Foreclosure Complementarities: Exclusionary Bundling and Predatory Pricing*

Matteo Courthoud † Gregory S. Crawford ‡

October 22, 2021

Abstract

In recent merger cases across complementary markets, antitrust authorities have expressed foreclosure concerns. In particular, the presence of scale economies in one market might propagate to the complementary market, ultimately leading to the monopolization of both. In this paper, we investigate the interplay between two foreclosure practices: exclusionary bundling and predatory pricing in the setting of complementary markets with economies of scale. We show that the two practices are complementary when markets display economies of scale, exclusionary bundling is more likely and, when bundling is allowed, predatory pricing is more likely. We show that this outcome is due to exit-inducing behavior of dominant firms: shutting down predatory incentives restores competition in both markets. We investigate different policies: banning mergers between market leaders, allowing product bundling only when more than one firm is integrated and able to offer the bundle, and lastly knowledge sharing across firms in order to limit the economies of scale. All policies are effective, each for a different reason.

Keywords: Merger policy, digital markets, industry dynamics, foreclosure

JEL Classification: C63, L13, K21

*Preliminary, please don't circulate, cite, or quote.

†Department of Economics, University of Zurich, Email: matteo.courthoud@econ.uzh.ch

‡Department of Economics, University of Zurich and Centre for Economic Policy Research (CEPR), Email: gregory.crawford@econ.uzh.ch

1 Introduction

Hardly a month goes by without a new policy initiative targeting the market power of the largest digital platforms (GAFA).[1] What began with a host of reports by competition authorities and independent antitrust experts raising concerns about this market power[2] has turned into tangible policy proposals seeking to limit it.[3] Despite this, there is an important gap in these proposals: they don't adequately address merger policy towards digital platforms. Despite there being widespread consensus that competition authorities have "*got it wrong*" in approving past mergers by these platforms that have helped solidify and extend their market power (e.g. Facebook/Instagram, Facebook/WhatsApp, and Google/Doubleclick),[4] the latest proposed combination, between Google and Fitbit, the wearable manufacturer and health data collector, seems likely to be cleared by European regulators, despite vociferous objections from independent academic economists.[5]

The source of the problem is that existing merger guidelines are poorly suited to deal with the types of harms to competition brought by the largest digital platforms. Current antitrust law and practice looks favorably on mergers of complements, motivated by the result (dating back as far as Cournot (1838)) that the monopoly price to consumers of two

[1]GAFA refers to Google, Amazon, Facebook, and Apple. It is sometimes extended to include Microsoft, in which case it is written GAFAM.

[2]The list of reports includes the Australian Competition and Consumer Commission (2019) "Digital Platforms Inquiry" report, the Furman et al. (2019) "Unlocking Digital Competition" report for the UK Competition and Market Authority, the Crémer et al. (2019) "Competition in the Digital Era" report for the European Commission, the Duch-Brown (2017) "The Competitive Landscape of Online Platforms" report for the Joint Research Center on Digital Economy, the Stigler Platforms (2019) Final Report on Digital Platforms, and the Schallbruch et al. (2019) "Competition Law 4.0" report for the German Commission.

[3]The European Commission has launched new tools to regulate "gatekeepers" in the digital economy (source: `https://ec.europa.eu/digital-single-market/en/digital-services-act-package`). The UK Competition and Markets Authority has called for a new digital markets regulatory regime (source: `https://www.gov.uk/government/news/andrea-coscelli-calls-for-new-digital-markets-regulatory-regime`). The US Department of Justice has issues a report highlighting concentration in digital economy (source: `https://judiciary.house.gov/news/documentsingle.aspx?DocumentID=3429`).

[4]From the Furman et al. (2019) report: "*Historically there has been little scrutiny and no blocking of an acquisition by the major digital platforms... Our recommendations [are to] update merger policy [by] ensuring that it can be more forward-looking and take better account of technological developments*". From the Commission (2019) report: "*Mergers framework should be updated ... [to account for the effects of] the acquisition of potential competitors and economies of scope created via control of data sets*". Particular concern with cases "*where a dominant platform and/or ecosystem which benefits from strong positive network effects and data access, which act as a significant barrier to entry, acquires a target with a currently low turnover but a large and/or fast-growing user base and a high future market potential*".

[5]See for example the joint statement of leading competition policy scholars on VoxEu (source `https://voxeu.org/article/googlefitbit-will-monetise-health-data-and-harm-consumers`).

complementary goods is less than the total price charged by single-product monopolists (or, more generally, that mergers of complements allow an internalization of externalities that benefits consumers).[6] Features common to large digital platform mergers, however, such as complementarity (often but not always motivated by access to data), increasing returns to scale in the acquirer's and/or target's market, and the potential for leveraging market power across markets, however, can easily reverse this simple intuition. Indeed, both Carlton and Waldman (2002) and Choi and Stefanadis (2001), motivated by the famous (in antitrust circles) Microsoft/Netscape monopolization case, show that a monopolist in one market (e.g., Microsoft) could tie its dominant product (Windows) to an affiliated product (Internet Explorer) in a potentially competitive complementary product market (browsers) and deter efficient entry (by Netscape) not only in the complementary (browser) market, but also in the market where it is dominant (operating systems).

This paper presents a general model of dynamic competition that generalizes these insights and demonstrates that foreclosure commonly arises in complementary markets where (especially dominant) firms have available strategies to leverage market power (e.g. tying). In particular, we analyze how the economic fundamentals underlying many large digital platform markets (complementarity, increasing returns to scale, leveraging strategies) interact to determine industry structure and dynamics and show how policy interventions can mitigate (potentially significant) consumer harm.

While the literature on bundling to foreclose investigates the incentives of a dominant firm to extend its market power to a complementary market, we take a step back and ask ourselves how this firm acquired the market power in the first place. Was it the competitive outcome in a market with economies of scale or was it obtained through exclusionary practices? In order to allow for both possibilities, we build on the work of Besanko et al. (2010) on learning-by-doing. In their model, firms can decrease their future marginal cost by acquiring experience through sales. This positive feedback loop gives firms the incentive to price aggressively at the bottom of the learning scale in order to acquire a future competitive advantage. On the other hand, aggressive prices can also be driven by the incentive to drive competitors out of the market, what is commonly known as "predatory pricing". We add a complementary market to their framework, together with the ability of firms to merge across market and bundle their products.

We show that markets converge to competitive outcomes in the absence of tying or bundling, but to monopoly with it. The reason is two-fold. On one hand, the presence of

[6] Cournot, Augustin. Recherches sur les Principes Mathematiques de la Theorie des Richesses, Paris: Hachette, 1838. (English translation by N. T. Bacon published in Economic Classics [Macmillan, 1897] and reprinted in 1960 by Augustus M. Kelly.).

a complementary market, if firms are not able to integrate, dampens the predatory pricing incentives since part of both the static and dynamic pricing externalities across markets are not internalized. Therefore, mergers and bundling increase consumer welfare due to an internalization of externalities and a sharpening of price competition. On the other hand, the asymmetries in market positions they induce can cause competitors to exit, yielding only an integrated monopoly in steady state, decreasing both consumer surplus and total welfare.

Furthermore, we show that the two foreclosure practices - predatory pricing and exclusionary bundling - are complementary. As we have seen in the previous section, the presence of economies of scale in one market increases the incentives of firms to bundle their products to internalize the cross-market pricing externalities. However, it also increases the incentives of firms to bundle their products in order to exclude competitors. We show that this anti-competitive exclusionary incentive is amplified by the presence of economies of scale. On the other hand, the presence of a complementary market and the possibility of product bundling increases the incentives of firms to price aggressively. This extra incentive is not driven by the economies of scale (that are not present in the complementary market), but by the possibility of monopolizing not just one market but two, by means of product bundling and predatory pricing.

Therefore, while economies of scale might transform competition *in* the market into competition *for* the market, the ability of firms to bundle products can transform competition for *one* market into competition for *multiple* markets. Indeed, we also show that product complementarity is not necessary to obtain the results presented in the previous paragraph. Even if the two markets are completely independent, firms have the incentive to bundle their products to propagate market power across markets. Crucially, this also increases their predatory pricing incentives in the first market, making market tipping in the market with economies of scale more likely.[7]

In the last Section of the paper, we assess the effects of policy interventions like those proposed to address the problems of dominance by the largest digital platforms, including restrictions on tying, restrictions on mergers by dominant firms, data sharing/interoperability, and non-discrimination provisions.[8] In particular, we examine the option of prohibiting mergers among dominant firms, not allowing bundling of products if no other firm is inte-

[7]These results are not tied to the specific form of increasing returns; we choose to express them as learning-by-doing for its computational convenience, but the insights of our analysis apply across a range of economic environments that generate increasingreturns (e.g., economies of scale (in data or more generally), network effects, etc.)

[8]See, for example, the policy proposals to address Google and Facebook's market power in online advertising markets in CMA (2020), excellent market study by the UK's Competition and Markets Authority (CMA).

grated and therefore able to offer the bundle, and technology sharing to decrease the strength of the economies of scale.

The rest of the paper is organized as follows. We start by presenting the baseline model of firm competition in complementary markets in Section 2. In Section 3, we explore the equilibrium dynamics. We also assess the relative importance of bundling and learning-by-doing in determining equilibrium behavior. In Section 4, we instead decompose firms' incentives into competitive and anti-competitive. We inspect two potential anti-competitive effects, inducing competitors' exit and preventing future entry, for two different decisions, pricing and bundling. In Section 5, we introduce a set of potential policy interventions to alleviate the welfare losses generated by the combination of economies of scale and complementary markets. We study three different policies: limiting mergers, limiting bundling and data sharing. Section 6 concludes.

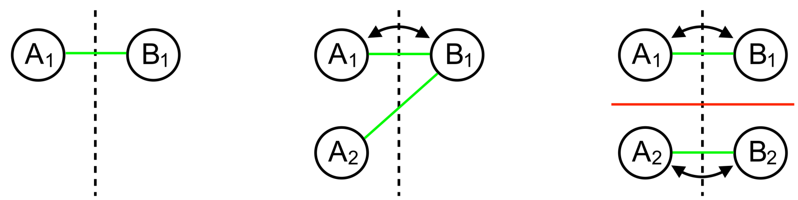
2 The Model

In this section, we provide an overview of the model. We first describe the baseline model of firm competition in complementary markets. Then we introduce learning-by-doing which brings the first dynamic dimension into the model: an experience ladder. Firms can improve their experience through sales and experience in turn reduces their marginal cost. In the second part, we introduce the second type of dynamics that stem from the fact that firms are able to enter the market, exit, merge among each other and, when merged, bundle their product together.

2.1 Baseline

Time is discrete and the horizon is infinite. There are two markets labeled A and B. At each point in time, up to two firms are active in each market and compete in prices with differentiated products. The state of the game is represented by a vector $\boldsymbol{\omega} = \{\omega_1, ..., \omega_4, \omega_{ownership}, \omega_{bundling}\} \in \Omega = \{0, ..., M\}^4 \times \mathcal{O} \times \mathcal{B}$, where the first four values $\omega_1, ..., \omega_4 \in \{0, M\}$ represent the amount of experience of each firm. M is the length of the learning curve. The state $\omega = 0$ indicates inactive firms. The fifth value, $\omega_{ownership} \in \mathcal{O}$ indicates whether there are integrated firms active in the market and their identity. The last value, $\omega_{bundling} \in \mathcal{B}$ indicates whether the integrated firms have bundled their products. We will refer to $\boldsymbol{\omega}$ as a state and Ω as the state space. Firms maximize their total future discounted profits. The discount factor is $\beta \in [0, 1)$. The solution concept we consider is Markov Perfect Equilibrium.

Static Profits. In the baseline model, products in the two markets are perfect complements: consumers demand one unit of a product from market A and one unit of a product from market B[9]. We call a combination of two products a "system". To better understand the market structure, we provide three illustrated examples in Figure 1.



(1) 2 firms, 2 products, 1 system

(2) 2 firms, 3 products, 2 systems

(3) 2 firms, 4 products, 2 systems

Figure 1: Examples of market structures

In Figure 1, circles indicate products, the dotted line separates the two markets, A and B, red lines indicate systems, and arrows indicate joint ownership. In the first figure from the left, there is one firm active in each market, producing one product each (A_1 and B_1). Hence, there is one system available to consumers (A_1B_1), plus the outside option which is always present and hence not depicted in the figures. In the second figure, there are two firms active in market A and one firms active in market B, producing one product each (A_1, A_2 and B_1 respectively). Overall, there are two systems available to consumers (A_1B_1 and A_2B_1). In the last figure, there are three firms. Two are not integrated and produce one product each (A_2 and B_2 respectively), while the last is integrated and produces products in both markets (A_1 and B_1). Because of bundling, there are two systems available to consumers (A_1B_1 and A_2B_2).

There is a continuum of consumers of unit mass. Consumer i's utility from buying one unit of product A_1 and one unit of product B_1 is given by

$$u_{i,A_1B_1}(\boldsymbol{p}) = v_i - \sigma(p_{A_1} + p_{B_1}) + \varepsilon_{i,A_1B_1} \tag{1}$$

where v_i is the value of the system for consumer i, p_{A_1} is the price of product A_1, p_{B_1} is the price of product B_1, σ is the price elasticity and ε_{i,A_1B_1} is the idiosyncratic preference of consumer i for system A_1B_1. There is an outside option which gives utility $u_{i,0} = v_i - \sigma p_0 + \varepsilon_{i,0}$. The random shocks ε_i are assumed to be independent and type 1 extreme value

[9]We can relax this assumption by allowing for partial complementarity: consumers prefer bundled products but are also able to buy the components separately. One parameter governs the extent of partial complementarity so that it spans the full range from market independence to full complementarity (current model). The results with partial complementarity are currently not included in the paper.

distributed so that the resulting demand function has the logit form. For example, assume that there are two products in market B, B_1 and B_2. The demand for product A_1 is

$$q_{A_1}(\boldsymbol{p}) = \frac{e^{-p_{A_1}/\sigma}}{e^{-p_{A_1}/\sigma} + e^{-p_{A_2}/\sigma} + e^{-p_0/\sigma}\left(e^{-p_{B_1}/\sigma} + e^{-p_{B_2}/\sigma}\right)^{-1}}, \tag{2}$$

where $\boldsymbol{p}$ is the vector of prices. $\left(e^{-p_{B_1}/\sigma} + e^{-p_{B_2}/\sigma}\right)^{-1}$ captures the fact that product A_1 can be combined either with product B_1 or with product B_2.

In each period, firms compete in prices and their static profits are given by

$$\pi_n(\boldsymbol{p}, \boldsymbol{\omega}) = q_{A_1}(\boldsymbol{p})(p_{A_1} - c_{A_1}), \tag{3}$$

where c_{A_1} is the marginal cost of production for firm A_1. The marginal cost is endogenous and it depends on the experience accumulated by the firms, through sales.

2.2 Learning-by-Doing

Learning-by-doing adds the first dimension to firm dynamics: firm experience. The mechanics of the model are the following: firms' marginal cost decreases with experience and experience increases with sales. The model is based on Besanko et al. (2010).[10] We abstract from organizational forgetting so that firms marginal cost can only decrease over time[11]

Experience. The information on firms' experience is contained in the first four dimension of the state vector $\boldsymbol{\omega} = \{\omega_1, ..., \omega_4, \omega_{ownership}, \omega_{bundling}\} \in \Omega = \{0, ..., M\}^4 \times \mathcal{O} \times \mathcal{B}$. The first four values represent firms' cumulative experience or stock of know-how, $\{\omega_1, ..., 4\} \in \{0, ..., M\}$. State zero indicates that the firm is inactive, or outside the market.

Dynamics. By making a sale, a firm adds one unit to its stock of know-how. The law of motion of firm know-how is

$$e_n' = e_n + q_n, \tag{4}$$

where e_n' and e_n denote firm n's stock of know-how in the future and current period, respectively, and the random variable $q_n \in \{0, 1\}$ indicates whether firm n makes a sale and gains a unit of know-how through learning-by-doing[12].

[10]See the original paper for a more detailed exposition and discussion.

[11]Organizational forgetting is modeled in Besanko et al. (2010) in the form of industry-wide shock that decreases firms' experience by one level, increasing their marginal cost.

[12]With organizational forgetting, where would be a further term (negative) to take into account the possibility that firm n's stock of know-how decreases because of organizational forgetting.

Learning-by-doing. Firm n's marginal cost of production $c(e_n)$ depends on its stock of know-how through a learning curve

$$c(e_n) = c_0 \max\{e_n, M\}^{1-\rho}, \tag{5}$$

where ρ is the learning parameter and represents the steepness of the learning curve. Marginal cost decreases by $100 \cdot \rho$ percent as the stock of know-how doubles. The marginal cost of production at the bottom of the learning curve, $c(1)$, is $c_0 > 0$ and M represents the maximum stock of know-how that a firm can accumulate.

2.3 Discrete Decisions

Entry and Exit. In order to ensure equilibrium existence, we follow Doraszelski and Satterthwaite (2010) and assume stochastic entry costs and exit scrap values. Moreover, in order to avoid equilibrium multiplicity in the static game, for each discrete decision, we allow only one firm to take it, in each period. In particular, in each period, one inactive firm (entrant) is selected uniformly at random and gets an entry opportunity. The selected firm draws an entry cost ϕ^E from a distribution $F^E(\phi^E)$. After observing its own cost, the selected entrant firm decides whether to enter the market or not. Afterwards, in each period, one active firm is selected uniformly at random and gets the possibility to exit the market. The selected firm draws a scrap value ϕ^X from a distribution $F^X(\phi^X)$ and decides whether to stay active or exit the industry and collect the scrap value. If a firm is producing more than one product (in both market A and market B), it draws a scrap value for each one of them. In case it decides to exit, it stops producing both products.

Mergers. We allow firms active in separate markets to merge with each other in order to form a joint multi-market entity. We do not consider mergers between firms active in the same market[13]. We also do not consider mergers between entities that are already integrated, i.e., if one of the two firms is already active in both markets we do not allow it to merge further. In order to avoid considering multiple mergers at the same time, we assume that in every period one merger pair is drawn uniformly at random from all the possible merger pairs. In each period, a random merger cost ϕ^M is drawn from a distribution $F^M(\phi^M)$. After observing the merger cost, the two firms decide whether to merge or not. If the two firms merge, they pay the merger cost and they become a joint entity.

Bundling. We allow integrated firms to bundle their products. Bundling makes the products of the integrated firm incompatible with those of their competitors. For example, in Figure 1, in the third figure, firms A_1 and B_1 have bundled their products so that systems

[13]We are considering mergers between firms in the same market together with other potential extensions.

A_1B_2 and A_2B_1 are no longer available to consumers. In every period, one integrated firm is drawn uniformly at random among all integrated firms. The selected integrated firm draws a random bundling cost ϕ^B from a distribution $F^B(\phi^B)$. After observing the bundling cost, the firm decides whether to bundle the two products or not. The bundling decision is irreversible as long as the firm is active in the market.

Timing. The overall timing of the game is the following:

1. Active firms compete in prices.
2. One integrated firm is drawn, they observe their bundling cost and decide whether to bundle their products.
3. One merger pair is drawn, they observe their merger cost and decide whether to merge.
4. Entrants observe entry costs and decide whether to enter the industry.
5. Active firms observe the static scrap values and decide whether to exit the industry.

The sequence of decisions is motivated by the following observations. First, since we are going to explore the effect of anti-competitive bundling and pricing in Section 4, we need the pricing and bundling decisions to precede the entry and exit decisions. Second, we would like the least number of actions to occur in the same period. Therefore, for example, we put mergers after bundling so that firms cannot merge and bundle in the same period.

2.4 Value and Policy Function

Firms maximize the net present value of their future cash flows. We define the value function as the net present value of firms' future cash flows, under the assumption that firms behave optimally. Let $V_n(\boldsymbol{\omega})$ denote the value function of firm n in state $\boldsymbol{\omega}$. The value function is implicitly defined by the Bellman equation

$$V_n(\boldsymbol{\omega}) = \max_{p_n} \; q_n(\boldsymbol{p})(p_n - c_n) + \beta \mathbb{E}_{\boldsymbol{\omega}'} \left[\sum_s q_s(\boldsymbol{p}) V_n^s(\boldsymbol{\omega}') \middle| \Phi \right], \tag{6}$$

where $\boldsymbol{\Phi} = \{\Phi_1, ..., \Phi_n\}$ is the set of bundling, merger, entry and exit strategies of each firm, V_n^s is the intermediate value function, conditional on system s being sold, but computed before the bundling, merger, entry and exit decisions. The possible systems when all two firms are active in both markets and there is no bundling are A_1B_1, A_1B_2, A_2B_1, A_2B_2 and the outside option, labeled with a 0. The expectation operator $\mathbb{E}_{\boldsymbol{\omega}'}$ is taken over the distribution of bundling and merger costs, exit scrap values and entry costs.

After firms select the optimal price and sales are realized, one firm is selected uniformly at random and gets the opportunity to exit. The selected firm takes the exit decision by comparing the random scrap value realization ϕ^X with its expected discounted future value conditional on remaining active. The exit policy function is given by

$$\Phi_n^X(\boldsymbol{\omega}, \phi^X | \omega_n > 0) = \arg\max \left\{ \phi^X \ , \ \beta \ \mathbb{E}_{\boldsymbol{\omega}'} \Big[V_n(\boldsymbol{\omega}') \ \Big| \ \boldsymbol{\omega}, \boldsymbol{\Phi} \Big] \right\}. \tag{7}$$

Before the exit phase, one firm gets the opportunity to enter in one of the available "slots". If two firms are active in one market, no further entry is possible (there can be at most two firms active per market). The entrant takes its decision by comparing the random entry cost realization ϕ^E with its expected future discounted value conditional on entry. The entry policy function is given by

$$\Phi_n^E(\boldsymbol{\omega}, \phi^E | \omega_n = 0) = \arg\max \left\{ 0 \ , \ -\phi^E + \beta \ \mathbb{E}_{\boldsymbol{\omega}'} \Big[V_n(\boldsymbol{\omega}') \ \Big| \ \boldsymbol{\omega}, \boldsymbol{\Phi} \Big] \right\}. \tag{8}$$

Before the entry and exit stage, a firm-pair is drawn uniformly at random from the set of all firm pairs. If the firm pair is eligible, the two firms bargain on the merger buyout price and decide whether to merge. Let $\boldsymbol{\omega}$ be the interim state before the merger, $\boldsymbol{\omega}'$ the state after the merger, $V^M_{n_B}(\cdot)$ and $V^M_{n_S}(\cdot)$ the interim value of the buyer and the seller, respectively and ϕ^M the merger cost realization. The merger price $\tau^*_{n_B,n_S}(\boldsymbol{s}')$ is determined by Nash Bargaining as the solution of

$$\max_{\tau} \ \Big(V^M_{n_B}(\boldsymbol{\omega}') - V_{n_B}(\boldsymbol{\omega}) - \phi^M - \tau \Big)^{\lambda} \Big(\tau + V^M_{n_S}(\boldsymbol{\omega}') - V_{n_S}(\boldsymbol{\omega}) \Big)^{1-\lambda}, \tag{9}$$

where $\lambda \in [0, 1]$ is the relative bargaining power of the buyer. The optimal bargaining price is equal to

$$\tau^*_{n_B,n_S}(\boldsymbol{\omega}) = \lambda \Big[V^M_{n_B}(\boldsymbol{\omega}') - V_{n_B}(\boldsymbol{\omega}) - \phi^M \Big] + (1-\lambda) \Big[V^M_{n_S}(\boldsymbol{\omega}') - V_{n_S}(\boldsymbol{\omega}) \Big], \tag{10}$$

where the first term in the square brackets is the reservation value of the buyer and the second term is the reservation value of the seller. The merger policy function is given by

$$\Phi_n^M(\boldsymbol{\omega}, \phi^M) = \arg\max \left\{ \phi^M \ , \ \beta \ \mathbb{E}_{\boldsymbol{\omega}'} \Big[V^M_{n_B}(\boldsymbol{\omega}') + V^M_{n_S}(\boldsymbol{\omega}') - V_{n_B}(\boldsymbol{\omega}) - V_{n_S}(\boldsymbol{\omega}) \ \Big| \ \boldsymbol{\omega}, \boldsymbol{\Phi} \Big] \right\}. \tag{11}$$

The first decision stage is bundling. One integrated firm is selected uniformly at random among the existing ones. The selected firm takes its bundling decision by comparing its expected discounted future value conditional on not bundling with its expected value conditional on bundling, plus the realization of the bundling cost ϕ^B. The bundling policy function is given by

$$\Phi_n^B(\boldsymbol{\omega}, \phi^B) = \arg\max \left\{ \beta \, \mathbb{E}_{\boldsymbol{\omega}'} \left[V_n(\boldsymbol{\omega}') \;\middle|\; \boldsymbol{\omega}, \boldsymbol{\Phi} \right] , \; -\phi^B + \beta \, \mathbb{E}_{\boldsymbol{\omega}'} \left[V_n(\boldsymbol{\omega}') \;\middle|\; \text{bundling}, \boldsymbol{\omega}, \boldsymbol{\Phi} \right] \right\} . \tag{12}$$

Equilibrium. The system of equations given by the value function (eq. 6) and policy functions (eqs. 7, 8, 11, 12) defines the Markov Perfect Equilibrium of the game.

2.5 Solution Method

The solution method is value function iteration. We start with an initial guess for the value function $V_n^0(\boldsymbol{\omega}) = 0 \; \forall n, \boldsymbol{\omega}$ and calculate the best reply functions of each firm to the old value and update the value and policy functions accordingly. Since the initial value function is equal to zero, we can interpret the computed equilibrium as the equilibrium of a finite repeated game with the time horizon going to infinity. This method does not solve the issue of equilibrium multiplicity but it is transparent with respect to which equilibrium we are referring to. Moreover, it ensures replicability of the results. The algorithm stops as soon as the distance between two successive iterations of the value function falls below a threshold $\varepsilon > 0$. The distance metric we use is the maximum absolute difference among all values. It is important to remark that the best reply operator is not a contraction and hence, there is no guarantee of convergence. We find, however, that the algorithm always converges for all the parametrizations explored in the simulations.

3 Industry Dynamics

In this Section, we are going to look at the long run industry dynamics. We first analyze market evolution under a single parametrization, trying to disentangle the effects of product complementarity from the effects of learning-by-doing. We then check how the results generalize across a broad range of model parametrizations.

3.1 Example of Dynamics

We begin this section by inspecting the equilibrium for a single parametrization. The baseline parameter values are reported in Table 1.

Parameter Description	Parameter	Value
Learning rate	α	0.5
Discount factor	β	0.95
Marginal cost	c_0	1
Maximum experience level	M	5
Price of the outside option	p_0	1.5
Price elasticity	σ	5
Exit scrap value	$F(\phi^X)$	$U[0, 1]$
Entry cost	$F(\phi^E)$	$U[0, 10]$
Merger cost	$F(\phi^M)$	$U[0, 1]$
Bundling cost	$F(\phi^B)$	$U[0, 1]$

Table 1: Model Parametrization

The model generates two types of market dynamics: within markets, as firms climb the learning curve by making sales and gaining experience, and across markets as firms enter, exit, merge and bundle their products. In order to understand how the equilibrium dynamics look like, we plot the alluvial flow of market transitions in Figure 2, starting with a uniform distribution over states. We plot the distribution at different points in time: after 1, 3, 5, 10, 30 and 10.000 (labeled as ∞) periods. It is important to notice that multiple market states have been aggregated together in the figure below, for the sake of exposition. In particular, the mixed monopoly-duopoly

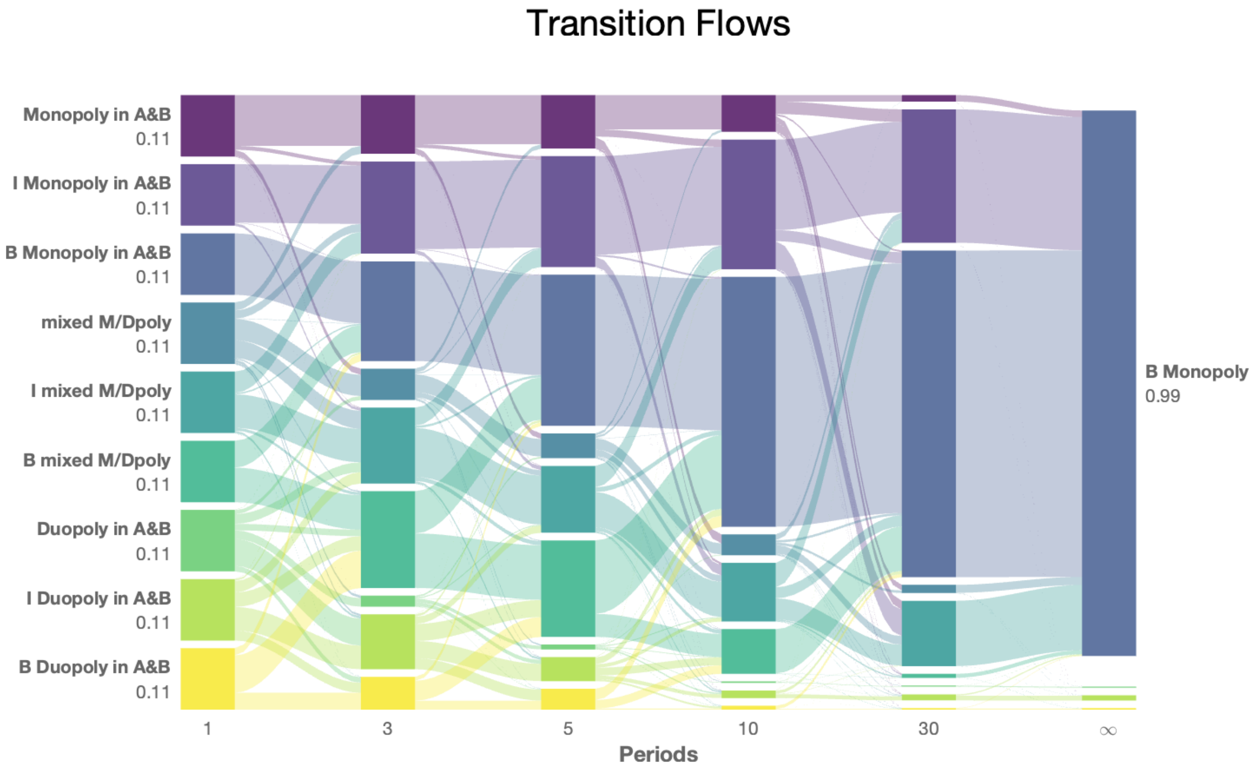


Figure 2: Equilibrium market transitions over a sequence of time steps: 1, 3, 5, 10, 30 and 10.000 (∞). "I" indicates that at least two firms are integrated across markets. "B" indicates that at least one integrated firm has bundled its products. The parameters are as indicated in Table 1.

As we can see, the market eventually degenerates to an integrated monopoly where the two firms have their products bundled together. How does it happen? We identify three crucial transitions:

1. High incentives of firms to merge and integrate.
2. High incentives of integrated firms to bundle their products.
3. Exit from states with bundled products.

First, we observe a the tendency of firms to merge and bundle products in the short run. However, over time, firms exit from these states so that eventually only one firm is left in the market, offering a bundled product. Bundling is also an effective entry deterrent. In fact, while we observe entry in the non-integrated and non-bundling monopolies, there is no firm entry in the bundling monopoly. Because of these reasons, the market structure converges to an extreme in the long run. However, there are also sizable effects in the short term. In order to have a measure of what tells short- and long-run apart, we use the length of the learning scale as a metric, $M = 5$. This is the minimum amount of time that it takes to a firm to reach the bottom of the learning curve. From Figure 2, we see that it takes only twice as much, 10 periods, for an integrated monopoly to be the most likely outcome, starting from any initial setting.

An important feature of the transitions to monopoly is the fact that consumer surplus initially increases, but in the long run it drops below the initial levels, because of market monopolization. In Table 2, we report some statistics for each state, averaged over the different steps of the learning curve. In particular, we report the average price (weighted by demand), total profits, consumer welfare and the probability of observing any entry or exit.

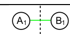
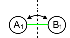
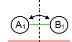
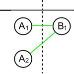
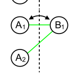
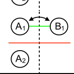
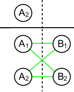
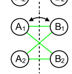
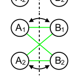
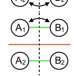
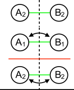
		Price	**Profits**	**Surplus**	**Welfare**
Monopoly in A&B		2.26	1.07	0.25	1.32
I Monopoly in A&B		2.4	1.09	0.34	1.43
B Monopoly in A&B		2.4	1.09	0.44	1.54
mixed M/Dpoly		2.44	1.22	0.32	1.54
I mixed M/Dpoly		2.43	1.14	0.34	1.48
B mixed M/Dpoly		2.4	1.09	0.46	1.54
Duopoly in A&B		0.95	-0.43	2.23	1.8
I Duopoly in A&B		1.2	-0.19	1.97	1.77
I Duopoly in A&B		0.71	-0.66	2.48	1.82
B Duopoly in A&B		-0.22	-1.64	3.35	1.7
B Duopoly in A&B		-2.35	-3.7	5.52	1.82

Table 2: Average statistics by market structure. The underlying parametrization is reported in Table 1. In detail, the columns are: price averaged over systems and weighted by demand, total firm profits, consumer surplus. The averages are computed over the stages of the learning curve.

As anticipated, consumer welfare is generally higher in states where firms bundle their products together. Indeed, bundling increases the strength of competition. However, it can also be used to increase the probability of rivals' exit and to prevent potential entry. This is indeed what we observe in Table 3. An integrated firm that faces competition from non-integrated firms in both markets, by bundling its products, can increase the probability of rivals' exit from 6% to 34%. An integrated monopolist that bundles its products can decrease the probability of entry from 2% to virtually zero.

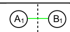
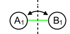
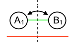
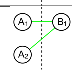
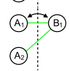
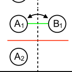
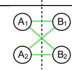
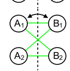
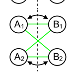
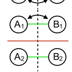
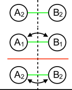
		Entry	Exit	Merger	Bundling
Monopoly in A&B		0.06	0	0.03	0
I Monopoly in A&B		0.02	0	0	0
B Monopoly in A&B		0	0	0	0
mixed M/Dpoly		0.07	0.04	0.19	0
I mixed M/Dpoly		0.06	0.08	0	0.28
B mixed M/Dpoly		0.02	0.21	0	0
Duopoly in A&B		0	0.04	0.34	0
I Duopoly in A&B		0	0.06	0.05	0.28
I Duopoly in A&B		0	0	0	0.32
B Duopoly in A&B		0	0.32	0.1	0
B Duopoly in A&B		0	0.34	0	0

Table 3: Average statistics by market structure. The underlying parametrization is reported in Table 1. In detail, the columns are: price averaged over systems and weighted by demand, total firm profits, consumer surplus. The averages are computed over the stages of the learning curve.

3.2 Comparative Statics

In order to understand how much the results above generalize, we solve the model for a broad range of parameter values. In particular, we concentrate on what we believe are the two most important dimensions of the model: the extent of market competition, governed by the price elasticity σ, and the intensity of learning, governed by the learning parameter ρ. We investigate a 20×20 grid over the two parameters. In particular, we take a uniformly distributed array of values that spans the interval $[1, 10]$ for σ and $[0.0, 1.0]$ for ρ. While the array of values is exhaustive for ρ, since it covers the whole unit interval, the choice of the interval for σ corresponds to the range that delivers the most interesting insights. Exploring the parameter space beyond those values does not seem to provide additional insights.

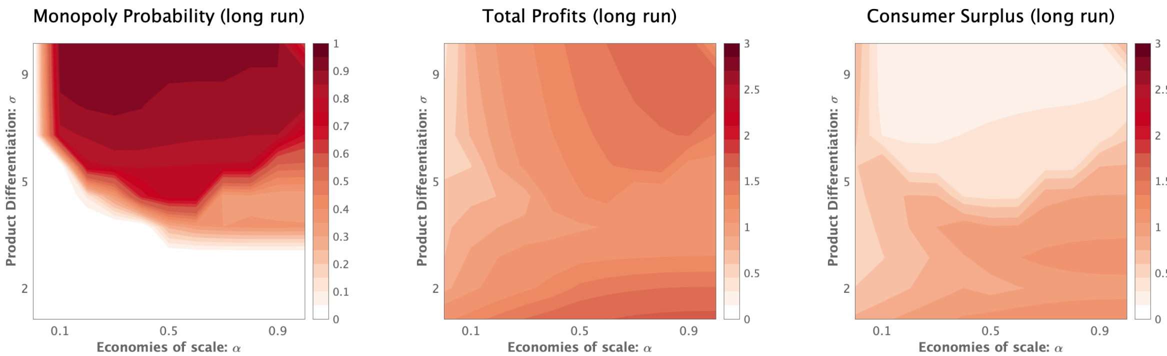


Figure 3: Summary statistics for different competition (σ) and learning (ρ) parameters. With *long run* we indicate the outcomes after 10.000 periods, With *NPV* we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1 \ \forall n$).

From Figure 3, we observe that for a broad range of parameters, the market degenerates to a monopoly in the long run. In particular, this happens when competition is high (high product differentiation σ) and when the benefits of learning are high (high ρ which implies high reduction in marginal cost with each sale). High competition makes monopoly more attractive with respect to duopoly while high learning increases the benefits from being aggressive in pricing along the learning curve and deepens asymmetries generated by learning-by-doing. Market monopolization has real consequences. If we look at the two rightmost figures, we see that total profits surge and consumer surplus plummets without competition.

In order to understand the role of the two major forces in our model, bundling and learning-by-doing, in Figure 4 we plot firms' profit margins and bundling probability in the short run. In the left-hand side panel we plot the average price minus marginal cost over the first five periods[14]. In the right-hand side panel, we plot the probability of observing product bundling in period five, i.e. the probability that at least a firm-pair has decided to integrate and bundle their products within the first five periods.

[14] We set five as the number of short run periods since it is the minimum amounts of periods that a firm needs to climb to the top of the learning curve. Results are robust to a different choice of the short run horizon.

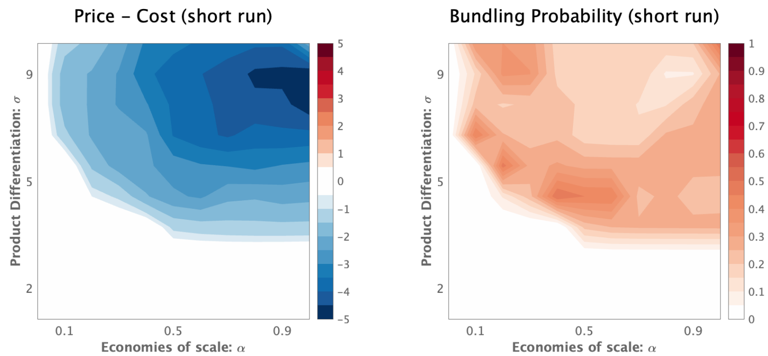


Figure 4: Summary statistics for different competition (σ) and learning (ρ) parameters. With *long run* we indicate the outcomes after 10.000 periods, With *NPV* we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1 \ \forall n$).

As we can see, both below-cost pricing and bundling are associated with parametrizations in which the market eventually degenerates to a monopoly in the long run. However, this is not sufficient to draw any conclusion on the impact of each mechanism on the final outcome. In the next section, we try to disentangle the two effects by shutting down each channel separately.

3.3 Bundling and Learning-by-doing

In order to disentangle the effect of bundling from the effect of learning-by-doing on the probability of long-run market monopolization, we separately shut down each of the two channels. First, we compute the model without allowing firms to bundle their products. In practice, this means that we lose the last dimension of the state space that becomes $\Omega = \{0, 1\}^4 \times \mathcal{O}$. We report comparative statics in Figure 5, relative to the baseline.

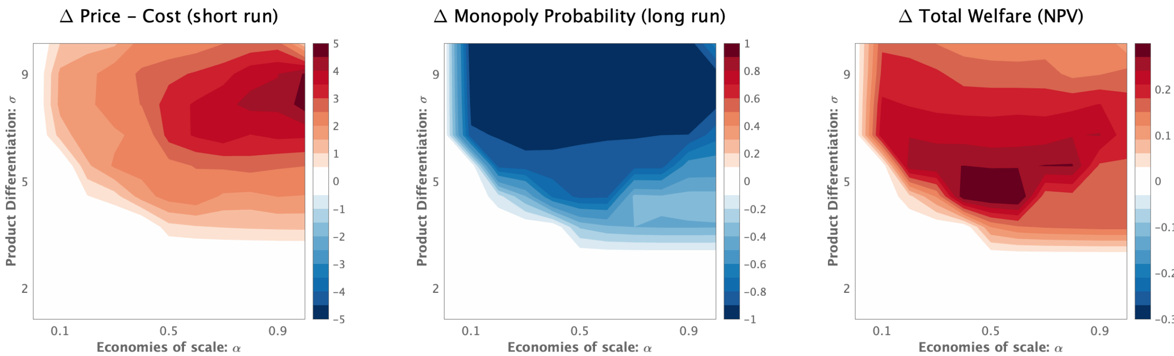


Figure 5: Summary statistics for different competition (σ) and learning (ρ) parameters. All the reported values are differences between the comparative statics without bundling and (minus) the baseline comparative statics. With *long run* we indicate the outcomes after 10.000 periods, With *NPV* we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1 \; \forall n$).

From Figure 5, we observe that without bundling, prices increase, exactly in the settings in which we were observing long-run market monopolization. For the parameters in which we did not observe long-run market monopolization, nothing changes. Moreover, we observe that this also has an impact on the net present value of total welfare. Therefore, it seems that not only bundling might be a crucial ingredient for firms to get market power, but it also increases the incentives of firms to engage in "predatory pricing". In the next Section we investigate more in detail whether indeed anti-competitive incentives are driving this behavior.

In Figure 6 we plot the relative comparative statics removing learning-by-doing. In particular, we remove the learning scale, setting active firms' marginal cost to the marginal cost at the top of the learning curve implied by the corresponding value of ρ. This implies that the size of the first four dimensions of the state space decreases from $M+1$ (the length of the learning curve, plus the inactive state) to 2 (inactive and top of the learning curve): $\Omega = \{0, M\}^4 \times \mathcal{O} \times \mathcal{B}$.

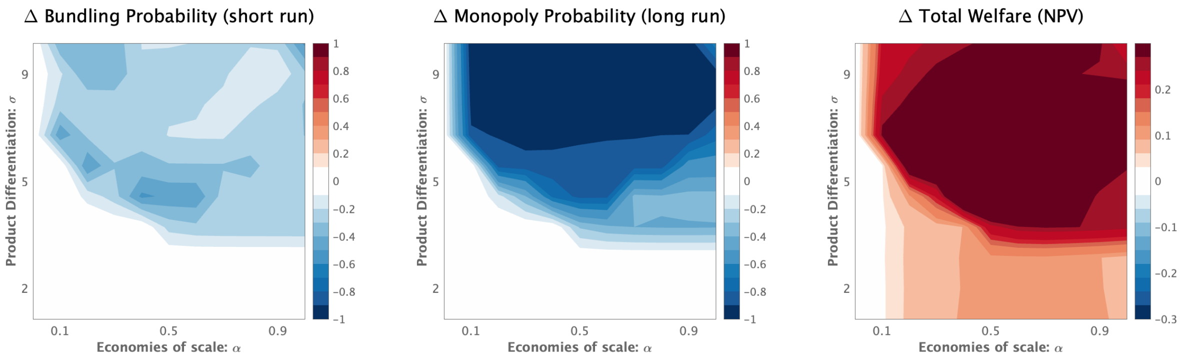


Figure 6: Summary statistics for different competition (σ) and learning (ρ) parameters. All the reported values are differences between the comparative statics without learning-by-doing and (minus) the baseline comparative statics. With *long run* we indicate the outcomes after 10.000 periods, With *NPV* we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1 \ \forall n$).

From Figure 6, we observe a result symmetric to the one of Figure 5: shutting down the incentives of firms to price aggressively also decreases their incentives to bundle products across markets. In turn, this has implications on market tipping and welfare.

Taken together, these findings suggest that product complementary and economies of scale open up more foreclosure opportunities than each feature alone. However, in order to draw conclusions on the anti-competitive nature of this behavior, we have to separate anti-competitive from competitive incentives. In the next section, we define anti-competitive incentives and we assess their relevance in determining equilibrium behavior.

4 Anti-competitive Incentives

In this Section, we investigate the role of anti-competitive incentives in determining equilibrium behavior. We follow the approach of Besanko et al. (2014) in order to identify the extent to which firm behavior is driven by anti-competitive forces. We expand their analysis in two dimensions. First, they consider only exit-inducing incentives, while we also consider entry-preventing incentives, in the spirit of Besanko et al. (2020). Moreover, we also analyze the bundling decision of the firm.

4.1 Definition

In the literature, there exist many different definitions of predatory incentives. Ordover and Willig (1981) define predatory behavior as "*a response to a rival that sacrifices part of the profit that could be earned under competitive circumstances were the rival to remain viable, in order to induce exit and gain consequent additional monopoly profit.*" Cabral and Riordan (1997) instead define an action predatory "*if (i) a different action would increase the probability that rivals remain viable and (ii) the different action would be more profitable under the counterfactual hypothesis that the rival's viability were unaffected.*". The European Commission (2009) defines predatory conduct as the practice of "*incurring losses or foregoing profits in the short term (referred to hereafter as 'sacrifice'), so as to foreclose or be likely to foreclose one or more of its actual or potential competitors with a view to strengthening or maintaining its market power, thereby causing consumer harm.*". Similarly, the Federal Trade Commission defines predatory pricing as "*a price reduction that is profitable only because of the added market power the predator gains from eliminating, disciplining or otherwise inhibiting the competitive conduct of a rival or potential rival*" (Bolton et al., 1999).

These quotes suggest that predatory motives are driven by competitors' exit or, more in general, by the objective to decrease competition. These motives are anti-competitive insofar as they exploit a dynamic inefficiency such as firm exit. However, according to this point of view, we should not consider only inducing competitor's exit in the definition of anti-competitive incentives but also preventing future entry. Both motives stems from lower competitive pressure and are dynamically inefficient because of the sunk costs they involve. Therefore, we define anti-competitive incentives the motives behind behavior that are generated by inducing rivals' exit or preventing their entry.

4.2 Anti-competitive Pricing

In our model, firms' pricing incentives can decomposed into two components: static pricing incentives and dynamic pricing incentives. In fact, prices do not only affect present profits, directly and indirectly through quantities, but also firms' future value. Transition probabilities along the learning scale depend on the probability of getting a sale $q(\boldsymbol{p})$, which in turn depends on firm prices. We can see the relationship more explicitly in the first order condition of the firm pricing problem, from Equation 6.

$$0 = \underbrace{\frac{\partial q_{A_1}(\boldsymbol{p})}{\partial p_{A_1}}(p_{A_1} - c_{A_1}) - q_{A_1}(\boldsymbol{p})}_{\text{static incentives}} + \underbrace{\beta \mathbb{E}_{\boldsymbol{\omega}'} \left[\sum_s \frac{\partial q_s(\boldsymbol{p})}{\partial p_{A_1}} V^s_{A_1}(\boldsymbol{\omega}') \right]}_{\text{dynamic incentives}}, \tag{13}$$

where $V^s_{A_1}$ is the intermediate value function, conditional on system s being sold, but computed before the bundling, merger, entry and exit decisions. The possible systems when all firms are active and there is no bundling are A_1B_1, A_1B_2, A_2B_1, A_2B_2 and the outside option. By affecting transition probabilities, firms' pricing decision affects the probability distribution of future states and therefore, indirectly, firms' exit and entry probabilities.

According to our definition of anti-competitive incentives in Section 4, we define anti-competitive pricing incentives (API) as the motives behind the firms' pricing decision that are driven by changes in competitors' entry or exit probabilities. For what concerns exit, we can isolate such incentives in the first order condition reported in Equation 13 as the dynamic pricing incentives driven by a change in rivals' exit probability.

$$API_{exit} = \underbrace{\beta \mathbb{E}_{\boldsymbol{\omega}'} \left[\sum_s \frac{\partial q_s(\boldsymbol{p})}{\partial p_{A_1}} V^s_{A_1}(\boldsymbol{\omega}') \middle| \Phi \right]}_{\text{true pricing incentives}} - \underbrace{\beta \mathbb{E}_{\boldsymbol{\omega}'} \left[\sum_s \frac{\partial q_s(\boldsymbol{p})}{\partial p_{A_1}} V^s_{A_1}(\boldsymbol{\omega}') \middle| \Phi_{-X}, \Phi^*_X \right]}_{\text{counterfactual pricing incentives}}, \tag{14}$$

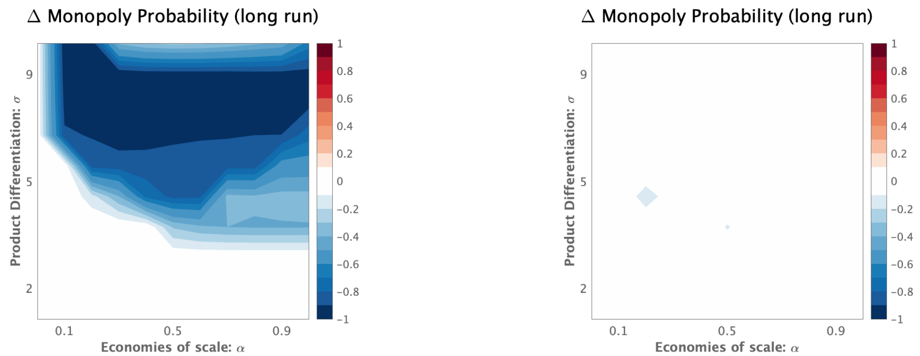
where Φ^*_X is the collection of exit policy functions computed not taking into account the advances along the learning curve due to the pricing decision. For example, let us focus on state $\boldsymbol{\omega} = \{1, 1, 1, 1, 0, 0\}$, where four firms are active and there is no integration and no bundling. The interim value function conditional on bundle A_1B_1 being sold is $V^{A_1B_1}(\boldsymbol{\omega}')$, where $\boldsymbol{\omega}' = \{2, 1, 2, 1, 0, 0\}$. The counterfactual conditional interim value is computed with one slight difference: we substitute the exit probability of each firm with the exit probability they would have had if firms A_1 and B_1 were a step lower in the learning curve, i.e. if the sale had not taken place. The anti-competitive pricing incentives (API) are given by the difference between the pricing incentives under the correct exit probabilities and the pricing incentives under the counterfactual exit probabilities.

In order to assess the impact of predatory incentives, we perform the following exercise. In the pricing decision problem of the firm, we remove the anti-competitive pricing incentives, for exit and entry separately. This means that the profit maximization problem from Equation 6 becomes

$$V_{A_1}(\boldsymbol{\omega}) = \max_{p_{A_1}} \, (p_{A_1} - c) q_{A_1}(\boldsymbol{p}) + \beta \mathbb{E}_{\boldsymbol{\omega}'} \left[\sum_s q_s(\boldsymbol{p}) V^s_{A_1}(\boldsymbol{\omega}') \middle| \Phi_{-X}, \Phi^*_X \right]. \tag{15}$$

The maximization problem described in Equation 6 determines equilibrium prices. However, importantly, the value function is computed using the true value function, and not the counterfactual value function that enters Equation 6.

We depict the difference in probability of long-run market monopolization in Figure 7.



(1) Removing exit-inducing pricing incentives

(2) Removing entry-preventing pricing incentives

Figure 7: Summary statistics for different competition (σ) and learning (ρ) parameters. All the reported values are differences between the comparative statics without predatory pricing incentives and (minus) the baseline comparative statics. With *long run* we indicate the outcomes after 10.000 periods, With *NPV* we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1\ \forall n$).

From Figure 7, we observe that anti-competitive exit-inducing pricing incentives are much more powerful than anti-competitive entry-preventing pricing incentives. While removing the latter has virtually no effect, removing the former significantly reduces the probability of long-run market monopolization for a wide array of parameter values. The effect on the net present value of total welfare is similar.

Importantly, this Figure, is informative with respect to parametrization for which we would like to observe efficacy of policy interventions. In fact, at least for what concerns competition policy, it would be optimal to act along dimensions affected by anti-competitive behavior, while leaving others unaffected.

4.3 Anti-competitive Bundling

In this section, we turn to the bundling decision and we analyze its anti-competitive component. As for pricing, we define anti-competitive incentives as those incentives motivated by the effect of the bundling decision on rivals' exit or entry probabilities. We follow the same logic of the previous section with only one difference: the decision problem. In this setting, we can identify the anti-competitive bundling incentives as the difference in expected future value, conditional on bundling, with and without the counterfactual exit probabilities.

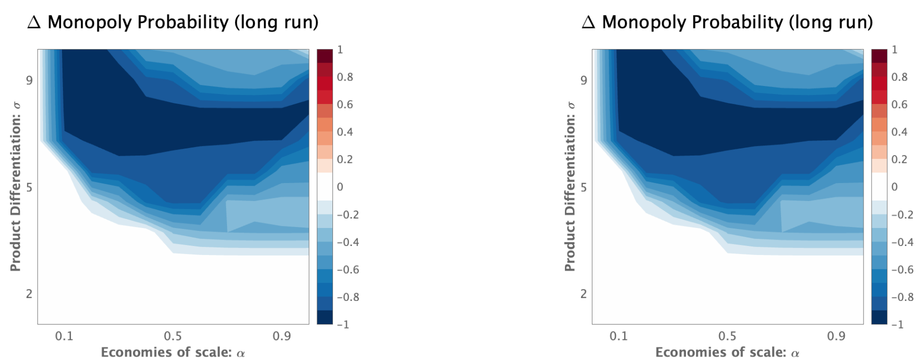
$$ABI = \beta\ \mathbb{E}_{\boldsymbol{\omega}'}\Big[V_n(\boldsymbol{\omega}')\ \Big|\ \text{bundling}, \boldsymbol{\omega}, \boldsymbol{\Phi}\Big] - \beta\ \mathbb{E}_{\boldsymbol{\omega}'}\Big[V_n(\boldsymbol{\omega}')\ \Big|\ \text{bundling}, \boldsymbol{\omega}, \boldsymbol{\Phi}_{-X}, \boldsymbol{\Phi}^*_X\Big]. \tag{16}$$

As before, we have substituted in the second expression, firms' exit probabilities conditional on bundling $\mathbf{\Phi}_X$ with firms' exit probabilities conditional on not bundling $\mathbf{\Phi}_X^*$.

We can test the extent to which anti-competitive exit-inducing bundling incentives drive firm behavior and determine the equilibrium by shutting them down and comparing the resulting equilibrium with the baseline. Shutting down anti-competitive exit-inducing bundling incentives means that the bundling policy function from Equation 12 becomes

$$\Phi_n^b(\boldsymbol{\omega}, \phi_n^b) = \arg\max \left\{ \beta \ \mathbb{E}_{\boldsymbol{\omega}'} \left[V_n(\boldsymbol{\omega}') \ \middle| \ \boldsymbol{\omega}, \mathbf{\Phi} \right] \ , \ -\phi_n^b + \beta \ \mathbb{E}_{\boldsymbol{\omega}'} \left[V_n(\boldsymbol{\omega}') \ \middle| \ \text{bundling}, \boldsymbol{\omega}, \mathbf{\Phi}_{-X}, \mathbf{\Phi}_X^* \right] \right\} . \tag{17}$$

We depict the difference in probability of long-run market monopolization in Figure 7. The reference point is the baseline setting described in Section 2.



(1) Removing exit-inducing bundling incentives

(2) Removing entry-preventing bundling incentives

Figure 8: Summary statistics for different competition (σ) and learning (ρ) parameters. All the reported values are differences between the comparative statics without predatory bundling incentives and (minus) the baseline comparative statics. With *long run* we indicate the outcomes after 10.000 periods, With *NPV* we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1 \ \forall n$).

Similarly to what we saw for pricing anti-competitive incentives, in Figure 8, we observe that anti-competitive exit-inducing pricing are indeed key in driving market monopolization. However, also exit-preventing incentives have a sizeable effect for bundling. In fact, product bundling can prevent firms from entering the market by forcing them to enter two markets instead of one, as pointed out in Carlton and Waldman (2002).

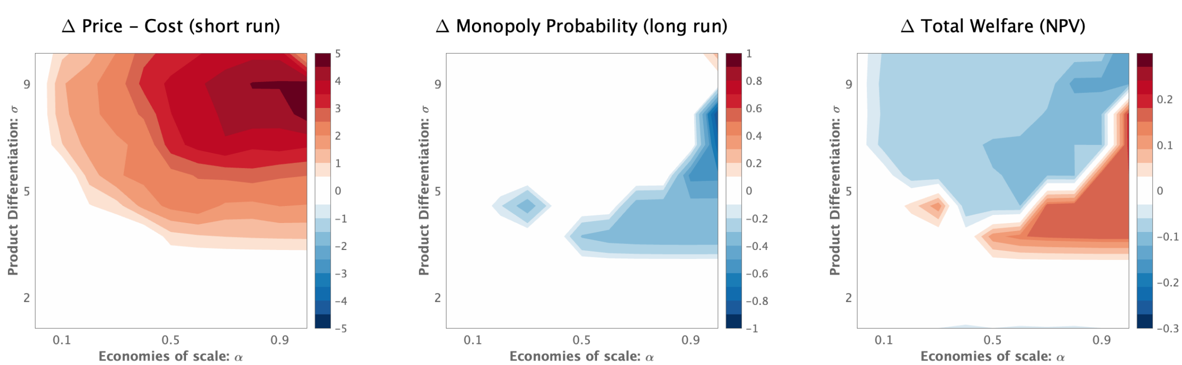
5 Competition Policy and Counterfactuals

In this section, we are going to explore a set of policies to prevent long-run market monopolization and eventually increase consumer welfare. We analyze three policies, each one motivated by a different observation regarding the dynamics behind market monopolization.

5.1 Limit Mergers

By closely looking at the dynamics, we observe that a key step towards market monopolization is mergers. This is partially an artifact of the model since we require firms to be integrated across markets in order to bundle their products together. We do not allow bundling among firms that are not integrated. However, if one was to closely inspect the dynamics of mergers, they would notice that they happen as soon as one firm takes the leadership in the learning curve. The key ingredient is asymmetry: as soon as one firm is ahead in the learning curve, it gets an advantage that can be exploited anti-competitively, first through mergers and afterwards through bundling.

In the first policy counterfactual, we do not allow mergers among firms that are ahead in the learning curve. This policy should have little effect in a world where firms behave competitively. If mergers are profitable per-se, we would observe firms still merging, but at an earlier stage. We plot the comparative statics in Figure 9.



(1) Limit Mergers **(2)** Limit Bundling **(3)** Data Sharing

Figure 9: Summary statistics for different competition (σ) and learning (ρ) parameters. All the reported values are differences between the comparative statics with limited mergers and (minus) the baseline comparative statics. With *long run* we indicate the outcomes after 10.000 periods, With NPV we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1\ \forall n$).

From Figure 9, we see that the policy has bite. The long-run market tipping probability decreases, however, the welfare effect is mixed. Interestingly, short-run prices generally increase.

5.2 Limit Bundling

In the second policy counterfactual, we consider limiting product bundling. The idea behind this policy comes from another observation of firms' behavior in equilibria that degenerate to market monopolization. The advantage of firms merging and bundling when they are ahead in the learning curve comes from two separate sources. The first was analyzed and addressed in the previous policy counterfactual: merging firms are ahead in the learning curve and therefore enjoy a lower marginal cost. The second effect instead come from bundling: the merged firms are able to offer the bundled product as a joint entity while the competitors are not integrated and therefore cannot offer the same product. This again introduces a strong asymmetry that is hard for the competing firm to overcome.

In this counterfactual, we prevent integrated firms from bundling products if there is no other joint entity capable of offering the same bundle. This implies that bundling can only happen in one state: when all firms are integrated across markets. We plot short- and long-run consequences in Figure 5.

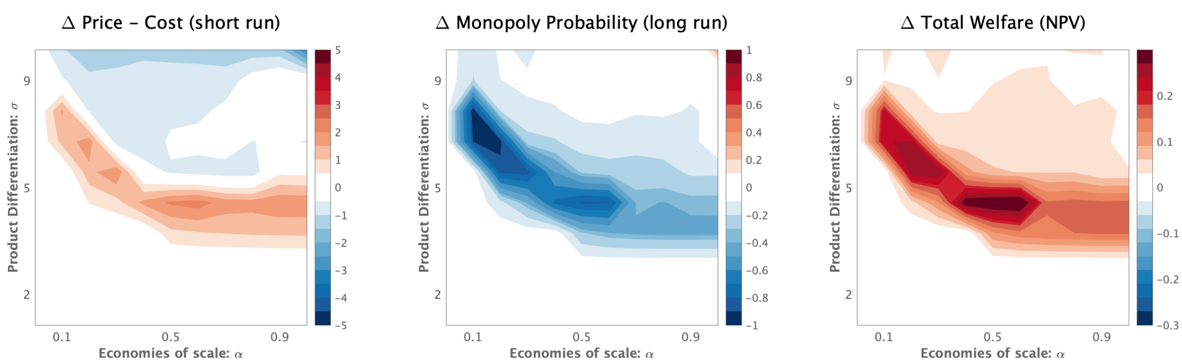


Figure 10: Summary statistics for different competition (σ) and learning (ρ) parameters. All the reported values are differences between the comparative statics with limited bundling and (minus) the baseline comparative statics. With *long run* we indicate the outcomes after 10.000 periods, With *NPV* we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1 \ \forall n$).

From Figure 10, we observe that the policy is indeed effective. The probability of market tipping decreases and welfare increases. Moreover, we observe that, in the region corresponding with the stronger welfare effects, short-run prices increase, confirming our intuition that bundling and pricing are complementary only to the extent in which they are anti-competitive.

5.3 Data Sharing

In the last policy counterfactual, we examine data or knowledge sharing. The idea underlining this counterfactual concerns the primary motive behind below-cost pricing: firms have the incentive to lower their price to capture future benefits. The key feature is exclusivity of the accumulation of knowledge, or experience in the model terminology. Only one firm at the time gains experience through sales and the benefits of experience are not shared.

In this counterfactual, we do not allow firms to be more than one level of experience apart. One interpretation of this policy is some kind of mandatory sharing of old technologies. The firm that wins the sale still gains an advantage both in absolute terms, but not in relative terms. In fact, the decrease in marginal cost is matched by a decrease in the marginal cost of its competitors. We plot the effects of the policy in Figure 11.

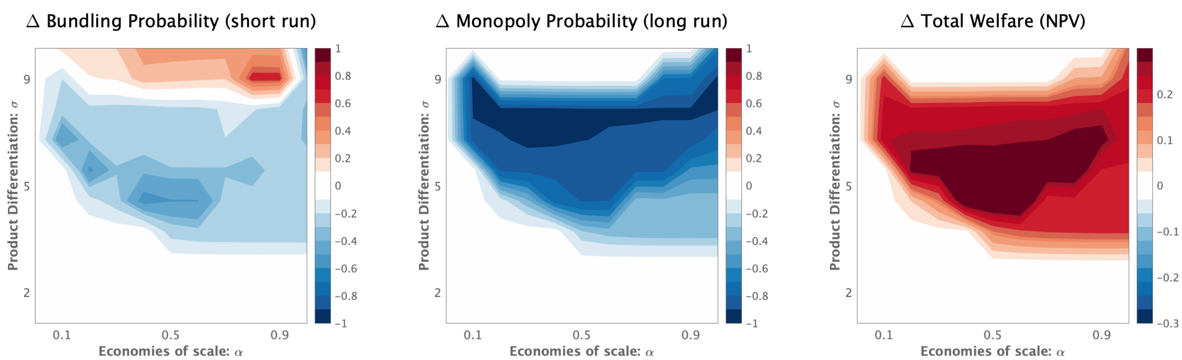


Figure 11: Summary statistics for different competition (σ) and learning (ρ) parameters. All the reported values are differences between the comparative statics with data sharing and (minus) the baseline comparative statics. With *long run* we indicate the outcomes after 10.000 periods, With *NPV* we indicate the average discounted outcomes over the first 10.000 periods, with *short run*, we indicate the average discounted outcomes over the first 5 periods. The initial state is non-integrated duopoly ($A \wedge B$ Duopoly), with all firms at the bottom of the learning curve ($\omega_n = 1 \; \forall n$).

From Figure 11, we observe that the policy not only decreases the probability of long-run market tipping and increases the net present value of total welfare, but also generally decrease the bundling probability.

6 Conclusion

In this paper, we have built a computational model of learning-by-doing with complementary markets in order to study the interplay between two foreclosure practices: predatory pricing and exclusionary bundling. We have seen that not only the two practices are often emerging together, but they seem to reinforce each other. Having a complementary market and the possibility to bundle products increases the incentives of firms to price below cost in order to exclude their competitors. On the other hand, having economies of scale in one market increases the incentives of firms to bundle their products to induce competitors' exit or prevent their entry.

We believe this insight is particularly relevant in markets that rely heavily on data. In fact, data can be a driver of both supply-side economies of scale and product complementarities. In these settings, the possibility to monopolize both markets can increase the incentives to be aggressive in pricing by increasing the long-term anti-competitive benefits, and hence justifying higher short-term costs, in the form of predatory prices. These incentives are particularly worrisome in presence of not just two, but multiple markets and can potentially explain the emergence of ecosystems in digital platform markets.

References

David Besanko, Ulrich Doraszelski, Yaroslav Kryukov, and Mark Satterthwaite. Learning-by-doing, organizational forgetting, and industry dynamics. *Econometrica*, 78(2):453–508, 2010.

David Besanko, Ulrich Doraszelski, and Yaroslav Kryukov. The economics of predation: What drives pricing when there is learning-by-doing? *American Economic Review*, 104 (3):868–97, 2014.

David Besanko, Ulrich Doraszelski, and Yaroslav Kryukov. Sacrifice tests for predation in a dynamic pricing model: Ordover and willig (1981) and cabral and riordan (1997) meet ericson and pakes (1995). *International Journal of Industrial Organization*, 70:102522, 2020.

Patrick Bolton, Joseph F Brodley, and Michael H Riordan. Predatory pricing: Strategic theory and legal policy. *Geo. LJ*, 88:2239, 1999.

Luis MB Cabral and Michael H Riordan. The learning curve, predation, antitrust, and welfare. *The Journal of Industrial Economics*, 45(2):155–169, 1997.

Dennis W Carlton and Michael Waldman. The strategic use of tying to preserve and create market power in evolving industries. *RAND Journal of Economics*, pages 194–220, 2002.

Jay Pil Choi and Christodoulos Stefanadis. Tying, investment, and the dynamic leverage theory. *RAND Journal of Economics*, pages 52–71, 2001.

CMA. Online platforms and digital advertising market study. Technical report, Competition and Markets Authority, 2020. Released July 1, 2020. Available at https://www.gov.uk/cma-cases/online-platforms-and-digital-advertising-market-study.

Australian Competition Consumer Commission. Digital platforms inquiry preliminary report. Technical report, 2019.

Antoine Augustin Cournot. *Recherches sur les principes mathématiques de la théorie des richesses*. 1838.

Jacques Crémer, Yves-Alexandre de Montjoye, and Heike Schweitzer. Competition policy for the digital era. Technical report, European Commission, 2019.

Ulrich Doraszelski and Mark Satterthwaite. Computable markov-perfect industry dynamics. *The RAND Journal of Economics*, 41(2):215–243, 2010.

Nestor Duch-Brown. The competitive landscape of online platforms. Technical report, JRC Digital Economy Working Paper, 2017.

European Commission. Guidance on the commission's enforcement priorities in applying article 82 of the ec treaty to abusive exclusionary conduct by dominant undertakings. Technical report, European Commission, 2009.

Jason Furman, Diane Coyle, Amelia Fletcher, Derek McAuley, and Philip Marsden. Unlocking digital competition: Report of the digital competition expert panel. Technical report, 2019.

Janusz A Ordover and Robert D Willig. An economic definition of predation: Pricing and product innovation. *The Yale Law Journal*, 91(1):8–53, 1981.

Stigler Committee On Digital Platforms. Final report. Technical report, Stigler Center, 2019.

M Schallbruch, H Schweitzer, and A Wambach. A new competition framework for the digital economy. Technical Report 2, 2019.