemma 2.12 shows that, for each $f \geq \underline{f}$, given the smallest $l \geq f+1$ with eqm $(l, f) = (NI, P)$, protection is offered at interim state (l', f) with $f+1 \leq l' \leq l-1$. To see why, if it were not the case, then Auxiliary Lemma 2.10 implies that, as soon as l' becomes sufficiently small so that $(l'-1, f)$ is below IC_P curve, we have eqm $(l'-1, f) = (NI, P)$; but this is a contradiction to l being the smallest technology level with eqm $(l, f) = (NI, P)$ (the only complication is when $l' = f+1$ and hence protection is not feasible at $(l'-1, f)$.)

Note that Proposition 1 considers Case 1. If we have Case 1(a), since $\underline{f} = 0$, then $L^{**}(0)$ is the smallest $l \geq 1$ with eqm $(l, 0) = (NI, P)$. By Auxiliary Lemma 2.12, at the ex ante state $(0, 0)$, we have either eqm $(0, 0) = (NI, NP)$ (and $(0, 0)$ is the steady state) or eqm $(0, 0) = (I, P)$. By Auxiliary Lemma 2.3, the latter implies that the equilibrium path is $(0, 0) \to (1, 0) \to \cdots \to (L^{**}(0), 0)$. Together with $L^{**}(f) \leq L(f) \leq L^{*}(f) \leq l_0 - f_0 = l^I - f^I$, Proposition 1 holds.

Consider next Case 1(b). By Auxiliary Lemma 2.7, eqm $\left(\left\lceil IC_M^{-1}(0)\right\rceil, 0\right) = (NI, P)$. By Auxiliary Lemma 2.3, there exists $L^{**}(f) \leq \left\lceil IC_M^{-1}(0)\right\rceil$ such that the equilibrium path is $(0, 0) \to (1, 0) \to \cdots \to (L^{**}(0), 0)$. Thus, Proposition 1 holds.

B.3 Proof of Proposition 2

Thresholds and Conditions. Let $\mathscr{IC}_{EA}$ be the set of $(l, f) \in \mathscr{L}^*$ such that $\pi^M(l+1, f) - c(l) - \pi^L(l, f) \geq 0$. Note that the set $\mathscr{IC}_{EA}$ does not necessarily have a cutoff structure. That is, even if (l, f) is in $\mathscr{IC}_{EA}$, $(l, f-1)$ may not be in $\mathscr{IC}_{EA}$.[3]

Let IC_{EA} be the largest technology level $l \in \mathscr{L}^*$ such that $\pi^M(l'+1, l') - \pi^L(l', l') - c(l') \geq 0$ for all $l' \leq l$. Note that the case considered in Proposition 1, where $\widehat{l} \geq 1$ implies

$$IC_P(l) \leq l - 1, \tag{B.13}$$

for all $1 \leq l \leq l^{\max}$. In addition, to avoid a tedious tie-breaking, we assume that, for each $(l, f) \in \mathscr{L}^*$ and $y, y' \in \{L, M\}$, we have

$$\pi^y(l+1, f) - \pi^{y'}(l, f) \neq c(l). \tag{B.14}$$

Next, as in (B.11), for each $(l, f) \in \mathscr{L}^*$ satisfying $l \geq f + 1$ and $f \geq IC_P(l)$, t, and $(l', f') \in \mathscr{L}^*$ such that there exists a feasible path from (l, f) to (l', f') spending t periods:

$$\pi^P(l, f) > 1_{\{l' > f'\}} \delta^t \pi^P(l', f'). \tag{B.15}$$

Finally, Lemma 1 shows that Assumptions 1 and 4 imply that for each $l \in \mathscr{L}_1^*$,

$$IC_D(l+1) - IC_D(l) \leq 0 \text{ and } IC_D(l) \geq IC_M(l). \tag{B.16}$$

Equilibrium steady state characterization. Let (l, f, k) be the tuple of payoff-relevant states, where $k \in \{0, ..., \kappa\}$ indicates how many consecutive periods the leader has been protected. Having $k = \kappa$ means that the follower disappeared. The ex ante state (l, f, k) represents the state at the beginning of the period, while the interim state (l, f, k) represents the state after the leader's investment decision.

We say that the subgame perfect equilibrium is *weakly renegotiation-proof* if the policymaker breaks her indifferent between two actions by taking the action that gives the higher continuation payoff for the leader. We use weak renegotiation proof subgame perfect equilibrium as our equilibrium concept. In equilibrium, we show

[3] To see why, rewrite $\pi^M(l+1, f) - c(l) - \pi^L(l, f) \geq 0$ as $\pi^M(l+1, f) - \pi^L(l+1, f) + \pi^L(l+1, f) - c(l) - \pi^L(l, f) \geq 0$, or equivalently, $(1-\rho)\left[\hat{\pi}^M(l+1) - \pi^L(l+1, f)\right] + \pi^L(l+1, f) - \pi^L(l, f) - c(l) \geq 0$. The last three terms represent the benefit of investment in duopoly, which is decreasing in f. By contrast, the first term is proportional to the benefit of protection, which is increasing in f. Thus, it is not clear if the incentive to invest is higher or lower with higher f.

that the steady state technology level is no less than IC_{EA} (Proposition 2). To prove this result, we first provide a counterpart of Lemma B.1.

Lemma B.3 *The weak-renegotiation-proof subgame perfect equilibrium exists and is unique and Markov perfect.*

The formal proofs to this lemma and all auxiliary lemmas in this section are provided in the Supplementary Appendix Section 3.

In Lemma B.1, given the ex ante state (l, f), if the leader does not invest and the policymaker protects the leader, the next ex ante state is again (l, f). Here, given the ex ante state (l, f, k), if the leader does not invest and the policymaker protects the leader, the next ex ante state is $(l, f, k+1)$. Thus, the state is always "moving up" unless the follower has disappeared or the competition is head to head $(l = f)$, $k = 0$, and the leader does not invest. Since the policymaker has no choice in these exceptional cases, simple subgame perfection and backward induction implies uniqueness, except for tie-breaking. Given this lemma, we write the policymaker's value function at ex ante state (l, f, k) as $V(l, f, k)$.

We next pin down the state transition for (l, f) with $f \geq IC_P(l)$ and $f > IC_D(l)$. In this case, the leader does not invest unless investment leads to protection and no investment leads to no protection. Thus, the policymaker protects the leader if $l > f$ and $k < \kappa - 1$, and the leader does not invest unless the current state profile is on the 45-degree line. If the current state profile is on the 45-degree line, then $k = 0$. This is because the follower must be in the market in order to catch up to the leader for the state profile to reach the 45-degree line; once the state profile stays on the 45-degree line, protection is no longer feasible. Thus, no investment leads to no protection by feasibility, while investment leads to protection. Therefore, the firm with an investment opportunity invests if and only if $(l, f) \in \mathscr{IC}_{EA}$.

Lemma B.4 *For each (l, f, k) with $(l, f) \in \mathscr{L}^*$ and $k \in \{0, ..., \kappa\}$, the leader's equilibrium strategy satisfies the following:*

1. *If $l > f$ at the ex ante state (l, f, k), the leader does not invest if $f \geq IC_P(l)$ and $f \geq IC_D(l)$.*

2. *If $l = f$ at the ex ante state (l, f, k), then the firm with an investment opportunity invests if and only if $(l, f) \in \mathscr{IC}_{EA}$.*

The policymaker's equilibrium strategy satisfies the following:

3. *If $k = \kappa - 1$, then the policymaker does not protect the leader at the interim state (l, f, k) if and only if either $l - 1 > f$ or $(l, l) \in \mathscr{IC}_{EA}$.*

4. *If $f \geq IC_P(l)$, $f \geq IC_D(l)$, and $k < \kappa - 1$,*

   (a) *If $f = l$, the policymaker protects the leader at interim state $(l + 1, f, k)$.*

   (b) *If $f < l$, the policymaker protects the leader at interim state (l, f, k).*

5. *If $f \geq IC_P(l)$, then the value $V(l, f, k)$ at the ex ante state (l, f, k) is decreasing in k and $V(l, f, k) \leq \frac{\pi^P(l+1,l)}{1-\delta}$ if $f = l$ and $V(l, f, k) \leq \frac{\pi^P(l,f)}{1-\delta}$ if $f \leq l - 1$.*

Given Lemma B.4, to show that the leader's technology level is no less than IC_{EA} in the long run, it suffices to show that the equilibrium path reaches a state (l, f, k) with $f \geq IC_P(l)$, $f \geq IC_D(l)$, and $k \leq \kappa - 1$.

First, in Auxiliary Lemma 3.1, we consider an ex ante state $(l, f, \kappa - 1)$ and leader's investment decision $\iota \in \{0, 1\}$ at $(l, f, \kappa - 1)$ and show that, if the leader invests at the ex ante state $(l + \iota, f + 1, 0)$ or $l + \iota > f + 1$, then not protecting is optimal at the interim state $(l + \iota, f, \kappa - 1)$ given equation (12) in the main text. This is because protection is feasible in the continuation play after the policymaker does not protect the leader at the interim state $(l + \iota, f, \kappa - 1)$.

Second, Auxiliary Lemma 3.2 shows that equilibrium path reaches a state (l, f, k) either with $l \geq IC_{EA}$ or with $f \geq IC_P(l)$, $f \geq IC_D(l)$, and $k \leq \kappa - 1$. The result is obtained by noting that the steady state (l, f, k) satisfies either $l = f$ or $k = \kappa$ since otherwise either f increases without protection or k increases with protection. If the steady state is $(l, l, 0)$,[4] consider the last interim state $(l, l - 1, k)$ before reaching (l, l, k). At that interim state, the policymaker would be better off by protecting the leader, as her payoff would be zero once the ex ante state reaches $(l, l, 0)$. This is a contradiction.

If the steady state is (l, f, κ), then consider the last interim state $(l, f, \kappa - 1)$ before reaching (l, f, κ). By Auxiliary Lemma 3.1, we have $l = f - 1$ and the leader does not invest at the ex ante state $(l, f + 1, 0)$. Since protection is not feasible given $l = f + 1$, the leader not investing implies $f + 1 \geq IC_D(l) \geq IC_D(l + 1)$. Moreover, by (B.13), once the leader invests at the ex ante state $(l, f + 1, 0)$, the interim state $(l + 1, f + 1, 0)$ satisfies $f + 1 \geq IC_P(l + 1)$, and Lemma B.4 implies that the policymaker will protect the leader. Nonetheless, the leader does not invest.

[4] See above why $k = 0$ on the 45-degree line.

Thus, $(l, f+1) \notin \mathscr{IC}_{EA}$. Given $l = f+1$, we have $l \geq IC_{EA}$. This concludes the proof that in the steady state, the leader's technology level is no less than IC_{EA}.

B.4 Proof of Lemma 6

If ρ is equal to zero, then $\pi^M(l+1, f) - \pi^M(l, f) = \hat{\pi}^M(l+1) - \hat{\pi}^M(l)$ and hence the result holds from Assumption 4 with a strict inequality. Since the state space is finite, by the continuity of the payoff function with respect to ρ, the result holds.

B.5 Proof of Proposition 3

By Propositions 1 and 2, l^* is no higher than the solution to $IC_M(l)$ =0. Thus, $\pi^M(l^*+1, 0) - \pi^M(l^*, 0) \geq c(l^*)$. On the other hand, l^{**} is no less than the solution to $IC_D(l, f) = l$ and hence $\pi^L(l^{**}+1, l^{**}) - \pi^L(l^{**}, l^{**}) \leq c(l^{**})$.

If $l^* \geq l^{**}$, then since c is increasing, we have $\pi^M(l^*+1, 0) - \pi^M(l^*, 0) \geq \pi^L(l^{**}+1, l^{**}) - \pi^L(l^{**}, l^{**})$. Given Lemma 6, for $\rho < \rho'$, we have $\pi^M(l^*+1, 0) - \pi^M(l^*, 0) \leq \pi^L(l^*+1, l^{**}) - \pi^L(l^*, l^{**})$. By Lemma 6, this implies $l^{**} \geq l^*$, as desired.