Overlapping Ownership and Technology Adoption*

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Abstract

We analyze how overlapping ownership influences technology adoption in duopolistic innovation timing games with no information lags. In the absence of overlapping ownership, first-mover advantage drives a preemptive race, where both firms compete to become the leader, as described by Fudenberg and Tirole (1985). This results in early adoption (at high cost) and rent equalization. In contrast, we show that common or cross-ownership can slow down technology adoption. Beyond a certain threshold of overlapping ownership—which can be relatively low—a second-mover advantage emerges, shifting the preemptive race into a waiting game and ultimately leading to delayed technology diffusion and the elimination of rent equalization.

Key words: Common ownership; Overlapping ownership; Second-mover advantage; Technology adoption; Timing games; Waiting games

JEL Classification: L13; O31; O33

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1 Introduction

This paper analyses incentives for technology adoption in the presence of investors or firms with stakes in multiple competing firms (overlapping ownership).[1] In the last twenty years, many firms have experienced a significant change in their ownership structure driven by these types of investments. Davis (2008) calls the phenomenon the "new finance capitalism", whereby a small group of large investment funds have passive stakes in hundreds of rival companies. The participation of common investors in competitors have been facilitated by a lax regulation,[2] and it is by now extensive (Backus et al, 2021a), and becoming progressively more important over time (He and Huang, 2017).

Theoretical analyses show that common ownership tends to reduce the intensity of competition because firms internalize a share of the rivals' profit (Rotemberg, 1984; Bresnahan and Salop, 1986; Reynolds and Snapp, 1986; Farrell and Shapiro, 1990; Salop and O'Brien, 2000). Although recent empirical evidence confirms this finding in different industries, results are mixed and some works find non-statistically significant effect.[3] In practice, the phenomenon has raised concerns of competition authorities (Elhauge, 2016; Posner et al., 2017; Bebchuk et al., 2017; Schmalz, 2018; Azar and Schmalz, 2017), driven by fears that common ownership may indeed lead to higher prices and, consequently, higher mark-ups, which negatively affect both microeconomic levels (consumer surplus) and macroeconomic outcomes, and may even exacerbate inequality.[4]

The increased in horizontal shareholding began in the eighties and continues to the present day. Coincidentally, this period exhibits lower labor and capital shares, reduced business dynamism, and greater dividends and share buybacks.[5] More importantly to the focus of our paper, empirical evidence suggests that common ownership may have been negatively affecting innovative activity. Gutiérrez and Philippon (2017a) compare Tobin's

[1] We use the convention that overlapping ownership encompasses common and cross-ownership. Common ownership refers to the case where *investors* have stakes in different competing firms, while cross-ownership refers to the case where *firms* have stakes in other rival firms.

[2] Nain and Wang (2018) report that less than 1% of acquisitions are scrutinized by the Federal Trade Commission, and an even smaller proportion are completely blocked.

[3] For example, significant effects are found in the US airline industry (Azar, Schmalz and Tecu, 2018) and in the US banking industry (Azar, Raina and Schmalz, 2021). Additionally, Nain and Wang (2018) find that partial equity ownership between competitors causes higher prices and higher price-cost margins in a large, cross-industry sample in the US. However, some other works find non-statistically significant effect: O'Brien and Waehrer (2017), Lewellen and Lowry (2021), and Backus et al. (2021b).

[4] Elhauge (2016, 2020) discuss the positive relationship between common ownership and inequality, and show that intensive periods of anticompetitive behaviors (because of low antitrust enforcement) and high presence of common ownership correspond to high levels of inequality in the US.

[5] De Loecker, Eeckhout and Unger (2020) find evidence of a steady increase in markups in the US, from 21% in 1980 to 61% in 2016, driven by an increase in market power. The authors also find a negative relationship between markups and demand for labor and capital. The lower labor share (from 62% in 1967 to 41% more recently) is also observed in Kehrig and Vincent (2020), and the lower capital share (from 32% of gross value added in 1984 to 25% in 2014) is also observed in Barkai (2020) and in Hartman-Blaser, Lustig and Xiaolan (2019). For an analysis of ownership, investment, and shareholder payouts, see Gutiérrez and Philippon (2018).

q and actual investments since the nineties, and observe that while the two variables are correlated, from 2000 the investment rate is lower than Tobin's q would predict (accumulated stock is 10% lower than it should be in 2015). Gutiérrez and Philippon (2017b, p. 93) estimate that approximately 65-75% of the observed gap can be attributed equally to market concentration and common ownership, and that common ownership causes even higher payouts and lower investments in less competitive industries. They also note that the specific mechanisms by which quasi-indexer institutional ownership affects investment are not yet completely understood.

One attempt to improve our understanding on this matter is López and Vives (2019), which examines the impact of overlapping ownership on the incentives for firms to make cost-reducing R&D investments. Specifically, greater overlapping ownership raises and reduces both innovation and output levels when R&D spillovers are high and low, respectively. However, technological progress depends not only on innovation but also on the adoption of new technologies. Therefore, the design of socially optimal policies should account for both incentives (Fudenberg and Tirole, 1985). Given that the investment gap and the decline in business dynamism coincide with the emergence of common ownership, it is worth exploring whether—and understand how—this may be slowing down the adoption of new technologies and affecting incentives to become a market leader: in the 1990s, the probability that a market leader would be replaced by a competitor within the next three years was 45%; today, it is only 30% (Philippon, 2019).

To explore the adoption of new technologies and leadership incentives under different ownership and corporate control structures, we use the Reinganum (1981) model of competition and timing. However, we make the more realistic assumption of no information delays, meaning that companies can observe and respond to rivals' actions instantly, allowing us to study the perfect equilibrium, as in Fudenberg and Tirole (1985).

We aim to answer the following questions: *Does preemption remain the outcome of the technology adoption game under overlapping ownership? Or is its growing presence weakening technology adoption and leadership incentives? How do different types of corporate control structures affect technology diffusion in the industry?* Our goal is to re-examine the literature on technology diffusion and the result of income equalization when horizontal shareholdings exist.

In the standard adoption model, where the cost of adoption decreases over time and there is no overlapping ownership, endogenous diffusion in adoption times occurs only with open-loop strategies —that is, when firms can precommit to their adoption times (Reinganum, 1981). However, with overlapping ownership, a firm's profit diverges from an investor's incentives. We show that this divergence can transform industries where preemptive races would naturally arise into waiting games, thereby slowing down adoption.

In particular, we show that when overlapping ownership (whether common ownership or cross-ownership) is sufficiently high, the preemptive race outcome disappears, and the unique subgame perfect equilibrium exhibits staggered innovations: one firm (the leader) adopts first at a high-cost, while the rival waits for a lower cost to adopt the new technology. Both adoption times occur later than in the race outcome. In this equilibrium, the follower earns higher profits than the leader, and there is no rent dissipation.

We focus on two relevant cases of common ownership: silent financial interests (SFI) and proportional control (PC). Our analysis shows that under PC—the framework commonly used in the empirical literature to study the effects of common ownership on prices—technology adoption is delayed more significantly than under SFI. Furthermore, the threshold of common ownership at which firms transition from playing a preemptive game to a waiting game is lower under PC. In our example, this threshold is approximately half of that observed under SFI.

In our analysis, we assume the presence of two investors. However, we also extend the model to scenarios with $I > 2$ investors and find that the threshold triggering the waiting game decreases as the number of investors increases. This result therefore reinforces our main findings.

The strategic timing of technology adoption has long been a central theme in industrial organization and innovation economics. The debate over first-mover versus second-mover advantages has generated a rich body of literature examining the conditions under which firms may benefit from being pioneers or followers in adopting new technologies. Rather than providing an exhaustive review of this literature, we focus on highlighting the most closely related studies.[6] Reinganum (1981)'s model predicts a "diffusion" equilibrium with staggered adoption times, due to firms' inability to respond strategically to their rivals' actions. In the presence of strategic behaviour, however, firms will compete to be the first to precommit: Fudenberg and Tirole (1985) show that under perfect information and no reaction lags, firms adopt preemptively to prevent rivals from gaining an advantage, resulting in closer adoption times across firms but also leading to rent dissipation. Second-mover advantages have been identified in other models with perfect information and no reaction lags, but these typically consider technologies that enhance product quality rather than those that improve firms' production efficiency.[7] Notable contributions in this

[6] Smirnov and Wait (2021) provide a brief and recent overview of this literature and its applications, including delays and clustering of entry, patenting, and exit or asset sales in declining industries. The literature also examines how R&D costs, asymmetric information, and uncertainty affect firms' incentives to innovate.

[7] Hoppe and Lehmann-Grube (2005) find a second-mover advantage in an innovation timing game where firms decide when to launch a new product, meaning they are not active in the market prior to entry. In their model, the marginal cost decreases over time while the per-period R&D cost remains constant. In our setting, however, as in Reinganum (1981) and Fudenberg and Tirole (1985), the marginal cost remains constant over time before adoption, the adoption cost decreases over time, and firms are active in the market before adopting the innovation. Katz and Shapiro (1987) find that a patent race can transform into a waiting game under the additional assumptions of imitable innovations that spill over to the rival or non-drastic innovations that can be licensed. Their setting, however, differs in that once one firm adopts the innovation, the rival cannot catch up and adopt it at the same time or later.

context are Dutta et al. (1995) and Hoppe and Lehmann-Grube (2001, 2005). Dutta et al. (1995) analyze a general duopoly model of product innovation where firms face a trade-off between launching a product at its current quality level or waiting to develop a higher-quality version. Hoppe and Lehmann-Grube (2001, 2005) show, however, that when quality improvements occur at low cost over time, firms again engage in a preemption race, leading to payoff equalization in equilibrium. In particular, they show that only when quality improvements require high R&D costs does the nature of competition shift from preemption to a waiting game, as firms may strategically delay to benefit from higher returns on improved product quality.

Our work demonstrates that even in the case of cost-reducing technologies (that is, in a setting similar to Fudenberg and Tirole, 1985), and without introducing additional assumptions, the mere presence of overlapping ownership transforms a game predominantly characterized by first-mover advantage into a waiting game in which firms strategically prefer to adopt the technology last. Our framework also applies to scenarios where a production-efficient technology is initially highly polluting, prompting socially concerned managers to delay adoption until its environmental impact diminishes. Moreover, while multiple peaks in payoff functions are common in many innovation timing games—often requiring specialized algorithms for their resolution (Hoppe and Lehmann-Grube, 2005; Smirnov and Wait, 2015, 2021)—we find that introducing overlapping ownership in the cost-reducing technology model preserves the property of continuous, single-peaked payoff functions.

The remainder of this paper is organized as follows. In the next section, we present the general model with overlapping ownership. Section 3 analyses the strategic adoption of a new technology. In subsection 3.1, we briefly discuss the case of no overlapping ownership. In subsection 3.2, we solve the model for different levels of horizontal shareholdings, examine particularly relevant scenarios of common ownership (silent financial interests and proportional control), and then extend the analysis to an arbitrary number of investors. Section 4 concludes.

2 The model

There are two identical firms, indexed by $i, j = 1, 2$. At date 0, a cost-reducing innovation becomes available, and each firm has the option to adopt it in each period t. We consider continuous time, perfectly observable firm decisions, and no information lags.[8] To model common ownership and control, we follow the approach of Rotemberg (1984) and Salop

[8]Specifically, we adopt assumption A1 from Hoppe and Lehmann-Grube (2005): *"Time is continuous in the sense of 'discrete but with a grid that is infinitely fine'."* The continuous-time outcome is then defined as the limit of the discrete-time outcomes. See Hoppe and Lehmann-Grube (2005, footnote 4) for more details.

and O'Brien (2000): each manager maximizes a weighted average of the portfolio profits of the firm's investors, given the existing ownership and control structures in the market. This model is the main framework used in the common ownership literature and has been further microfounded by introducing an initial voting-based phase in which shareholders vote to appoint the manager (see Azar, 2011; Brito et al., 2023; and Moskalev, 2019).

For simplicity, we consider two investors (this assumption is relaxed later): Investor 1 is the major shareholder of firm 1, and Investor 2 is the major shareholder of firm 2. Let $\omega_i < 1/2$ represent the stake of investor i in firm j, and let γ_i represent the extent of investor i's control over firm j, with $i \neq j$. The manager of firm i maximizes:

$$\phi^i = (1-\gamma_j)\upsilon^i(\pi_i, \pi_j) + \gamma_j \upsilon^j(\pi_j, \pi_i),$$

where υ^i denotes investor i's portfolio profit:

$$\upsilon^i(\pi_i, \pi_j) = (1-\omega_j)\pi_i + \omega_i \pi_j,$$

and π_i and π_j are the cash flows of firm i and firm j, respectively. The manager's optimization problem is equivalent to maximizing:

$$\Pi^i = \pi_i + \lambda_i \pi_j,$$

where

$$\lambda_i = \frac{\gamma_j(1-w_i) + (1-\gamma_j)w_i}{(1-\gamma_j)(1-w_j) + \gamma_j w_j}. \tag{1}$$

Throughout the paper, we assume symmetric stakes, $\omega_1 = \omega_2 = \omega \leq 1/2$. Consequently, $\lambda_i, \lambda_j = \lambda \in [0,1]$, where $\lambda = 0$ indicates no common ownership or independently maximizing firms, and $\lambda = 1$ represents a cartel. This model also encompasses cross-ownership (López and Vives, 2019). With symmetric stakes, the only distinction between common and cross-ownership lies in the definition of λ; yet, as will become clear below, the main qualitative conclusions remain unchanged.[9] Thus, while our primary focus is on scenarios where investors hold stakes in competing firms, our analysis also extends to cases where firms acquire stakes in competitors.

Cash flows are defined in reduced form as follows: π_{an} denotes the net cash flow of firm i when it has adopted the innovation while firm j has not, and π_{na} denotes firm i's net cash flow when it has not adopted the innovation while firm j has. Similarly, when both firms have adopted the innovation, each receives a profit flow of π_{aa}, and before adoption, each firm obtains a profit flow of π_{nn}. At equilibrium, cash flows depend on ω_1, ω_2, γ_1 and γ_2. To simplify the exposition, we denote equilibrium cash flows as functions of $\omega \geq 0$ by

[9] In the case of cross-ownership with symmetric stakes, λ takes the form $\alpha/[1-(n-2)\alpha]$, where n is the number of firms and α represents the stake each firm holds in a rival (or competing) firm (see López and Vives, 2019, Appendix A.1.1).

π_{xy}^{ω} for $x, y \in \{a, n\}$, given fixed values of γ_1 and γ_2; thus, $\pi_{xy}^{\omega} \equiv \pi_{xy}(w) : [0, 1/2] \to \mathbb{R}_+$. We assume that the competitive model yielding profit flows π_{an}^{ω}, π_{aa}^{ω}, π_{nn}^{ω}, and π_{na}^{ω} has a unique equilibrium for all ω. For ease of notation, we omit the superscript ω when $\omega = 0$.

Standard assumptions in the literature (Reinganum, 1981) are as follows:

Assumption 1. (i) $\pi_{an} > \pi_{aa} > \pi_{nn} > \pi_{na}$; (ii) $\pi_{an} - \pi_{nn} > \pi_{aa} - \pi_{na}$.

Firm i achieves the highest cash flow when it has adopted the innovation, while firm j has not. Additionally, there is a business-stealing effect: adoption by firm i negatively impacts the profit flow to firm j, resulting in the lowest flow, π_{na}. Assumption 1(ii) introduces an incentive for preemptive adoption: the gain from adoption is higher for the first adopter than for the second. Assumption 1 holds in both a linear differentiated Bertrand model and a linear Cournot model. We extend Assumption 1 as follows:

Assumption 1′. (i) $\pi_{an}^{\omega} > \pi_{aa}^{\omega} > \pi_{nn}^{\omega} > \pi_{na}^{\omega}$; (ii) $\pi_{an}^{\omega} - \pi_{nn}^{\omega} > \pi_{aa}^{\omega} - \pi_{na}^{\omega}$ for all ω.

The new Assumption 1′ is mild: while common ownership may shift the equilibrium operating profit levels, it does not alter the nature of competition. The assumption holds in the examples discussed in this paper, which are described in the Appendix.

Let $k(t) = \bar{k}(t)e^{-rt}$ represent the present value of the manager's adoption cost at time t, where r is the interest rate and $\bar{k}(t) \geq 0$ denotes the cost of adopting the technology at time t.

We extend the assumptions of Fudenberg and Tirole's (1985) to include common ownership:

Assumption 2. (i) $\pi_{an}^{\omega} - \pi_{nn}^{\omega} \leqq -k'(0)$; (ii) $\inf_t\{\bar{k}(t)\} < (\pi_{aa}^{\omega} - \pi_{na}^{\omega})/r$; (iii) $\forall t$, $\bar{k}'(t) < 0$, and $\bar{k}''(t) > 0$ for all ω.

Under Assumption 2(i), there are no incentives to adopt the technology at date 0, while Assumption 2(ii) implies that all firms will eventually adopt in finite time: $\int_0^{\infty}(\pi_{aa}^{\omega} - \pi_{na}^{\omega})e^{-rt}dt > \inf_t\{\bar{k}(t)\}$. Finally, technological progress facilitates adoption of the innovation: the current cost, $\bar{k}(t)$, decreases over time, although at a declining rate.

3 Strategic adoption of a new technology

In this section, we study the strategic adoption of a cost-reducing innovation. Let $V^i(T_i, T_j)$ be the present payoff of the manager of firm i when it adopts the innovation at date T_i, while the competing firm adopts it at date T_j. Suppose that firm 1 adopts first and firm 2 follows; then $T_1 \leq T_2$, and the net present value for the managers of firms 1 and 2 is, respectively,

$$V^1(T_1, T_2) = \int_0^{T_1} \Pi_{nn} e^{-rt}\,dt + \int_{T_1}^{T_2} \Pi_{an} e^{-rt}\,dt + \int_{T_2}^{\infty} \Pi_{aa} e^{-rt}\,dt - k(T_1)$$

and

$$V^2(T_2,T_1)=\int_0^{T_1}\Pi_{nn}e^{-rt}\,dt+\int_{T_1}^{T_2}\Pi_{na}e^{-rt}\,dt+\int_{T_2}^{\infty}\Pi_{aa}e^{-rt}\,dt-k(T_2),$$

where $\Pi_{an}\equiv\Pi^1(\pi^{\omega}_{an},\pi^{\omega}_{na})$, $\Pi_{na}\equiv\Pi^2(\pi^{\omega}_{na},\pi^{\omega}_{an})$, $\Pi_{aa}\equiv\Pi^i(\pi^{\omega}_{aa},\pi^{\omega}_{aa})$ and $\Pi_{nn}\equiv\Pi^i(\pi^{\omega}_{nn},\pi^{\omega}_{nn})$ for $i=1,2$.

Strategic adoption models for new technologies generally do not distinguish between whether the cost of adopting the technology is borne by the firm or by the manager, as these models implicitly assume that their objectives are aligned. In many cases, however, adopting new technologies imposes a significant cost on managers in terms of effort, dedication, and time.[10] Our analysis is motivated not only by these real-world examples but also by the observation that institutional investors can influence corporate governance precisely by refraining from pressuring managers to undertake decisions that require substantial managerial effort (Azar, Schmalz and Tecu, 2018)—such as gaining market share, entering new markets, investing in R&D, or, in our case, adopting and implementing a new technology. Moreover, our approach also captures the case of a production-efficient technology that is initially highly polluting, but that socially concerned managers might refrain from adopting in its early stages due to its environmental impact. As the technology evolves and becomes less polluting, these managers may then decide to adopt it.

3.1 No overlapping ownership

This section revisits the benchmark case where investors (or firms) hold no stakes in rival firms, which implies: $\Pi_{an}=\pi_{an}$, $\Pi_{na}=\pi_{na}$, $\Pi_{aa}=\pi_{aa}$ and $\Pi_{nn}=\pi_{nn}$. To address this case, we begin by assuming that firm 1 adopts the innovation at date $T_1=t$. Consequently, firm 2 maximizes $V^2(T_2,t)$ subject to the constraint $T_2\geq t$. In our analysis, we will rely on the important property that the objective function $V^2(T_2,t)$ is single peaked.[11] First, Assumption $1'(ii)$ and Assumption $2(i)$ yield $\partial V^2(0,t)/\partial T_2>0$.[12] Second, Assumptions $2(i)$ and $2(ii)$ ensure that the innovation will be adopted at some finite date. Finally, define

$$\vartheta(t)\equiv -k'(t)e^{rt}=-\left(\bar{k}'(t)-r\bar{k}(t)\right)>0.$$

[10] Consider, for example, Enterprise Resource Planning (ERP) systems, Supply Chain Management (SCM) technologies, Customer Relationship Management (CRM) systems, and cloud computing, all of which initially required significant managerial effort to implement and integrate but have become more accessible and manageable over time.

[11] More precisely, this definition excludes peaks represented as intervals.

[12] $\partial V^2(0,t)/\partial T_2>0\Leftrightarrow -k'(0)>\pi_{aa}-\pi_{na}$, and we have that $-k'(0)\geq\pi_{an}-\pi_{nn}>\pi_{aa}-\pi_{na}>0$. Assumption 2(i) implies the first *weak* inequality, whereas Assumption $1'(ii)$ implies the second *strict* inequality.

The function ϑ is strictly decreasing and therefore invertible. Using the first-order condition, we obtain that

$$T_2^* = \vartheta^{-1}(\pi_{aa} - \pi_{na})$$

is unique: $V^2(T_2, t)$ is single-peaked or strictly quasiconcave. Notice that firm 2 adopts either at date T_2^* or, if $t > T_2^*$, at date t. Taking this reaction into account, net present values can be expressed as a function of firm 1's adoption date, t, as follows: $L(t)$ for firm 1 (the leader) and $F(t)$ for firm 2 (the follower),

$$L(t) = V^1(t, T_2^*) \text{ and } F(t) = V^2(T_2^*, t) \text{ if } t < T_2^*$$

and

$$L(t) = F(t) = M(t) \text{ if } t \geq T_2^*,$$

where

$$M(t) \equiv V(t,t) = V^1(t,t) = V^2(t,t).$$

When $t \geq T_2^*$, both firms adopt simultaneously at date t, and the present payoff is $M(t)$.

The leader has no incentive to adopt the innovation at the initial date. Using reasoning analogous to that applied to the function $F(t)$, it can be shown that $L(t)$ is also single-peaked. The optimal adoption date for the leader is therefore $T_1^* = \arg\max_{t \in [0, T_2^*]} L(t)$, which yields:

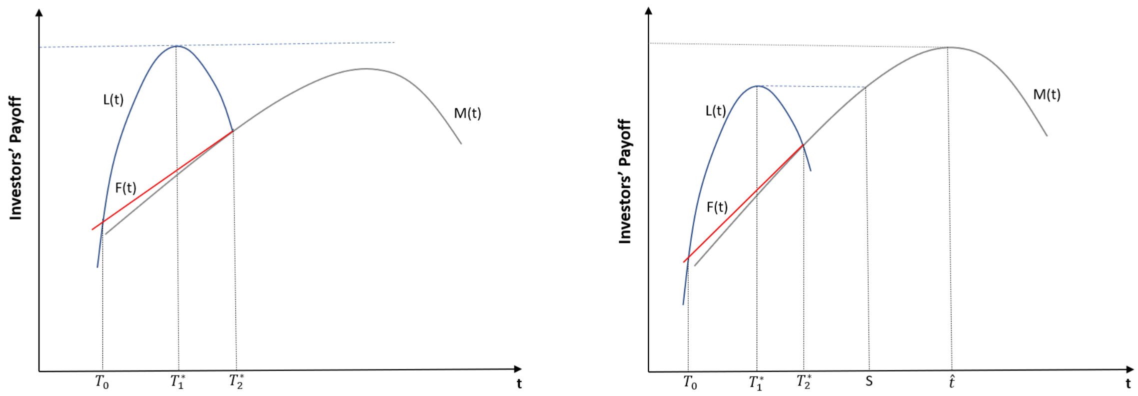
$$T_1^* = \vartheta^{-1}(\pi_{an} - \pi_{nn}).$$

The analysis in Fudenberg and Tirole (1985) relies on payoffs being quasiconcave. Here, we draw upon the property that payoffs are single-peaked or strictly quasiconcave, which naturally arise from the same initial assumptions laid out in their work. It is worth emphasizing, however, that single-peaked payoffs guarantee the existence of unique solutions, T_1^* and T_2^* (with $T_1^* \neq T_2^*$ by Assumption 1(ii)), and further allow us to establish strict inequalities:

$$L(T_1^*) \equiv V^1(T_1^*, T_2^*) > V^1(T_2^*, T_2^*) = V^2(T_2^*, T_2^*) > V^2(T_2^*, T_1^*) \equiv F(T_1^*). \tag{2}$$

The first *strict* inequality results from the existence of a unique, positive, and finite $T_1^* \neq T_2^*$, while the last inequality holds because V^2 is strictly increasing with t. Thus, $L(T_1^*) > F(T_1^*)$, implying a first-mover advantage. Below, we show that in the presence of overlapping ownership, the inequality $V^2(T_2^*, T_2^*) > V^2(T_2^*, T_1^*)$ may no longer hold, potentially resulting in a second-mover advantage. Fudenberg and Tirole (1985) identify two possible cases, which we illustrate for completeness in Figure 1 and briefly discuss below.

Case $L(T_1^*) > M(\hat{t})$, where $\hat{t}(> T_2^*)$ is the optimal date that maximizes $M(t)$. In



(a) $L(T_1^*) > M(\hat{t})$ (b) $L(T_1^*) \leqq M(\hat{t})$

Figure 1: L(t), F(t) and M(t).

this case, both firms have an incentive to be the leader and therefore to adopt at T_1^*. (See Figure 1(a)). Since we consider closed-loop strategies (with no information lags) and firms' decisions are perfectly observable, the first-mover advantage results in a preemption race that ultimately leads to rent equalization for the two firms. Intuitively, if one firm is about to adopt at T_1^*, the rival has an incentive to adopt slightly earlier (since $L(t) > F(t)$). Anticipating this, the first firm would aim to preempt by adopting slightly before its rival. The difference between $L(t)$ and $F(t)$ decreases as the adoption date approaches, and incentives to preempt continue until reaching $T_1 = T_0$, where T_0 is the unique date such that $L(t) = F(t)$. The adoption game has a unique subgame perfect equilibrium. In this equilibrium, one firm adopts at date T_0 and the other follows at T_2^*, resulting in equal payoffs for both firms (rent equalization outcome).[13]

Case $L(T_1^*) \leqq M(\hat{t})$: In this case, in addition to the diffusion equilibrium with adoption times (T_0, T_2^*) and rent equalization, there exists a continuum of joint-adoption equilibria with adoption times $t \in [S, \hat{t}]$, where $S(< \hat{t})$ is the date at which the joint adoption payoff equals the leader's optimal payoff: $L(T_1^*) = M(S)$. (See Figure 1(b)).

3.2 Common ownership

Assuming symmetry in the minority stakes ($\omega_1 = \omega_2 = \omega > 0$) and control parameters ($\gamma_1 = \gamma_2 = \gamma \geq 0$), equation 1 yields $\lambda_i = \lambda^{CO} \in (0, 1]$, where

$$\lambda^{CO} \equiv \frac{\gamma(1-\omega) + (1-\gamma)\omega}{(1-\gamma)(1-\omega)}.$$

Consistent with our earlier assumption, we suppose that, in the case of sequential adoption, firm 1 adopts first. We now aim to demonstrate that, in the presence of common

[13]This equilibrium is in mixed strategies, with each firm having a probability of 1/2 of being the leader.

ownership—as opposed to its absence—the function $F(T_1^*)$ can exceed $L(T_1^*)$.

With common ownership, the relevant objective for optimization is financial profits Π^i, with $\lambda_i = \lambda^{CO}$, as opposed to operating profits π_i.[14] Naturally, both expressions are equivalent when $\omega = 0$, thus the model satisfies:

$$(i') \ \Pi_{an} > \Pi_{aa} > \Pi_{nn} > \Pi_{na}; \quad (ii') \ \Pi_{an} - \Pi_{nn} > \Pi_{aa} - \Pi_{na} \text{ for } \omega = 0.$$

We will analyze how the level of holdings affects the validity of condition (i'). Our examination begins with an exploration of the last inequality in the condition, after which we turn our attention to the first inequality. Violations of these inequalities has direct and significant implications for the emergence of a second-mover advantage.

■ $\boldsymbol{\Pi_{nn} > \Pi_{na}}$. As ω increases towards 1/2, λ^{CO} increases towards 1 for $\gamma \geq 0$ (the larger the γ, the quicker this convergence). Consequently, the financial profit functions $\Pi_{an} \equiv \Pi^1(\pi_{an}^\omega, \pi_{na}^\omega)$ and $\Pi_{na} \equiv \Pi^2(\pi_{na}^\omega, \pi_{an}^\omega)$ converge from their initial values π_{an} and π_{na} towards the sum of both firms' profits at the cartel output level, $(\pi_{an}^{1/2} + \pi_{na}^{1/2})$. In other words, as ω approaches the critical value of 1/2, firms increasingly align their strategies to maximize the combined profits of two asymmetric firms. The controlling investor of the more efficient firm gradually owns less of it and more of the less efficient firm as ω increases, and the reverse occurs for the investor controlling the less efficient firm. As Π_{na} raises from π_{na} towards the monopoly profits, the last inequality in condition (i') may no longer hold true. This possibility is formally established in the following lemma:

Lemma 1. *There exists a common ownership threshold* $\omega \in (0, 1/2)$ *above which* $\Pi_{na} > \Pi_{nn}$.

Proof. As ω approaches 1/2, Π_{na} converges to $(\pi_{an}^{1/2} + \pi_{na}^{1/2})$, while Π_{nn} converges to $2\pi_{nn}^{1/2}$. Therefore, there exists a threshold $\omega \in (0, 1/2)$ above which $\Pi_{na} > \Pi_{nn}$ if $\pi_{an}^{1/2} + \pi_{na}^{1/2} > 2\pi_{nn}^{1/2}$, or, equivalently, if $\pi_{an}^{1/2} - \pi_{nn}^{1/2} > \pi_{nn}^{1/2} - \pi_{na}^{1/2}$. This condition is satisfied because $\pi_{an}^{1/2} - \pi_{nn}^{1/2} > \pi_{aa}^{1/2} - \pi_{na}^{1/2} > \pi_{nn}^{1/2} - \pi_{na}^{1/2}$. The first inequality follows from Assumption $1'(ii)$, and the second follows from Assumption $1'(i)$. □

The term $|\Pi_{nn} - \Pi_{na}|$ precisely denotes the net flow of gain or loss experienced by the follower when the leading firm refrains from adopting the innovation at date t. This term directly shapes the follower curve:

$$F'(t) = (\Pi_{nn} - \Pi_{na})e^{-rt} \quad \text{and} \quad F''(t) = -r(\Pi_{nn} - \Pi_{na})e^{-rt}. \tag{3}$$

Consequently,

- if $\Pi_{nn} > \Pi_{na}$, which holds at $\omega = 0$, F is strictly increasing and concave, and

[14] In the case of cross-ownership, the value of λ depends on the number of firms (n) and the rivals' stock size (α), with λ approaching 1 as α approaches $1/(n-1)$.

- if $\Pi_{nn} < \Pi_{na}$, which may hold for $\omega > 0$, F is strictly decreasing and convex.

Without common ownership, the business-stealing effect leads to a *too low* value for Π_{na}. As a result, the positive difference $\Pi_{nn} - \Pi_{na} > 0$ benefits the follower whenever the leader delays adoption. This explains why the follower always prefers the leader to delay adoption, meaning that F increases with the date of first adoption, t. In contrast, with common ownership, the follower may prefer the leader to adopt earlier since it receives a share of firm 1's profits. Specifically, when common ownership reaches a sufficiently high level, Π_{na} exceeds Π_{nn}, making the difference negative and causing $F(t)$ to decrease as t increases. During any period of time in which firm 1 refrains from adopting the technology, investor 2 earns Π_{nn} but misses out on the difference $\Pi_{na} - \Pi_{nn}$.

Initially, under the assumption of a moderate and positive ω, it is plausible to posit the existence of a second-mover advantage, characterized by $F(T_1^*) > L(T_1^*)$, in the context of an increasing and concave function $F(t)$. However, the subsequent lemma rules out this possibility:

Lemma 2. *If a second-mover advantage exists, the function $F(t)$ must be strictly decreasing and convex.*

Proof. From (2), we know that when the inequality $V^2(T_2^*, T_2^*) > V^2(T_2^*, T_1^*) \equiv F(T_1^*)$ holds, there is first-mover advantage: $L(T_1^*) \equiv V^1(T_1^*, T_2^*) > V^1(T_2^*, T_2^*) = V^2(T_2^*, T_2^*)$. Therefore, a necessary condition for second-mover advantage is:

$$F(T_1^*) \equiv V^2(T_2^*, T_1^*) > V^2(T_2^*, T_2^*) \equiv M(T_2^*).$$

Substituting terms and simplifying, we obtain:

$$F(T_1^*) - M(T_2^*) = \frac{1}{r}\left(\Pi_{na} - \Pi_{nn}\right)\left(e^{-rT_1^*} - e^{-rT_2^*}\right),$$

which is strictly positive if and only if $\Pi_{na} > \Pi_{nn}$. Under this condition, and from (3), it follows that $F'(t) < 0$ and $F''(t) > 0$. □

From Lemmata 1 and 2, we conclude that a necessary condition for the emergence of a second-mover advantage is that common ownership must be sufficiently large, leading to $\Pi_{nn} < \Pi_{na}$. This condition implies that the profit earned by an investor when neither firm adopts must be lower than the profit received by the principal investor of the follower when only one firm adopts.

■ $\boldsymbol{\Pi_{an} > \Pi_{aa}}$. We now turn our attention to the first inequality of (i'). Consider markets characterized by strategic complements and differentiated products. In such markets:

$$\Pi_{aa} = \max\{\Pi_{an}, \Pi_{aa}, \Pi_{nn}, \Pi_{na}\} \text{ for } \omega \text{ close to } 1/2.$$

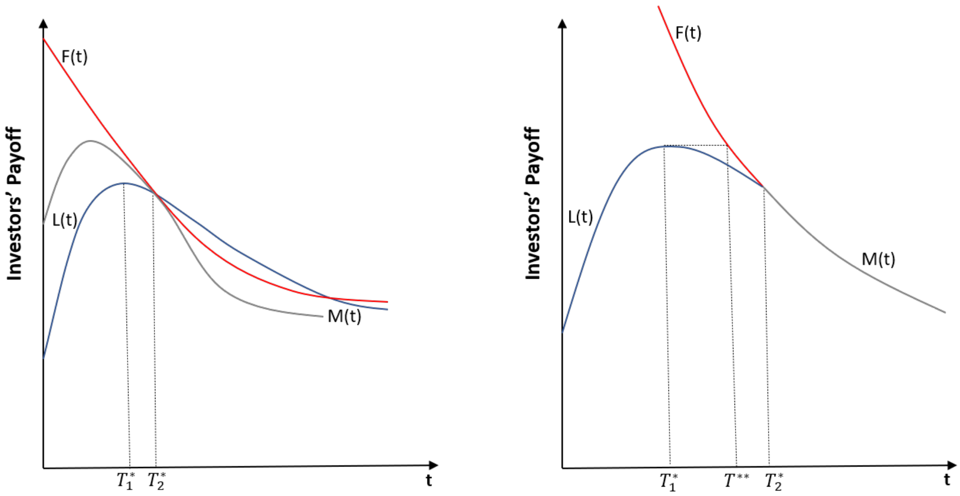


Figure 2: Strategic complements and differentiated products with common ownership.

In contrast, in markets with strategic substitutes and linear costs:

$$\Pi_{na} \to \Pi_{an} = \max\{\Pi_{an}, \Pi_{aa}, \Pi_{nn}, \Pi_{na}\} \text{ for } \omega \text{ close } 1/2.$$

In a Cournot model with homogenous products and constant, asymmetric costs, firms maximizing joint (gross) profits allocate all production to the most efficient firm. On the other hand, in a model with strategic complements and differentiated products, the highest joint returns are achieved when both firms adopt the innovation, as their production costs are minimized. In this latter case, the inequality $L(t) > M(t)$ no longer holds for $t < T_2^*$. Specifically:

$$L(t) - M(t) = \left(\frac{\Pi_{an} - \Pi_{aa}}{r}\right)\left(\frac{1}{e^{rt}} - \frac{1}{e^{rT_2^*}}\right). \tag{4}$$

At $\omega = 0$, we observe that $\Pi_{an} > \Pi_{aa}$. Consequently, as previously discussed, $L(t) = V^1(t, T_2^*)$ exceeds $M(t) = V(t,t)$. However, when $\omega > 0$, the leader accrues a fraction of the follower's profits, potentially favoring earlier adoption by the follower. This effect is particularly relevant when the shared profits during competition at peak efficiency exceed those obtained when only one firm operates at that level of efficiency. Specifically, if ω is sufficiently large that Π_{aa} surpasses Π_{an}, the relationship reverses, yielding $M(t) > L(t)$. Under these circumstances, the inequality $F(t) > L(t)$ also holds, since $F(t) > M(t)$ for any given $t < T_2^*$.[15]

□ **Second-mover advantage.** From equation (4) we conclude that $F(t) > L(t)$ *for all* $t < T_2^*$ when ω is sufficiently high such that the first inequality in (i') no longer holds, i.e., $\Pi_{aa} > \Pi_{an}$. While this condition is sufficient for the emergence of a second-

[15]By definition of the follower's optimal choice, T_2^*, we have: $F(t) = V^2(T_2^*, t) > V^2(t,t) = M(t)$.

mover advantage, it is not strictly necessary. The reason is that, as long as the F curve exceeds the L curve *for any* $t \leq T_1^*$, firms have no incentive to adopt before T_1^*. Given this, there exists a unique subgame-perfect equilibrium in which one firm adopts at T_1^* and the follower adopts at T_2^*, earning a higher payoff (Dutta et al., 1995).[16] This equilibrium is characterized by pure strategies and is asymmetric. Thus, a necessary and sufficient condition for the transition of the preemption game into a waiting game is that $F(T_1^*) - L(T_1^*) > 0$, or, equivalently,

$$\frac{1}{r}\left[\left(k(T_1^*) - k(T_2^*)\right) r - \left(e^{-rT_1^*} - e^{-rT_2^*}\right)\left(\Pi_{an} - \Pi_{na}\right)\right] > 0, \tag{5}$$

where $k(T_1^*) - k(T_2^*) > 0$ and $e^{-rT_1^*} - e^{-rT_2^*} > 0$ since $T_1^* < T_2^*$. Clearly, this condition holds for $\omega \to 1/2$. We thus establish the following result:

Proposition 1. *There exists a level of common ownership* $\omega \in (0, 1/2)$ *such that* $F(T_1^*) > L(T_1^*)$.

These findings are illustrated in Figures 2(a) and 2(b). Figure 2(b) provides a focused view of the relevant adoption dates. At sufficiently high levels of common ownership, the F and M curves lie above the L curve for all $t < T_2^*$. Given that $F(T_1^*) > L(T_1^*)$, firms have no incentive to preempt before T_1^*. The rationale is that the follower accrues greater profits, establishing a clear second-mover preference. Let T^{**} denote the point at which $L(T_1^*) = F(T^{**})$. If firms were to adopt the technology after T^{**}, it would be more beneficial for either firm to adopt at T_1^*. This leads to the existence of a unique subgame-perfect equilibrium in pure strategies, facilitating technology diffusion where firm 1 adopts at T_1^* and firm 2 at T_2^*, with the latter realizing higher profits. Furthermore, under this scenario, common ownership eliminates the range of joint-adoption equilibria that might otherwise exist in an industry without such holdings.

3.2.1 Silent financial interests

In the presence of silent financial interests (SFI), investors 1 and 2 control and are the principal shareholders of firm 1 and 2, respectively, each possibly holding a non-controlling minority interest in the competing firm. Here, the control parameters are set to $\gamma_1 = \gamma_2 = 0$, and as a result, the manager of firm i assigns a weight to the profit of firm j equal to

$$\lambda_i = \lambda^{SFI} \equiv \frac{\omega}{1-\omega},$$

[16] See Smirnov and Wait (2021) for an extension of this result to heterogeneous players and multi-peaked and non-monotonic payoff functions. See also Hoppe and Lehmann-Grube (2005) for general conditions ensuring the existence of a unique equilibrium in cases where the L curve is multi-peaked or discontinuous.

which is investor i's relative stake in firm j compared to the holdings in her own firm. This weight is bounded within the interval $[0, 1]$.

In Appendix A, we provide an example of price competition with differentiated products in the context of silent financial interests. Under the parameter values assumed in the example, the absence of common ownership leads to $L(T_1^*) > F(T_1^*)$, where $T_1^* = 1.98$, triggering a preemption race that concludes at $T_0 = 0.48$. This race equalizes profits with sequential adoption at $T_1 = T_0 = 0.48$ and $T_2^* = 2.05$.

Principal investor profits in the non-adopting firm, Π_{na}, increase with ω due to a shift in holdings towards the more efficient firm. This leads to $\Pi_{na} > \Pi_{nn}$ when $\omega > 0.1444$, which results in a decreasing and convex $F(t)$. Conversely, principal investor profits in the adopting firm, Π_{an}, decrease with ω until the rival firm adopts the technology. After adoption, investor profits, Π_{aa}, increase with ω. In particular, for $\omega > 0.1554$, the inequality $\Pi_{aa} > \Pi_{an}$ holds, indicating the presence of a second-mover advantage with $F(t) > L(t)$. However, a second-mover advantage emerges at a lower level of common ownership: the condition (5) is satisfied when $\omega \geq 0.15$. For further details, see Appendix A.1.

3.2.2 Proportional control

Concerns about the anti-competitive effects of common ownership often focus on a select group of large investment funds that claim to follow a passive investment strategy. This strategy suggests that SFI should be considered when analyzing the effects of common ownership. However, substantial evidence indicates that being a passive investor does not necessarily equate to being a passive owner (Appel, Gormley and Keim, 2016) or imply adopting a hands-off approach to management. In fact, institutional investors frequently play an active role in corporate governance (Azar et al., 2018). The empirical literature commonly evaluates price effects and market power in the context of proportional control (O'Brien and Waehrer 2017; Azar et al. 2018; Nain and Wang 2018; Park and Seo 2019; Lewellen and Lowry 2021; Backus et al. 2021b; Koch et al. 2021). Schmalz (2018) provides a comprehensive survey of this literature.

Proportional control (PC) typically implies one vote per share, which means that $\gamma_i = \omega_i$. Assuming symmetry in holdings, this yields:

$$\lambda_i = \lambda^{PC} \equiv \frac{2\omega(1-\omega)}{(1-\omega)^2 + \omega^2}.$$

It follows that $\lambda^{PC} > \lambda^{SFI}$ for any $\omega \in (0, 1/2)$. This indicates that under proportional control, managers internalize rival firms' profits to a greater extent than under SFI. Specifically, achieving an equivalent level of profit internalization requires a smaller stake under PC than under SFI.[17] This hierarchy implies that, under PC, the level of common ownership at which the Π_{nn} and Π_{na} curves intersect (or equivalently, Π_{an} and Π_{aa}) is lower compared to SFI. Consequently, under PC, the follower curve adopts a convex and decreasing form at a reduced threshold of common ownership compared to SFI. Similarly, the $M(t)$ curve lies above the $L(t)$ curve at a lower common ownership level than in the SFI scenario. Under PC, the transition from a preemption game to a waiting game occurs at a lower degree of common ownership than under SFI. Condition (5) reveals that a second-mover advantage arises when Π_{an} is sufficiently close to Π_{na}, and under PC, this happens at a lower ω. This is because Π_{an} decreases and Π_{na} increases, both more rapidly, as ω increases.

We make the following assumption:

Assumption 3. $\Pi_{aa}^{PC} - \Pi_{aa}^{SFI} < \Pi_{na}^{PC} - \Pi_{na}^{SFI}$.

The implication of this assumption is that if firm i has adopted the innovation, a higher degree of rival's profit internalization ($\lambda^{PC} > \lambda^{SFI}$) results in greater gains for the principal investor of firm j when she has not adopted the innovation, compared to the scenario where both firms have adopted it. The intuition is as follows: due to the business stealing effect, π_{na} is relatively low and π_{an} is relatively high. Higher levels of common ownership leads to a higher λ, which in turn leads to less aggressive competition and allows the principal investor of the non-innovating firm to capture a larger share of the rival's too high profits ($\Pi_{na} = \pi_{na} + \lambda\pi_{an}$). However, when both firms have adopted the innovation, the business stealing effect is no longer present. In this case, a higher λ contributes only to a reduced level of competition ($\Pi_{aa} = \pi_{aa} + \lambda\pi_{aa}$). Assumption 3 holds in our example below with linear demand and constant marginal cost. It is also worth noting that Π_{an} decreases from π_{an} to $(\pi_{an}^{1/2} + \pi_{na}^{1/2})$ as ω increases from 0 to 1/2. Since $\lambda^{PC} > \lambda^{SFI}$, Π_{an} diminishes more rapidly under PC than under SFI, leading to $\Pi_{an}^{PC} < \Pi_{an}^{SFI}$. This allows us to establish the following result:

Proposition 2. *Let $\omega > 0$ be such that second-mover advantage exists. Then:*

$$(T_2^*)^{PC} > (T_2^*)^{SFI} \text{ and } (T_1^*)^{PC} > (T_1^*)^{SFI}.$$

Proof. First, $T_2^* = \vartheta^{-1}(\Pi_{aa} - \Pi_{na})$ with $(\vartheta^{-1})' < 0$. By Assumption 3, $\Pi_{aa}^{SFI} - \Pi_{na}^{SFI} > \Pi_{aa}^{PC} - \Pi_{na}^{PC}$ for all $\omega \in (0, 1/2)$. It follows that $(T_2^*)^{PC} > (T_2^*)^{SFI}$.

Second, note that $\Pi_{an}^{PC} < \Pi_{an}^{SFI}$, or, equivalently, $\Pi_{an}^{PC} - \Pi_{an}^{SFI} < 0$. Additionally, $\Pi_{nn}^{PC} - \Pi_{nn}^{SFI} > 0$ since $\lambda^{PC} > \lambda^{SFI}$. Thus, $\Pi_{nn}^{PC} - \Pi_{nn}^{SFI} > \Pi_{an}^{PC} - \Pi_{an}^{SFI}$, or equivalently, $\Pi_{an}^{SFI} - \Pi_{nn}^{SFI} > \Pi_{an}^{PC} - \Pi_{nn}^{PC}$ for all $\omega \in (0, 1/2)$. Since $T_1^* = \vartheta^{-1}(\Pi_{an} - \Pi_{nn})$ with $(\vartheta^{-1})' < 0$, it follows that $(T_1^*)^{PC} > (T_1^*)^{SFI}$. □

[17] López and Vives (2019) show that with symmetric stakes the relationship $\lambda^{PC} > \lambda^{SFI} > \lambda^{CO}$ holds, where CO refers to cross-ownership by firms.

Proportional control further delays technology adoption compared to silent financial interests. In Appendix A.2, we solve the earlier example under proportional control. As expected, the common ownership level needed to generate second-mover advantage is lower, approximately half of that required under SFI. In our example, second-mover advantage arises (condition (5) holds) for $\omega \geq 0.08$. Notice that acquisitions solely for investment purposes are exempt from notification if they are below 10% of the total shares.[18] We also find that $(T_2^*)^{PC} > (T_2^*)^{SFI} > T_2^*$, and that $(T_1^*)^{PC} > (T_1^*)^{SFI} > T_0$.

3.2.3 Extension to $I > 2$ investors

To extend the model to scenarios with more than two investors ($I > 2$), let γ_{ij} represent the extent of control that investor i exercises over firm j. Similarly, let ω_{ij} denote the ownership stake of investor i in firm j. Thus, the manager of firm 1, for instance, seeks to maximize $\sum_{i=1}^{I} \gamma_{i1}\Pi^i$, which can be expressed as: $\sum_{i=1}^{I} \gamma_{i1}\omega_{i1}\pi_1 + \sum_{i=1}^{I} \gamma_{i1}\omega_{i2}\pi_2$. The objective simplifies to maximizing $\pi_1 + \lambda_{12}\pi_2$, where:

$$\lambda_{12} = \frac{\sum_{i=1}^{I} \gamma_{i1}\omega_{i1}}{\sum_{i=1}^{I} \gamma_{i1}\omega_{i2}}.$$

Here, λ_{12} represents the relative importance that the manager of firm 1 assigns to the profits of firm 2, compared to firm 1's own profits. By analogy, λ_{21} can be derived in the same way.

In scenarios characterized by silent financial interests, we have $\gamma_{ij} = 0$ for $i \neq j$. Thus, under symmetric stakes, this yields:

$$\lambda_{ij}^{SF} = \frac{\omega}{1-(I-1)\omega}.$$

Conversely, under proportional control, where $\gamma_{ij} = \omega_{ij}$ for $i \neq j$, and assuming symmetric stakes, we obtain:

$$\lambda_{ij}^{PC} = \frac{2[1-(I-1)\omega]\omega + (I-2)\omega^2}{[1-(I-1)\omega]^2 + (I-1)\omega^2}.$$

Both parameters, λ_{ij}^{SFI} and λ_{ij}^{PC}, increase with the total number of investors I, provided that $\omega < 1/I$. This reinforces the paper's main result: the level of common ownership required to shift from a first-mover advantage to a second-mover advantage in technology adoption games decreases as the number of investors increases.

[18] This exemption is established under the Hart-Scott-Rodino Antitrust Improvements Act of 1976 (HSR Act), as outlined in 16 C.F.R. §802.9, which specifies the "investment-only" exemption.

4 Conclusion

The presence of common investors—including, among others, investment managers, conglomerate holding companies, pension funds, and hedge funds—in competing firms is a widespread phenomenon that continues to grow across many industries. Competition authorities have expressed concerns regarding its potential anticompetitive effects. These concerns are consistent with most of an emerging body of literature that underscores the need for increased antitrust focus and scrutiny. Studies have highlighted that common ownership may not only lead to higher markups and lower consumer surplus but also contribute to lower labor and capital shares, as well as higher levels of inequality.

Empirical evidence also suggests that common ownership negatively affects innovative activity. To shed light on this issue, we analyze how common ownership influences technology adoption in a duopolistic innovation timing game.

We show that financial links between firms reshape the incentives to act as a leader or a follower in the adoption of new technologies. In the absence of common ownership, the preemptive race results in early adoption and equal payoffs. However, we show that beyond a certain threshold of common ownership, the model transitions to a second-mover advantage, transforming the preemption game into a waiting game. Notably, this threshold does not need to be excessively high; it can be relatively low, that is, below the 10% threshold outlined in the "investment-only" exemption, as specified in 16 C.F.R. §802.9.

We further analyze the scenarios of silent financial interests and proportional control. Our results indicate that common ownership slows down the adoption of new technologies more significantly under proportional control than under silent financial interests. Additionally, common ownership eliminates the joint adoption equilibrium. Finally, as the number of investors increases, the level of common ownership required to shift from a preemption game to a waiting game decreases.

Appendix A

Consider a representative consumer (from a population with a large number of identical consumers) with the following utility function for consumption levels q_1 and q_2:

$$U = \alpha(q_1 + q_2) - \frac{1}{2}(\beta q_1^2 + 2\gamma q_1 q_2 + \beta q_2^2)$$

where $\alpha, \beta > 0$ and $\beta^2 - \gamma^2 > 0$ (to ensure that U is strictly concave). $\gamma > 0$ implies that goods are substitutes. Let p_i and p_j be the price of firm i and j, respectively. Direct demands are then given by $q_i = a - bp_i + dp_j$ for $i \neq j$ with $a = \alpha/(\beta+\gamma)$, $b = \beta/(\beta^2 - \gamma^2)$

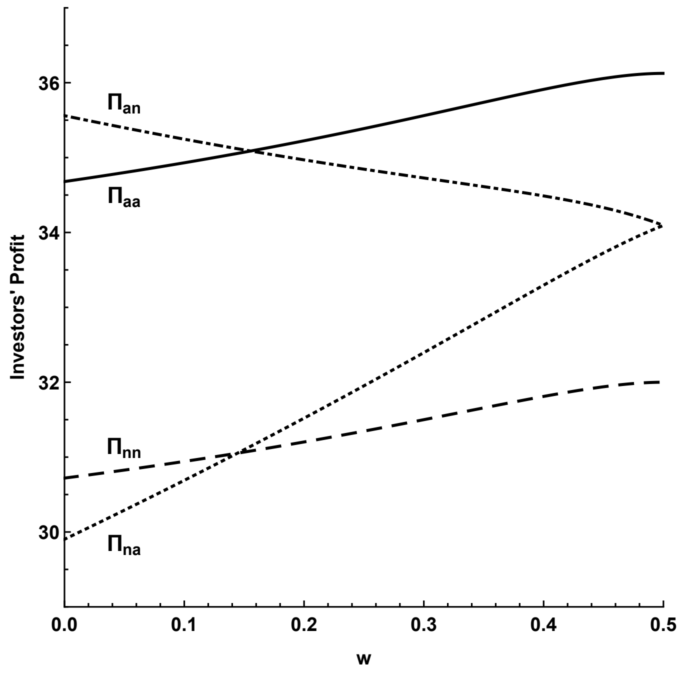


Figure 3: Investors' portfolio profits under SFI.

and $d = \gamma/(\beta^2 - \gamma^2)$.[19] Marginal cost is constant, positive and equal to $c < a/(b-d)$ when the firm has not adopted the innovation, and equal to xc, with $x < 1$, when it has. Profit flows are $\pi_{aa} = (p_i - xc)q_i$ and $\pi_{nn} = (p_i - c)q_i$ for $i = 1, 2$, and if firm 1 adopts first: $\pi_{an} = (p_1 - xc)\, q_1$ and $\pi_{na} = (p_2 - c)\, q_2$. The discounted cost of adoption is given by $k(t) = \sigma e^{-(\theta+r)t}$ with $\sigma > 0$ and where θ is the rate of technological progress: $-\bar{k}'(t)/\bar{k}(t)$, with $\bar{k}(t) = \sigma e^{-\theta t}$. This cost function satisfies Assumption 2(ii) and (iii). Assumption 2(i) requires that $\sigma(\theta + r) > \pi_{an} - \pi_{nn}$.

We consider $\alpha = 20$, $\beta = 3/2$ and $\gamma = 1/2$, thus $a = 10$, $b = 3/4$ and $d = 1/4$: $q_i = 10 - (3/4)p_i + (1/4)p_j$. We assume that the innovation decreases cost by 25% ($x = 0.75$); we also assume that the marginal cost is $c = 4$, and as for the discounted cost of adoption that $\sigma = 18$ and $\theta = r = 0.2$.

A.1 Example: silent financial interests

Figure 3 illustrates investors' profit as a function of the level of common ownership under SFI. At $\omega = 0$, $\Pi_{xy} = \pi_{xy}$, with $x, y \in \{a, n\}$. For $\omega > 0$ and at the equilibrium, the cash flows π_{xy} depend on ω. By continuity, at ω close to zero, the relationships (i') and (ii') hold. The investor's profit of the non-adopting firm increases with ω because she has less of his own firm and more of the most efficient firm: for $\omega > 0.1444$, the inequality $\Pi_{na} > \Pi_{nn}$ holds, and as a result $F(t)$ becomes decreasing and convex. For the same reason, the investor's profit of the adopting firm decreases with ω when the other firm

[19] For more details, see Vives (1999, pp. 145-147).

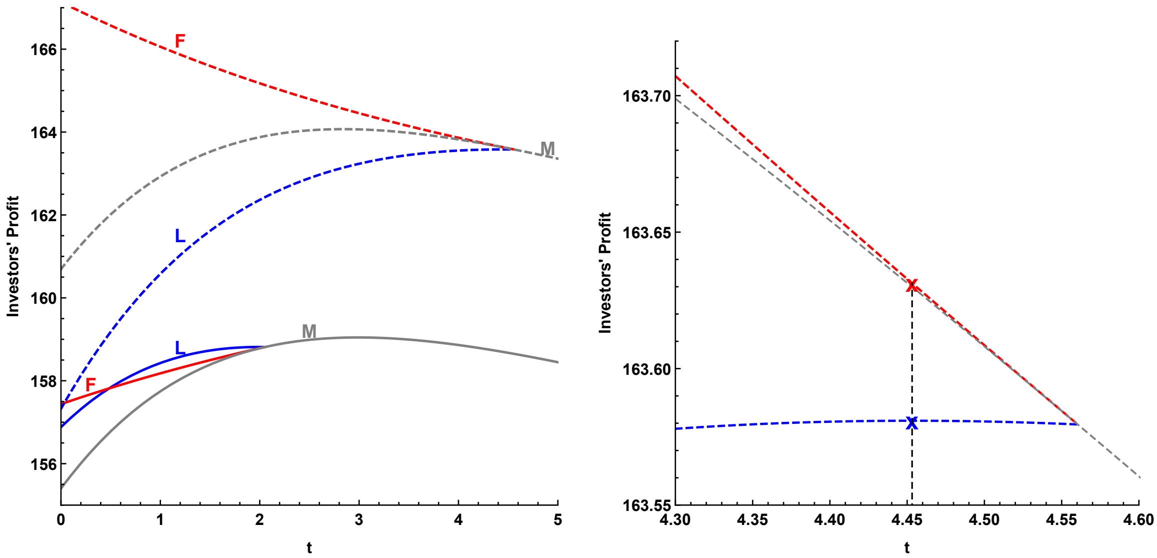


Figure 4: Leader, Follower and Joint Adoption curves under SFI.

has not adopted yet, while her profit increases with ω when it has; when $\omega > 0.1554$, we have that $\Pi_{aa} > \Pi_{an}$, and there is second-mover advantage since $F(t) > L(t)$ for all $t < T_2^*$. Notice however that second-mover advantage can arise even for lower level of common ownership since the condition $\Pi_{aa} > \Pi_{an}$ is stricter than the necessary condition (5). In our example, second-mover advantage emerges when $\omega \geq 0.15$.

Figure 4 plots the discounted investors' payoffs as functions of firm 1's adoption date, t, and for $w = 0$ (solid curves) and $\omega = 0.35$ (dashed curves). With no common ownership, $L(T_1^*) > F(T_1^*)$, where $T_1^* = 1.98$. This triggers a preemption race until $T_0 = 0.48$, which results in equal profit for the two investors with adoption times $T_1^* = T_0 = 0.48$ and $T_2^* = 2.05$. The presence of common ownership shifts upwards the L, F and M curves. On top of that, the profit of the follower's controlling investor decreases with the adoption time of firm 1 since she also obtains a share of the leader's profit, which is higher than the share she gets when both firms are not as efficient: $\Pi_{nn} - \Pi_{na} < 0$. Note also that at this level of common ownership: $\Pi_{aa} > \Pi_{an}$, thus: $F(t) > M(t) > L(t)$ for any $t < T_2^*$. Figure 4b zooms in the curves in the case of common ownership, and marks the maximum of the L curve, which is achieved at $T_1^* = 4.45$, illustrating that $F(T_1^*) > L(T_1^*)$. The game transforms from a preemption race into a waiting game with equilibrium in pure strategies that exhibits technology diffusion. The result is that common ownership slows down technology adoption: it delays firm 1's adoption from $T_0 = 0.48$ to $T_1^* = 4.45$, and firm 2's adoption from 2.05 to 4.56, yielding a higher profit for investor 2 than investor 1.

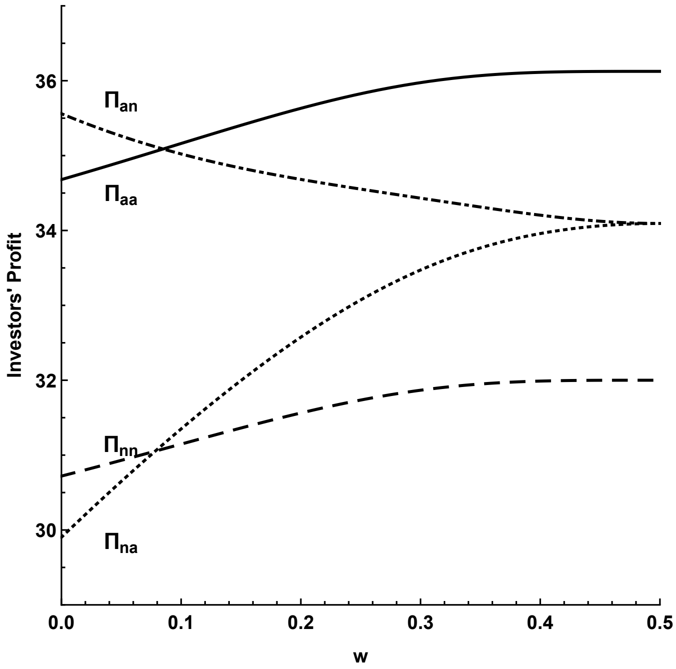


Figure 5: Investors' portfolio profits under PC.

A.2 Example: proportional control

Here we consider the same model and parameter values assumed in Subsection A.1, but under proportional control. Figure 5 depicts investors' profit as a function of ω. We observe that Π_{nn} and Π_{na} equalizes for $\omega = 0.078$, whereas this occurs for a higher level under SFI: $\omega = 0.144$. (The follower curve becomes strictly decreasing and convex from a lower level of common ownership.) We also have that Π_{aa} and Π_{an} equalizes for $\omega = 0.084$; thus, starting from this level the joint adoption curve $M(t)$ lies above the leader curve $L(t)$ for $t < T_2^*$; with SFI this occurs however for $\omega = 0.155$. The main result is that the common ownership level needed to create second-mover advantage is lower; approximately half of the previous level: under PC second-mover advantage arises (condition (5) holds) for $\omega \geq 0.08$, whereas under SFI this occurs for $\omega \geq 0.15$.

In Figure 6 we plot the discounted investors' payoffs as functions of firm 1's adoption date for SFI (solid curves) and PC (dashed curves) with $\omega = 0.35$.

Recall that in the case of no common ownership, due to $L(T_1^*) > F(T_1^*)$, there is a preemption race that results in equal profit for the two investors with adoption times: $T_1^* = T_0 = 0.48$ and $T_2^* = 2.05$. For $\omega = 0.35$, there is second-mover advantage with both SFI and PC. From Proposition 2 we know that $(T_2^*)^{PC} > (T_2^*)^{SFI} > T_2^* = 2.05$. Thus, technology adoption by the follower is delayed with respect to the case of SFI. In particular, $(T_2^*)^{PC} = 5.70$ and $(T_2^*)^{SFI} = 4.56$. As a result, the follower curve with PC swifts upwards with respect to the SFI case: $F(0) = \Pi_{aa}/r - k(T_2^*)$. This also explains why the leader curve shifts downwards ($L(0)^{SFI} > L(0)^{PC}$) since $L(0)$ decreases with the

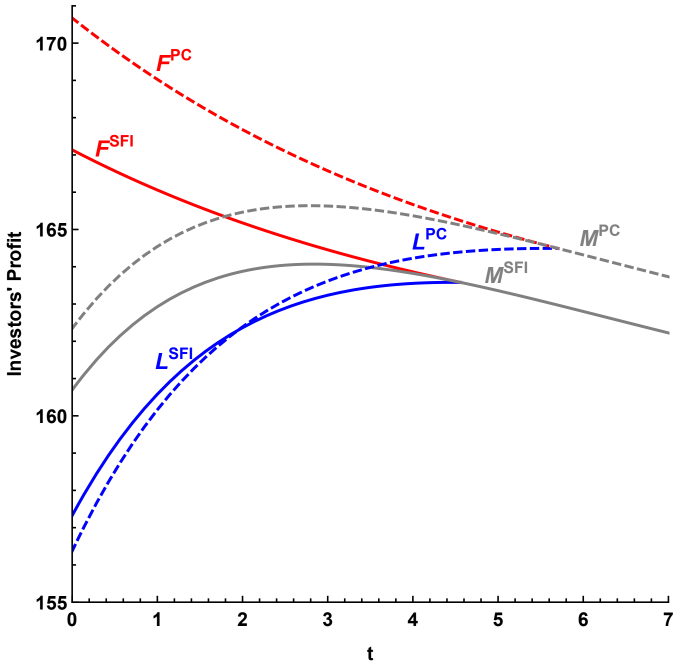


Figure 6: Leader, Follower and Joint Adoption curves under PC.

optimal time of adoption of the follower:

$$L(0) = \left(\frac{\Pi_{an}}{r} - k(0)\right) + \frac{\Pi_{aa} - \Pi_{an}}{r} e^{-rT_2^*}.$$

When the follower adopts the technology, the leader's profit goes from amount Π_{an} to amount Π_{aa}; and when ω is sufficiently high, as it is the case here, $\Pi_{aa} > \Pi_{an}$, so the later the follower adopts the technology the lower the leader's profit.

From Proposition 2 we also know that $(T_1^*)^{PC} > (T_1^*)^{SFI} > T_1^* = T_0 = 0.48$. In particular, $(T_1^*)^{PC} = 5.56$ and $(T_1^*)^{SFI} = 4.45$. Technology adoption is slower with PC than with SFI for both the leader and the follower. On top of that, in both cases the follower yields higher profit than the leader, with highest profit levels recorded in the case of proportional control.[20]

[20]With SFI, the follower's profit is 163.631 and the leader's profit is 163.581, whereas with PC the follower's profit is 164.57 and the leader's profit is 164.493. With no common ownership, both the leader's and the follower's profit is 157.814.

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