UNITE AND CONQUER:
Seller Collusion in Multi-Sided Markets

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Abstract

This paper aims to examine the relationship between marketplace design and seller competition on online platforms. Using a game-theoretic model, we investigate how various design choices, such as pricing strategies, may influence the likelihood of seller collusion and the incentives of platforms to either break or sustain cartels. Our findings suggest that high transaction fees may reduce competition between sellers by increasing their incentives to collude, and platforms may also have an incentive to manipulate competition. Our theoretical framework also allows for the examination of additional design features, such as information disclosure and the number of products, and relates to the literature on optimal taxation. Overall, this research aims to contribute to the limited academic discussion on how the design of multi-sided markets affects competition on (online) marketplaces.

JEL Classification codes: D40, L10, L40

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1 Introduction

In an increasingly digitized economy, consumers can access a growing range of products and services via online marketplaces. Examples range from e-commerce marketplaces like Amazon and eBay, over accommodation websites such as Airbnb or Booking.com, to mobile app stores and many more. Such *multi-sided* marketplaces add value to sellers by attracting many consumers beyond local markets. Similarly, consumers may benefit from greater product variety. This gives rise to positive indirect network effects: a growing number of buyers attracts more sellers and vice versa.

It is no surprise that with online marketplaces' gain in economic relevance in recent years, the number of associated high-profile antitrust cases that feature anti-competitive behaviour of sellers has risen substantially [see, e.g., OECD, 2018].[1] And the further use of algorithmic pricing will likely amplify this number [Calvano et al., 2020; Ezrachi and Stucke, 2019; Competition and Markets Authority, 2021]. Despite the high complexity of marketplace design and its crucial effects on competition, the academic debate on anti-competitive behaviour among sellers within multi-sided markets, however, has been surprisingly limited.

In this paper, we investigate how a platform's marketplace design choices affect sellers' incentive to collude and whether such a platform has an incentive for self-regulation. Building on a game-theoretic model, we delineate a platform's fee structure (i.e., its pricing model) from its remaining design choices about product variety and product transparency as well as its decisions to ration users. Based on these different channels of influence, we then probe sellers' incentives to coordinate on prices and study how such a platform can manipulate their' incentives to steer competition in its own favour. Ultimately, we provide conditions under which a platform is able to correct sellers' anti-competitive behaviour and when its incentives differ from that of a social planner whose goal is to maximize total welfare.

Perhaps unsurprisingly, we find that a platform can indeed affect sellers' ability to collude through its marketplace design choices and the fee it imposes. In particular, given that the platform can ration users and control the degree of perceived variety of goods sold within a product category, the platform can govern and, hence, steer seller competition in its own favour. Moreover, by varying the imposed usage fee, the platform is also able to manipulate sellers' profit margins at the potential risk of

[1] Cases are numerous. For instance, several sellers in the DVD and Blu-Ray segment on Amazon were recently pleaded guilty by the US Department of Justice [2022] for tacit price collusion. Similarly, the Italian AGCM [2020] fined resellers in the earphone segment on Amazon. Other famous cases involve the use of pricing algorithms to mitigate competition, such as in the posters and picture frames online market as investigated and prosecuted by the British Competition and Markets Authority [2016] or the US Department of Justice [2015, 2016]. Moreover, the Competition and Markets Authority [2018] finds evidence for the "widespread use of algorithms to set prices, particularly on online platforms" [p.3].

decreasing overall buyer demand: if sellers compete, increasing usage fees may be passed on to buyers, resulting in higher prices, which ultimately renders the platform less attractive to buyers. Hence, if sellers compete, the platform may ration buyers by raising usage fees since this decreases the size of the positive indirect network effects.

In addition, the platform can also have an incentive to encourage seller collusion –and this incentive is especially strong whenever buyer demand is either entirely inelastic or very elastic. Particularly when buyer demand is very elastic, the platform has to trade off whether extracting profits from the product category outweigh the profits from the overall volume in its marketplace by exploiting its underlying network effects. Intuitively, given that a retail platform can only make profits by extracting (parts of the) sellers' profits when buyer demand is inelastic, its own profits are maximized whenever most of the buyer surplus is captured by the sellers. As a result, when demand is inelastic, the platform first tries to maximize seller profits by encouraging them to charge the highest possible price (which may be attained through collusion), only to extract these profits in a subsequent step. This creates motives for the platform to establish a *hub-and-spoke cartel* [Ezrachi and Stucke, 2016]: the platform has an incentive to centrally coordinate sellers' price setting (e.g., by giving price recommendations to sellers or even by internalizing their price setting) to charge higher prices.[2]

Alternatively, if buyer demand is very responsive to prices, the platform needs to leave some surplus to buyers, which will ultimately be captured by sellers and, hence, crowds out buyer demand. Since, in this case, neglecting to capture seller profits would be inefficient, the platform induces seller collusion to reap this extracted surplus once again from the sellers. Therefore, if buyers react strongly to price changes, the platform can make greater profits by inducing seller collusion.

The remainder of this paper is organized as follows. In Section 2, we discuss the related literature. Section 3 outlines the basic model and describes the timeline of the game. The model features three types of agents: buyers, sellers, and a monopoly platform. Sellers provide horizontally differentiated goods within a product category on the platform. The platform can make design choices about its usage fees and other marketplace-relevant design features, such as the number of users and the degree of perceived product variation. The subsequent section studies platform governance choices through the lens of the previously described model. Potential policy implications are drawn in Section 5. Section 7 concludes.

[2] Examples include Amazon's 'Automate Pricing' and Aribnb's 'Smart Pricing' tools. The Competition and Markets Authority [2021] reports that other sharing economy platforms employ similar tools that allow sellers to delegate pricing to the platform or even require them to do so.

2 Related Literature

This paper contributes to various strands of the literature in industrial organization studying multi-sided markets. This includes the literature on pricing in multi-sided markets, platform governance, platforms managing (seller) competition, and platform regulation as the literature studying the feasibility of seller coordination.

2.1 Platform Pricing in Multi-Sided Markets

A substantial part of the literature studying multi-sided markets primarily focuses on the interplay between a platform's underlying network effects and pricing decisions [Caillaud and Jullien, 2003; Rochet and Tirole, 2003, 2006; Armstrong, 2006; Armstrong and Wright, 2007; Weyl, 2010]. Typically discussed pricing models in the previous literature include *transaction* (or per-unit) fees, fixed *membership* fees, *royalty* fees (also called ad valorem or revenue-sharing fees), or *two-part tariffs*.

Building on these theories, we additionally investigate other design aspects of a platform beyond its pricing feature –such as user rationing, the degree of information disclosure, and limiting product variety– that have been so far neglected by this strand of the literature.

2.2 Platform Governance

While considering pricing aspects, we also contribute to the more recent literature stream that studies platform governance decisions [see, e.g., Boudreau, 2010; Parker and Van Alstyne, 2018; Hagiu and Spulber, 2013; Edelman and Wright, 2015; Hagiu and Wright, 2019; Teh, 2022; Schlütter, 2020; Johnen and Somogyi, 2021].

However, most of these works examine implications of innovation on platforms [Boudreau, 2010; Parker and Van Alstyne, 2018; Hagiu and Spulber, 2013; Edelman and Wright, 2015; Hagiu and Wright, 2019]. However, Teh's paper [2022] comes closest to ours, which we developed independently from him, by examining how a platform's fee structure affects seller competition. Different to Teh [2022] however, our framework takes the dynamics of seller competition into account, and platforms' pricing and design decisions are fully endogenous. Yet, if we neglect cross-group network effects between buyers and sellers, our models coincide.

Schlütter [2020] studies the effect of *price parity clauses* (PPCs) used as a design element on seller collusion on a platform that acts as an intermediary (thereby neglecting indirect network effects). Although exploring PPCs is not the primary goal of this paper, we propose a model where sellers' outside option is normalized to zero. Hence, one possible way of interpreting sellers' outside option in our model is that sellers expect to make the same profits across all available distribution channels.

In another paper, Johnen and Somogyi [2021] look at the role of *drip pricing* as a marketplace design tool. In their model, an online platform has the ability to reveal additional product attributes (such as shipping and return policies) either in advance or at the end of a buyer's purchasing process. While Johnen and Somogyi [2021] mainly focus on the question of why specific product attributes tend to be shrouded in online marketplaces, this paper aims to shed light on the interplay between implemented marketplace design features and seller competition.

2.3 *Managing Seller Competition*

Due to its overlap with the literature on platform governance, we also relate to the literature that studies platforms managing competition among sellers [Belleflamme and Peitz, 2019; Anderson and Bedre-Defolie, 2021; Padilla et al., 2022; Nocke et al., 2007; Hagiu, 2009; Teh, 2022; Schlütter, 2020]. In most of these papers, the number of sellers on the platform is determined endogenously by the platform's pricing decision, which, in turn, can be affected by other exogenous factors (such as cross-group network effects or consumer preferences). For instance, Belleflamme and Peitz [2019] and Karle et al. [2020] study a platform imposing membership fees and its consequences on the number of sellers (thereby also the degree of competition between sellers). Closely related, Edelman and Wright [2015], Hunold et al. [2018] and Schlütter [2020] abstract from network effects to explore PPCs restricting sellers to charge lower prices elsewhere than via the platform.

In contrast to these works, and similar to the work by Teh [2022], our approach enables the separation of pricing decisions from other design features like product variety or information disclosure to analyze their impact on total welfare. In fact, if we neglect potential cross-group network effects between buyers and sellers, our model is identical to the one proposed by Teh [2022]. Different to Teh [2022], however, we model sellers' choices on "how to compete" more explicitly, in addition to a platform's preferences over its marketplace design.

Although related, another literature stream looks at a very distinctive setting where platforms can sell their own products [Anderson and Bedre-Defolie, 2021; Padilla et al., 2022]. Here, a platform acts not only a marketplace manager but also as a competitor to third-party sellers. In such setting, platforms face a trade-off between maximising profits via the management of network effects and via selling its own products, oftentimes resulting in an incentive for *self-preferencing*: the platform favors its own products by foreclosing buyer demand to third-party sellers. Our setting, on the other hand, abstracts from this possibility and focuses on platforms who first *design* and then *manage* their marketplace.

2.4 *Algorithmic Collusion on Platforms*

Another related strand of the literature focuses on seller collusion in multi-sided markets based on the use of price matching algorithms [Calvano et al., 2020, 2021; Klein, 2021; Miklós-Thal and Tucker, 2019; Ezrachi and Stucke, 2019; Hansen et al., 2021]. In a set of simulation studies, for instance, Calvano et al. [2020, 2021] find that when sellers use algorithms to price their products, tacit collusion is almost certain to arise, independent of cost or demand asymmetries, the number of sellers, and uncertainty. Moreover, such cartels remain stable over time, even though seller algorithms have not been initially trained nor instructed to do so.

Most of these works, however, neglect network effects between buyers and sellers. Therefore, their main focus lies on the feasibility of seller cartels without direct coordination among the colluding parties. Our work, on the other hand, provides a more theoretical perspective on seller collusion and highlights mechanisms in which a platform can encourage seller collusion. In particular, we show that platforms can be motivated by the *hub-and-spoke* argument [Ezrachi and Stucke, 2019] to establish some form of price coordination among sellers when buyer demand is very elastic. In addition, we explore how other marketplace design features of a platform may shape seller competition.

2.5 *Regulating Online Platforms*

Finally, there is a growing scrutiny on the regulatory side about harmful commercial practices by established online platforms (oftentimes called tech giants or gate keepers).[3] Such practices include, e.g., (potential) *killer acquisitions* [Hemphill, 2020; Cunningham et al., 2021; Motta and Peitz, 2021] as suspected after Meta's acquisition of Giphy,[4] *self-preferencing* by Amazon and Google (i.e., favoring their own products over third-party seller products on their marketplaces) [Hagiu et al., 2022], *predatory pricing* by Amazon [Khan, 2016], or *misleading sales tactics* by Booking.com to put pressure on consumers [Teubner and Graul, 2020]. We contribute to this debate by stressing how network effects may incentivise a platform to exploit its marketplace design features to encourage seller collusion.

[3] See, e.g., New York Times: https://www.nytimes.com/2020/07/30/technology/europe-new-phase-tech-amazon-apple-facebook-google.html. An example of regulators' concerns about, and (soon-to-be) implemented actions against, such practices can be found in, e.g., the *Digital Markets Act* by the European Commission [2022].

[4] See, e.g., Financial Times: https://www.ft.com/content/662c8e3f-4909-4bec-9131-c0237bb4897d.

3 Theoretical Framework

This section outlines the model. We first describe competition on the platform level and then explain seller competition within a particular product category. Next, we explain how network effects arise in this framework before providing the timeline of the game.

3.1 *Competition and Network Effects on the Platform*

To understand how marketplace design features shape seller competition and how platforms may benefit from it, we propose a simple model in the spirit of Armstrong [2006] and Johnen and Somogyi [2021] featuring three types of agents: a monopoly platform, sellers, and buyers. We assume that there are $N \in \mathbb{N}$ sellers and $N^B \in [0, 1]$ buyers on the platform.

Buyers interact with sellers via the platform in a given product category (or market segment), and sellers provide horizontally differentiated goods within each product category. Quality differences in goods can thus be seen as products of sellers who compete in different market segments, while sellers in the same category provide imperfect substitutes. Hence, a pair blue trainers shares the same market with a pair of red trainers, but not with a pair of red boots. However, to simplify things, we assume without loss of generality that there is only one product category. Also, for the sake of tractability, we assume that sellers' outside option is homogeneous and normalized to zero.[5] Buyers have an idiosyncratic stand-alone utility $u^B \in \mathbb{R}$ from joining the platform that follows some continuous distribution F with support $[0, 1]$.[6] Further, let $v \in \mathbb{R}_{++}$ be buyers' homogeneous valuation for goods within a given product category.[7] Sellers charge a price $p \in \mathbb{R}_+$. Thus, a buyer's utility from joining the platform

[5] The homogeneity assumption about the sellers' outside option implies that increasing the number of buyers also increases the benefit for sellers without attracting more sellers in equilibrium. Hence, all sellers with a non-negative profit will join the platform in equilibrium. This limits the extend of cross-group network effects and simplifies the demand system without eliminating these network effects.

[6] Assuming $u^B \sim F[0, 1]$ captures the idea that each buyer has an individual outside option that is randomly distributed. Note that we do not impose any restrictions on the sign of u^B. It can therefore be either, positive (i.e., buyers enjoy being on the platform –perhaps for reputational or personal reasons– even though they might end up buying nothing in equilibrium), zero (i.e., buyers simply want to make the best deals, but they derive no stand-alone utility merely from being on the platform), or negative (i.e., buyers generally dislike the platform but use it to purchase goods since it provides the best value-for-money).

[7] We assume that buyers' valuation for goods within a product category is sufficiently large such that the market (segment) is covered (see Assumptions A1 and A2 below). Note, however, that together with the homogeneous valuation v for goods, the specification of u^B allows for indirect network effects on the buyer side.

is

$$U^B = u^B + (v - p) * N. \tag{1}$$

Similarly, a seller's benefit from joining the platform is equal to the total profits π that she can make in the marketplace:

$$U^S = \pi * N^B. \tag{2}$$

The valuations U^B and U^S capture two common assumptions. First, it is assumed that each buyer interacts with every seller on the platform and vice versa, such that their expected perceived per-user benefit is $(v - p)$ and π, respectively. Hence, the platform can manage indirect network effects between users: buyers benefit from the presence of a greater number of sellers and vice versa. In addition, each additional interaction is assumed to have the same marginal value to each user group.

We focus on a platform charging a transaction (or per-unit) fee $f \in \mathbb{R}_+$.[8] Without loss of generality, we further assume that the platform does not impose any fees on buyers [Weyl and Fabinger, 2013]. Hence, the outlined model is most applicable to retail platforms or cases where buyers cannot observe fees born by sellers.

We model the platform in a way similar to Armstrong [2006] or Johnen and Somogyi [2021]. As mentioned above, the platform charges f to sellers and has no marginal costs. We assume that the platform cannot discriminate among sellers or buyers. Total platform profits can then be summarized as

$$\Pi_P(f) = f * N * N^B(p(f)). \tag{3}$$

Hence, the platform faces a trade-off between charging a higher transaction fee f and maximizing overall trading volume $N * N^B$ on its marketplace.

3.2 Product Category Competition

In each product category, sellers compete in a Salop [1979] fashion: there is a continuum of buyers and $N \in \mathbb{N}$ sellers who provide horizontally differentiated goods. Sellers are equally distributed across a circular city with a perimeter equal to one. Let $\tau \in \mathbb{R}_+$ be the product-differentiation parameter within a given product category. Sellers are symmetric and have no marginal costs. Let $p_i \in \mathbb{R}_+$ be the price charged by seller $i \in N$ and $p_{-i} \in \mathbb{R}_+$ be the price charged by i's competitors $N \setminus \{i\}$. The total profits of seller i are then given by

$$\pi_i(p_i, p_{-i}) = (p_i - f - c) * d_i(p_i, p_{-i}), \tag{4}$$

[8] While our subsequent analysis features a model of transaction fees, we provide an extension to various other fee structures. Namely, in Section 6, we discuss how our results relate to royalty fees, fixed membership fees and two-part tariffs.

where $d_i(p_i, p_{-i}) = 1/N + (p_{-i} - p_i)/\tau$ is seller i's demand.

Buyers, on the other hand, have a particular taste or idea about the product they want to purchase but observe these horizontally differentiated goods. Following the convention of the spatial economics literature, τ can alternatively be interpreted as the transportation cost that buyers incur in order to purchase the product of seller i. For the sake of tractability, we assume linear transportation costs in each product category. As discussed above, buyers' willingness to pay is homogeneous and equal to $v \in \mathbb{R}_{++}$. Also for the sake of simplicity, their outside option consists of not buying (can be relaxed). For ease of presentation, we assume that this outside option is at the sellers' locations [see, e.g., Bénabou and Tirole, 2016; Heidhues and Kőszegi, 2018].[9]

3.3 *Network Effects on the Platform*

The total number of users on the platform is subject to indirect network effects (or cross-group externalities). In particular, while buyers exhibit such network effects, the total number of sellers on the platform is fixed. To see this, note that the number of sellers is given by

$$N = N(p, N^B) = \Pr[\pi(p) * N^B \geq 0]. \tag{5}$$

Since by assumption their outside option is homogeneous and normalized to zero, sellers always join the platform as long as they can generate non-negative profits. Hence, in equilibrium either all N sellers join or not.

In contrast to sellers, buyers prefer lower prices and a greater presence of sellers on the platform. The platform thus has an incentive to increase the total number of interactions in its marketplace. Similar to the number of sellers, the total number of buyers on the platform is given by

$$N^B = N^B(p, N) = \Pr[u^B + (v - p) * N \geq 0], \tag{6}$$

with

$$\frac{\partial N^B}{\partial p} < 0 \quad \text{if } N > 0 \qquad \text{and} \qquad \frac{\partial N^B}{\partial N} \geq 0 \quad \forall p \leq v. \tag{7}$$

The first partial derivative in expression 7 states that, everything else equal, buyers prefer lower prices given the existence of sellers on the platform. The second partial derivative reflects indirect network effects on the buyer side: as long as prices do not exceed buyers' willingness to pay, they prefer a larger number of sellers. Given that sellers provide horizontally differentiated goods, this also provides a microfoundation for buyers' taste for variety.

[9] One way of interpreting this assumption is that buyers first have to go to the sellers (facing transportation costs τ), and *then* decide whether to buy or not. As a result, τ only influences the level of competition between sellers without affecting the attractiveness of seller i's product relative to the outside option for a given buyer.

3.4 Timeline of the Game

The timeline of the game is as follows: First, the monopoly platform makes a design choice and decides its pricing strategy. Second, buyers and sellers decide whether to join the platform or not. Third, within each product category, sellers decide on whether to compete or to collude. In case of no collusion, sellers compete in the manner as outlined above. In case of collusion, sellers coordinate to charge the highest price possible (i.e., the monopoly price).[10] Buyers then decide whether to purchase goods via the platform or not. We solve this model by studying subgame perfect equilibrium and then use backward induction.

4 Competition and Platform Governance

Based on the model above, this section describes a platform's governance decisions given sellers' ability to collude. In particular, we establish a platform's best response to set transaction fees when sellers compete and when they collude. Moreover, we also show under which conditions the platform actually prefers seller collusion over competition within its marketplace. Before, however, we discuss possible market equilibria.

4.1 Market Equilibria

On the platform, sellers compete by providing horizontally differentiated goods. Based on the model outlined in Section 3, buyers decide to purchase a good as long as their willingness to pay is greater than the price they face. Similarly, sellers offer their products on the platform as long as they can make non-negative profits. This introduces a trade-off for the platform in its governance decision: To maximize volume in the marketplace, the platform has an incentive to keep prices low enough such that it maximizes the number of buyers. At the same time, however, the platform generates profits from imposing its transaction fee, which increases the overall price and hence may crowd out buyers.

Given this trade-off, we first describe the set of market equilibria to start with our analysis. We then study the effects of this trade-off in more detail. The following lemma shows that, depending on buyers' willingness to pay and transportation costs, a product category is either competitive or features local monopolies.

Lemma 1 (Competitive Equilibria)**.** *There exists a unique market equilibrium. In particular, the marketplace is* competitive *if*

$$v > f + \tau/N. \tag{8}$$

[10] In principle, colluding sellers could agree to charge *any* price above the marginal costs. However, we later show in Section 6 that results remain qualitatively unchanged when sellers have this option.

Alternatively, the marketplace features local monopolies *if* $v < f + \tau/N$*. Moreover, both cases* coinincide *whenever* $v = f + \tau/N$*.*

Proof. We proof this lemma by contraposition. Given buyers' outside option (i.e., not buying) is at the seller's location, a buyer purchases a good from seller i iff $v - p_i - \tau x_i \geq 0 \iff v \geq p_i$.

Suppose first that $v < f + \tau/N$. Then, seller i's best response

$$\pi_i(p_i, p_{-i}) = (p_i - f) * d_i \tag{9}$$

is to maximize profits with respect to p_i, where p_{-i} denotes the price set by seller i's rivals along the Salop circle and $d_i = 1/N + (p_{-i} - p_i)/\tau$ denotes i's demand. Since sellers are symmetric, profit maximization reveals that the optimal price charged by all sellers satisfies

$$p^{com} \equiv p_i = f + \tau/N, \tag{10}$$

and they all obtain the same market share $d_i = 1/N$ for all $i \in N$. But, since buyers' participation constraint reads $v \leq f + \tau/N$, not all buyers along the Salop circle will purchase (buyer rationing). Given that buyers are uniformly distributed across the Salop circle, however, there exist at least one buyer at seller i's location, who will buy from seller i as long as $p_i \leq v$. Thus, the profit maximizing price is $p^{mon} \equiv v$, yielding a profit of $\pi^{mon} = (v - f)/N$ for each seller. As a result, if v is sufficiently low or τ is sufficiently large, sellers will act as local monopolies.

Conversely, suppose it holds that $v > f + \tau/N$. Then, if seller i sets a price $p_i > p^{com}$, this leads to a loss in market share (i.e., $d_i < 1/N$) and hence lower profits. Therefore, if $v > f + \tau/N$, sellers compete along the Salop circle with $p_i = p^{com}$ and $\pi^{com} \equiv \pi_i = \tau/N^2$ for all $i \in N$.

Finally, if $v = f + \tau/N$, the profit maximizing price resulting from competition is equal to the monopoly price, i.e., $p^{com} = p^{mon} = v$ for all $i \in N$ due to symmetry. Hence, both cases coincide. □

Lemma 1 shows that there are two types of competitive equilibria, depending on whether Condition 8 is met. In particular, when buyers' willingness to pay v is sufficiently high (or transportation costs τ are sufficiently low), there is demand around the Salop circle. Moreover, sellers are distributed around the Salop circle at equal distance from each other. Then, the competitive outcome is equal to Bertrand competition with imperfect substitutes: charging a price that exceeds the competitive price p^{com} leads to a loss in demand, leading to lower profits. Hence, charging p^{com} constitutes an equilibrium.

Alternatively, if v is sufficiently low (or τ sufficiently large), buyers 'movements' are locally bounded. Hence, the Salop circle is not entirely covered. Then, for each seller i, the optimal strategy is to charge the monopoly price $p_i = p^{mon} = v$ since there is at least one buyer at seller i's location who is willing to buy the product. As a result, sellers act as local monopolies within a product category when $v < f + \tau/N$.

Regardless of the competitive equilibrium, sellers seek to maximize profits. Therefore, to link profits and prices within each equilibrium, the following corollary carves out their underlying relationship:

Corollary 1 (From Lemma 1)**.** *Let p^{mon} and and p^{com} be the monopoly and competitive price, respectively. Then,*

i) if the marketplace is competitive, it holds that $p^{mon} > p^{com} \iff \pi^{mon} > \pi^{com}$.

ii) if the marketplace features local monopolies, it holds that $p^{mon} < p^{com} \iff \pi^{mon} < \pi^{com}$.

Proof. Take a competitive product category. Then $p^{mon} = v > c+t+\tau/N = p^{com}$, where the inequality stems from Lemma 1 since sellers compete in that product cateogry. However, if seller i is the only seller in that product category, i's profits are maximized at $p_i = p^{mon}$. Hence, $\pi^{mon} > \pi^{com}$. Conversely, by a similar reasoning, if sellers act as local monopolies, then $p^{mon} = v < c + t + \tau/N = p^{com}$ and $\pi^{mon} < \pi^{com}$. □

Generally, Corollary 1 displays how prices and profits differ when comparing seller competition with local seller monopolies. In particular, sellers have no incentive to compete in the monopolistic equilibrium: Given that buyers' willingness to pay is sufficiently low (or transportation costs are too high), sellers act as local monopolies and charge the highest price possible $p^{mon} = v$.

As mentioned earlier, however, this differs starkly when buyers have a high willingness to pay: in a competitive marketplace, sellers are exposed to the Bertrand trap. Even though charging higher prices would result in greater profits for each seller, charging a lower price leads to a competitive advantage and, hence, allows them to gain a greater market share by attracting more demand.

However, it is important to note that this also provides scope for sellers to create a cartel. In fact, once sellers can coordinate on prices, they can generate greater profits from forming a collusive agreement than when competing with each other. As an additional corollary from Lemma 1, we can thus state:

Corollary 2 (From Lemma 1)**.** *Only in a competitive marketplace, sellers have an incentive to collude since $\pi^{mon} > \pi^{com}$.*

Proof. A necessary condition for collusion is that sellers can make greater profits when charging a collusive price. Assume that if sellers collude, they charge a collusive price $p^{coll} = p^{mon} > p^{com}$. The first statement of Corollary 1 shows that $\pi^{mon} > \pi^{com}$ whenever sellers compete. Hence, only in a competitive market sellers have an incentive to collude. □

As a result, collusion can only arise in a competitive marketplace. Therefore, for the remaining part of the paper, we thus assume that $p^{mon} > p^{com}$ to rule out the economically uninteresting case of the monopolistic equilibrium:[11]

A1. $p^{com} < p^{mon}$

Following this, we next study a monopoly platform's governance decisions. Particularly, we first examine the platform's strategies when sellers compete, followed by the same analysis when sellers collude. We then look at whether a platform has an incentive to manipulate competition in its marketplace to foster price coordination among sellers.

4.2 No Seller Collusion

When sellers compete in the marketplace, they make profits equal to $\pi^{com} = \tau/N^2$ and charge prices $p^{com} = f + \tau/N$. The platform then maximizes profits with respect to the fees it imposes. Thus, the platform's problem formally reads:

$$\begin{aligned} \max_f \Pi_P(f) &= f * N^B(p(f), N) * N \\ \text{s.t. } p(f) &= p^{com} = f + \frac{\tau}{N} \end{aligned} \tag{11}$$

Based on this maximization problem, the following proposition replicates the result by Rochet and Tirole [2003]; Armstrong [2006] of a profit-maximizing monopoly platform: since the platform manages indirect network effects across users, it is able to charge fees above marginal costs. Further, setting a transaction fee that is too high is inefficient since this would reduce buyer demand, which reduces the total volume in its marketplace, and hence decreases profits.

Proposition 1 (Platform' best response – no collusion). *Suppose Lemma 1 holds and that sellers compete. Then, the monopoly platform's best response to maximize profits is*

$$f^{com} = \frac{N^B(p(f), N)}{-dN^B/dp} \quad \textit{and} \quad \eta^B = \frac{f}{N^B(p(f), N)} \frac{dN^B}{dp} \tag{12}$$

being the elasticity of buyers' demand with respect to prices on the platform.

Proof. The platform maximizes profits with respect to its transaction fees, i.e.,

$$\max_f \Pi_P(f) = f * N^B(p(t), N) * N, \tag{13}$$

whose first order condition (while neglecting arguments for a moment) solves

$$N^B * N * + N * f * \frac{dN^B}{df} = 0. \tag{14}$$

[11] Notice that this assumption is equivalent to say that buyers prefer seller competition over collusion. Moreover, it also gives a reasonable justification to focus on marketplaces of retail platforms.

Given that sellers charge $p^{com} = f + \tau/N$, they make profits $\pi^{com} = \tau/N^2 > 0$, so in equilibrium all sellers join the platform. Moreover, since seller profits are independent of f, also $dN/df = 0$. This reduces the first order condition to

$$N^B(p(f), N) + f * \frac{dN^B(p(f), N)}{df} = 0. \tag{15}$$

After rearranging terms, we can then derive both

$$\frac{N^B(p(f), N)}{-dN^B/dp} = f \equiv f^{com} \quad \text{and} \quad \frac{f}{N^B(p(f), N)} \frac{dN^B}{dp} \equiv \eta^B, \tag{16}$$

which concludes the proof. □

Notice that $N^B(p(f), N) > 0$ and $dN^B/df < 0$. Therefore, Proposition 1 tells us that in equilibrium, the platform charges a positive transaction fee f^{com}. Moreover, if sellers compete, they charge a price $p(f) = f + \tau/N$ and make profits equal to τ/N^2. Hence a double marginalization problem exists: the platform is unable to extract seller profits completely since sellers pass on higher transaction fees to buyers.

Proposition 1 also reveals further important comparative statics. For instance, a higher number of sellers N allows the platform to charge a higher transaction fee. In fact, a greater number of sellers per product category implies tougher competition between sellers, which results in lower prices and ultimately leads to lower profits for each seller. Tougher competition thus reduces the extent of the platform's double marginalization problem but also increases marketplace volume. Moreover, buyers benefit from more sellers due to indirect network effects. In turn, the platform can then exploit these two effects by setting a larger transaction fee.

Conversely, and by the same reasoning, rationing sellers is costly for the platform since reducing the number of sellers results in less competition. Sellers then can charge higher prices which entails greater profits for them but also reduces overall marketplace volume: first, because sellers pass on the imposed fees to buyers, and second, because less buyers join the marketplace overall. Hence, also double marginalization becomes a more prevalent issue for the platform. To counteract such events, the platform would have to decrease its fees.

Additionally, improving product comparability (e.g., by decreasing τ) may two effects. First, by making products appear more similar or displaying similar item for a given product search, seller competition becomes more fierce. This results in lower prices, which increases buyer demand on the platform. Second, also sellers' profits decrease, which reduces issues of double marginalization. Together, this allows the platform to set higher transaction fees.

Finally, increases in the elasticity of buyer demand around the competitive price p^{com} force the platform to set lower transaction fees. Intuitively, when buyer demand is responsive to prices, the platform must leave more surplus to buyers because else it is crowding out demand. Since sellers pass on fees to buyers, the platform thus has to reduce its fee to prevent buyers from leaving. Alternatively, the platform may try to increase buyers' stand-alone benefit u^B to counteract their increased sensitivity to prices by, e.g., providing or improving add-on services.

4.3 Seller Collusion

This previous subsection looked at a marketplace equilibrium where sellers compete. In that case, sellers charge prices $p^{com} = f + \tau/N$ and make profits $\pi^{com} = \tau/N^2$. Given that sellers compete, Proposition 1 characterizes the platform's optimal pricing strategy. As shown above, the optimal fee f^{com} extracts some surplus from sellers while still allowing for cross-group externalities such that the overall number of trades is maximized. However, since $\pi^{com} > 0$, the platform faces an issue of double marginalization that limits its ability to extract all surplus. Hence, a platform may find employing a transaction fee an inefficient tool.[12]

Contrary to the previous case, where sellers could not coordinate on prices, we now study an equilibrium where sellers have the ability to collude. In particular, we first look at the equilibrium of an infinitely repeated collusion game. In that part of the game, sellers –being symmetric and having the same discount factor for future profits– decide whether to coordinate on prices or to compete in the above fashion. We then carve out the platform's best response to seller collusion.

Based on Corollary 2, a necessary condition for seller collusion is that they can obtain higher profits (i.e., $\pi^{coll} > \pi^{com}$) if they coordinate on prices. Thus, given Assumption A1, we look at an infinitely-repeated game in discrete time with periods $k = 0, ..., \infty$ where sellers have a common discount factor $\delta \in (0, 1)$ and aim to maximize the discounted stream of (future) profits:

$$\sum_{k=0}^{\infty} \delta^k \pi(p). \tag{17}$$

Notably, the platform does not participate in the collusive agreement but may have a preferred conduct, i.e., seller competition or collusion. Also, by choosing its fee, the platform can influence how sellers act in its marketplace. Finally, the platform sets a symmetric transaction fee at the beginning of the first period that remains constant over time.

As before, we solve for subgame-perfect Nash equilibria in this infinitely-repeated subgame between sellers. To simplify the demonstration of our results, we assume

[12] In Section 6, we discuss further pricing tools that the platform could impose. As we show, having a fixed fee may eliminate double-marginalization completely when sellers compete.

sellers coordinate on the monopoly price p^{mon}.[13]

We are now going to model seller collusion by looking at the grim trigger strategies [Friedman, 1971] – that is, once a seller deviates from the collusive scheme, all sellers play their competitive strategies and earn π^{com} profits.[14] Suppose now that sellers form a cartel that coordinates on prices charging the monopoly price p^{mon}. Hence, once the cartel is formed, each colluding seller obtains $\pi^{mon} > \pi^{com}$. If one seller decides to deviate from the collusive scheme, the deviator sets a price p_i^{Dev} to maximise deviation profits. The following lemma summarizes this result:

Proposition 2 (Deviator strategy)**.** *Suppose all sellers coordinate to play p^{mon}. Now, if one seller deviates from the collusive scheme by playing p^{Dev}, the deviator's then obtains a market share d^{Dev} and generates profits π^{Dev} such that*

$$p^{Dev} = p^{mon} - \frac{p^{mon} - p^{com}}{2} \; ; \; d^{Dev} = \frac{1}{N} + \frac{p^{mon} - p^{com}}{2\tau} \; ; \; \pi^{Dev} = \pi^{mon} + \frac{(\pi^{mon} - \pi^{com})^2}{4\pi^{com}}. \tag{18}$$

Proof. Suppose $N-1$ sellers play p^{mon} and one seller deviates by playing p^{Dev}. Denote this seller's profits, market share, and prices with superscript Dev. Then, the deviator's best response p^{Dev} maximizes

$$\pi^{Dev}(p^{Dev}, p^{mon}) = (p^{Dev} - c - t) * \left(\frac{1}{N} + \frac{p^{mon} - p^{Dev}}{\tau}\right), \tag{19}$$

where p^{mon} is the price charged by the remaining $N-1$ sellers. Then, after taking the problem's first order conditions, this yields p^{Dev}, d^{Dev}, and π^{Dev} as stated above. $\square$

Proposition 2 shows that a deviating seller chooses a price below the cartel price p^{mon}. By doing so, the deviator is able to gain a greater market share $d^{Dev} > 1/N$, which maximizes her profits. Given that a deviation is profitable, the participation constraint to collude is

$$\pi^{mon} + \sum_{k=1}^{\infty} \delta^k \pi^{mon} \geq \pi^{Dev} + \sum_{k=1}^{\infty} \delta^k \pi^{com}. \tag{20}$$

[13] In principle, colluding sellers could agree on any price between p^{com} and p^{mon}. Hence, there is an infinite number of possible equilibria, as suggested by the Folk Theorem [Friedman, 1971]. In Appendix A, we generalize our findings by relaxing this assumption and show that our results still hold when colluding sellers have the possibility to charge a price $p^{coll} \in [p^{com}, p^{mon}]$.

[14] One might raise the remark that if one seller deviates in a given period, this does not necessarily imply that all sellers will play p^{com} immediately after that deviation, given that sellers compete along the Salop circle. However, applying that reasoning further, a first deviation from one seller then might leads to a cascade of sequential deviations from other sellers that, over an infinite horizon, does not change results qualitatively. Hence, we can neglect these periods of "deviation cascades" without loss of generality.

In other words, sellers cartelize if the profits from sticking to the collusive agreement exceed the profits from deviating once and playing competitive strategies for the remaining future.

Further, given this participation constraint for collusion, we can rearrange terms in Expression 20 to obtain a lower bound for the common discount factor:

$$\delta \geq \delta^* \equiv \frac{\pi^{Dev} - \pi^{mon}}{\pi^{Dev} - \pi^{com}}. \tag{21}$$

Hence, collusion is only stable if $\delta \geq \delta^*$. In other words, sellers need to be sufficiently "patient" in order to collude. Notice further that since $\pi^{mon} = \pi^{mon}(f)$ and thus $\pi^{Dev} = \pi^{Dev}(f)$, also the critical discount factor $\delta^* = \delta^*(f)$, while π^{com} is independent of transaction fees f. To provide some further insights on the stability of seller collusion, we show in the next lemma how collusion stability relates to the transaction fee imposed by the platform:

Lemma 2 (Collusion incentives). *Denote δ^* the critical discount factor for which colluding is subgame perfect. For π^{Dev} and π^{mon} as defined in Proposition 2 and Corollary 1, respectively, it holds that $\delta^*(f)$ is monotonically decreasing in f.*

Proof. Notice that a necessary condition for collusion is that the discount factor of the cartelizing sellers is large enough:

$$\delta \geq \delta^*(f) \equiv \frac{\pi^{Dev}(f) - \pi^{mon}(f)}{\pi^{Dev}(f) - \pi^{com}}. \tag{22}$$

In combination with the results in Proposition 2, we can thus simplify the enumerator to $\pi^{Dev}(f) - \pi^{mon}(f) = [\pi^{mon}(f) - \pi^{com}]^2/(4\pi^{com})$. Moreover, the denominator can be reduced to $\pi^{Dev}(f) - \pi^{com} = [\pi^{mon}(f) - \pi^{com}]^3/(4\pi^{com})$. Differentiating with respect to f then yields

$$\frac{d\delta^*(f)}{df} = -\frac{5}{N}\frac{\pi^{mon}(f) - \pi^{com}}{4\pi^{com}} < 0. \tag{23}$$

□

Lemma 2 shows that if sellers collude, a higher transaction fee reinforces sellers' incentives to collude once again. In fact, higher transaction fees reduce both deviator profits as well as profits under collusion. Yet, deviator profits decrease faster than collusion profits. In other words, higher transaction fees render the sellers' outside option of collusion (i.e., to compete) relatively less attractive. As a result, a higher transaction fee thus reinforces sellers' incentives to collude. Figure 1 illustrates the relationship between sellers' collusion incentives and transaction fees imposed by the platform.

How will the platform react once sellers collude? The following proposition establishes that the platform's best response is to adjust its transaction fees once a seller cartel has been implemented:

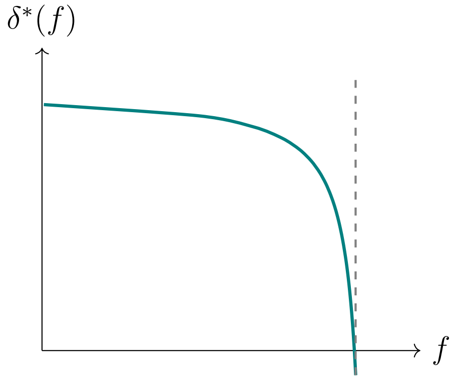

Figure 1: Threshold value or the discount factor δ^* depending on transaction fees f.

Proposition 3 (Platform's best response – collusion). *Suppose Lemma 1 holds and that sellers collude. Then, the monopoly platform's best response to maximize profits is*

$$\tilde{f}^{coll} = v. \tag{24}$$

Proof. Suppose sellers charge $p^{mon} = v$ and obtain $\pi^m = (v - f)/N$. Moreover, it holds that $dN^S(p^{mon}, N)/df = 0$, so higher fees do not crowd buyers anymore as long as $f \leq v$. Hence, it must be that $f \leq v$. In addition, also $dN/df = 0$, so any $f < v$ is inefficient since a setting higher fee increases profits but does not crowd out sellers. As a result, the platform's optimal fee is $\tilde{f}^{coll} \equiv f = v$. □

When sellers collude, buyer demand on the platform is minimized: sellers charge the monopoly price $p^{mon} = v$ – making buyers indifferent between realizing their outside option and purchasing. Consequently, the colluding sellers act like a monopoly and can thus extract all buyer surplus. This also limits indirect network effects on the buyer side. However, given these indirect network effects are already limited, colluding sellers earn $\pi^{mon} = (v - f)/N$ and the platform's best response is to extract this surplus once again by charging $\tilde{f}^{coll} = v$ irrespective of potential network effects. Therefore, by charging $\tilde{f}^{coll}$, the platform can eliminate its double double marginalization problem. As a result, the monopoly platform can thus act like a vertically integrated firm when sellers collude.

4.4 Collusion or Competition

Suppose the monopoly platform can now decide whether sellers collude or compete. In that case, which equilibrium will the it prefer? Notably, the platform's preferred conduct depends on its profits in the given scenario. Irrespective of the sellers' participation constraint to collude, it turns out that the platform prefers seller collusion whenever buyers' have a high willingness to pay v or demand is sufficiently elastic around p^{com}:

Lemma 3 (Preferred Conduct)**.** *The monopoly platform prefers seller collusion iff*

$$v > \frac{N^B(p^{com}, N)}{-dN^B/dp^{com}} * \frac{N^B(p^{com}, N)}{N^B(p^{mon}, N)}. \tag{25}$$

Proof. The platform prefers seller collusion iff

$$\Pi_P^{coll} > \Pi_P^{com} \iff \tilde{f}^{coll} * N^B(p^{mon}, N) * N > \tilde{f}^{com} * N^B(p^{com}, N) * N. \tag{26}$$

Moreover, together with the results from Propositions 1 and 3, we can rewrite this statement as

$$v * N^B(p^{mon}, N) > \frac{N^B(p^{com}, N)}{-dN^B/dp^{com}} * N^B(p^{com}, N), \tag{27}$$

which, after rearranging terms, yields the expression as shown in the Lemma. □

A higher willingness to pay v implies that less elastic demand. Hence, given that buyers react less sensitively to changes in prices, the platform wants the sellers to charge the higher price possible. In principle, since sellers' competitive prices are equal to $p^{com} = f + \tau/N$, the platform could increase its fee such that $p^{coll} = v$, but still the issue of double marginalization remains. However, when sellers collude, sellers charge p^{mon} by themselves, and the platform can re-extract that surplus from the sellers once again via its fee $\tilde{f}^{coll}$.

On the other hand, when the number of buyers is sufficiently price sensitive around p^{com}, a higher fee crowds out a great number of buyers (since sellers pass on the imposed fees to buyers). Thus, when buyers are very sensitive towards prices around p^{com}, the platform's preferred conduct is seller collusion.

Even though the platform may favor seller competition, encouraging seller collusion can still be challenging. Notably, the result of Lemma 3 neglects sellers' incentive compatibility constraint to collusion: As stated in Corollary 2, a necessary condition for seller collusion is $\pi^{mon} > \pi^{com}$. But as shown in Proposition 3, the platform optimal fee under collusion eliminates double marginalization.

But then, given sellers' incentive compatibility constraint from Corollary 2 is satisfied, may the platform still favor seller collusion in its marketplace? Similar to the previous Lemma, the answer also depends on buyers' willingness to pay and their sensitivity towards prices around p^{com} (however stronger). However, before stating our paper's mail result, we first derive the platform's optimal pricing strategy to seller collusion in compliance to the incentive compatibility constraint:

Lemma 4 (Platform's Best Response (IC) – Collusion)**.** *For any $\epsilon \in \mathbb{R}_{++}$, and in compliance to the incentive compatibility constraint (Corollary 2), the platform's optimal pricing strategy towards seller collusion is*

$$f^{coll} \ = \ v - \epsilon - \frac{\tau}{N}. \tag{28}$$

Proof. In Lemma 3, it was established that the optimal fee level maximizes platform profits while preventing a crowding out of users. Moreover, the incentive compatibility constraint in Corollary 2 read $v > f + \tau/N$. Hence, for f to be optimal, it must hold $v - \tau/N > f$, which implies that there exists and $\epsilon \in \mathbb{R}_{++}$ such that $f = v - \epsilon - \tau/N$. □

Proposition 4 (Equilibrium selection)**.** *Given the sellers' incentive compatibility constraint for collusion (Corollary 2), the platform's preferred conduct is seller collusion iff*

$$v \ > \ \epsilon + \frac{\tau}{N} + \frac{N^B(p^{com}, N)}{dN^B/dp^{com}} * \frac{N^B(p^{com}, N)}{N^B(p^{mon}, N)}. \tag{29}$$

Proof. Denote the platform's profits in the competitive and the collusive equilibrium by Π_P^{com} and Π_P^{coll}, respectively. As in Lemma 3, a monopoly platform prefers seller collusion whenever $\Pi_P^{coll} > \Pi_P^{com}$. Together with the result of Lemma 4, we can rewrite this inequality as

$$f^{coll} {*} N^B(p^{coll}, N) \ > \ f^{com} {*} N^B(p^{com}, N) \iff \left(v - \epsilon - \frac{\tau}{N}\right) \ > \ \frac{N^B(p^{com})}{-dN^B/dp^{com}} {*} N^B(p^{com}), \tag{30}$$

which, after re-arranging terms, yields the result from the Proposition. □

As shown in Proposition 1, under competition, sellers pass on the imposed fee to buyers via their prices, which in turn crowds out buyer demand in the marketplace. Hence, when buyers reacts strongly to prices, the platform's profits under the optimal level of transaction fees f^{com} are lower than its profits by imposing f^{coll} in the case where sellers collude. Therefore, when buyer demand is very elastic, the platform prefers seller collusion.

Moreover, and in line with Lemma 3, Proposition 4 shows that a platform is inclined towards price coordination among sellers whenever buyers' willingness to pay is sufficiently large. A large willingness to pay for goods is equivalent to say that buyers' reservation prices are high.

Interestingly, together this suggests that the platform's preference for seller collusion follows a u-shaped pattern in buyer demand elasticity: when buyer demand is very inelastic, sellers could charge a higher price without crowding out much demand. But since extracting buyer surplus under competition turns out to be inefficient for the platform (due to double marginalization), the platform prefers seller collusion. In this case, sellers capture all buyer surplus, which is then re-extracted once again by the platform via its fee. As a result, the platform prefers seller collusion when buyer demand is very inelastic or buyers have a large willingness to pay.

Given that the platform's profits under collusion exceed profits under competition when demand is either very elastic or very inelastic, it can thus have an incentive to encourage seller collusion, depending on demand characteristics. Consequently, given the platform's ability to design and to govern its marketplace, it may want to exploit this relationship. This gives rise to a novel theory of harm for seller collusion in online marketplaces that sheds light on the question of whether online platforms as marketplace designers may be held accountable, at least in parts, for consumer harming practices that involve price coordination among sellers. Following this result, we discuss potential consequences for policymakers and managers in the next section.

5 Policy Implications

The rapid evolution of digital markets has ushered in unprecedented opportunities and challenges for economists, policymakers, platform managers, and market participants alike. In a landscape where online platforms serve as intermediaries connecting buyers and sellers, the dynamics of competition have taken on novel dimensions. Recent research has unveiled a particularly intriguing facet: the latent incentives for these platforms to facilitate or tolerate seller collusion under certain market conditions.

As the main result of this paper, Proposition 4 shows that a platform can indeed have incentives to establish consumer-harming practices in its marketplace. In this section, we discuss potential cases in which such behaviour is more likely to arise and carve out implications for competition authorities to tackle these practices.

5.1 Negative Buyer Demand Shocks

Negative shocks in buyer demand result in a stronger elasticity. Based on Proposition 4, and depending on the change in buyer demand, the platform may have two potential strategies it can pursue. First, if the demand shock is small enough such that buyer demand remains sufficiently inelastic, Proposition 1 shows that it is optimal for the platform to set a lower transaction fee to increase overall volume in its marketplace. In turn, this makes collusion to sellers more attractive, but the critical discount factor also increases, as shown in Lemma 2, making collusion ultimately less likely. Alternatively, it can try to increase users' stand-alone benefit from joining the marketplace by offering or improving additional services like shipping or handling returns and refunds.

Second, if a shock is sufficiently large such that buyer demand becomes sufficiently elastic, it is optimal for the platform to set a very high transaction fee such that sellers are more likely to coordinate on prices. Then, once sellers collude, they capture all the surplus, and the platform extracts this surplus from the sellers via its imposed fee. Alternatively, the platform may be able to coordinate sellers' pricing strategies centrally by providing them with price recommendations, encouraging the use of centralized pricing tools or even by internalizing itself their pricing decisions. Policymakers and other authors usually refer to this alternative strategy as a *hub-and-spoke* cartel, which is suspected to be more prevalent once sellers use price-matching algorithms [see, e.g., Ezrachi and Stucke, 2019; Competition and Markets Authority, 2018]. Indeed, large online marketplaces like Amazon and Airbnb feature centralized pricing tools to give concrete price recommendations. In addition, the Competition and Markets Authority [2021] reports that other sharing economy platforms employ similar tools that allow sellers to delegate their pricing decisions to the platform or even require them to do so.[15]

In the contemporary landscape of digital commerce, it thus becomes increasingly important for competition authorities to exercise scrutiny when confronted with seller collusion in online marketplace, particularly in the wake of negative demand shocks. As our theoretical framework posits, negative demand shocks may incentivize online platforms to leverage their influential roles in shaping their marketplace, thereby fostering an environment conducive to coordinated pricing behavior among sellers to the detriment of final consumers.

5.2 *Platform Maturity and Established User Base*

Similarly, all else equal, seller collusion should be more common on already well-established platforms, since young platforms tend to maximize buyer surplus to attract more buyers. Hence, they would charge a lower transaction fee, making collusion less likely. Moreover, given that the platform's marketplace also provides a new environment for sellers, coordination on prices is even less likely. Thus, seller collusion should be less of an issue on platforms without an established user base.

Conversely, if a platform has already matured or has a well-established user base, it does not need to attract additional buyers anymore. Hence, indirect network effects are less detrimental, so that it can charge a higher transaction fee. But then, as Lemma 2 shows, increasing transaction fees also increases sellers' incentives to collude. More-

[15] The online marketplace Amazon [2023] offers its sellers its internalized pricing called 'Automate Pricing' together with a detailed step-by-step manual on how to employ it. Likewise, Airbnb [2023] offers a very similar tool (also with instructions) called 'Smart Pricing'. And even though it does not offer its own tool to automate seller prices, Expedia's online platform Vrbo [2023] encourages hosts to use a tool called 'MarketMaker' to make "make more competitive decisions". In a similar way, Fiverr [2023], an online platform that connects freelancers with clients, provides detailed information about how to set appropriate prices. Indeed, as its first point, Fiverr encourages freelances to "Take a Look at the Competition" when setting their prices.

over, the platform can avoid potential double marginalization problems when sellers collude. Therefore, collusion should be more common once a mature platform has an already established user base.

Consequently, regulators should thus be concerned about mature platforms with an already well-established user base, abusing their dominant position in their own marketplace. As put forward by the Competition and Markets Authority [2021], particular focus should hence be directed towards platforms in the sharing economy that already have many users and employ specific tools to regulate seller prices.

Need to distinguish my work from Rhodes et al. [2023] !!!

Need to make link to optimal taxation literature (ask elicit.org) !!!

6 Extensions

Our baseline analyses explored the implication of a platform's marketplace design decisions on competition between sellers and their incentives to collude. In this section, we expand the scope of our analysis in several directions.

6.1 *Other Pricing Strategies*

We previously studied a platform that levies transaction costs. However, we can generalize our results from Section 4 to other platform pricing models, such as royalty fees, fixed membership fees, and two-part tariffs. Notably, most of our results remain qualitatively unchanged. Hence, these findings are also robust to different pricing models employed by the platform. However, one exception are fixed membership fees, where the platform usually prefers seller collusion over competition.

6.1.1 Royalty Fees or Revenue Sharing

Same results (see notes): Platform profits are the same, and comparative statics for sellers also remains the same.

NEED TO MAKE SOME FORMAL STATEMENTS

Fixed Membership Fees. Then platform always prefers seller collusion. To see this, note that

$$\Pi^P = f_m * n^S(p(f_m), n^B) \tag{31}$$

and that

$$\pi^c = \frac{\tau}{N^2} = f_m^c \text{ with } p^c = c + \frac{\tau}{N} \quad \text{and} \quad \pi^m = \frac{v-c}{N} = f_m^m \text{ with } p^m = v, \tag{32}$$

so platform prefers seller collusion whenever $f_m^m > f_m^c \iff p^m > p^c$, which is always satisfied by A2 (given $t = 0$).

NEED TO MAKE SOME FORMAL STATEMENTS

6.1.2 Two-Part Tariff

Given this is transaction fees (or royalty fees) plus membership fees, results should remain qualitatively the same as fixed fees because the platform then can extract all the surplus from sellers.

NEED TO MAKE SOME FORMAL STATEMENTS

6.1.3 Imperfect Two-Part Tariff

Idea: P can set fixed fee, but only to a max value below the optimal value. Results should still be the same, but

NEED TO MAKE SOME FORMAL STATEMENTS

6.1.4 Cournot Competition

NEED TO MAKE SOME FORMAL STATEMENTS

6.2 Folk Theorem

See finding of lemma in Appendix.

6.3 Supply-Sided Network Effects

see extension with the salop circle depending on N^B

6.4 Platform competition

see paper by Johannes: Deceptive features

NEED TO MAKE SOME FORMAL STATEMENTS

6.5 Further ideas

6.5.1 Alternative Collusion Game (like Tit for Tat)

6.5.2 Proper Indirect NEs on both sides

6.5.3 Platform competition

7 Conclusion and Further Developments

Even though our current analysis is incomplete, our model establishes that online marketplaces do not necessarily act in favour of their users. In particular, when buyers are sensitive to price changes, the platform can have an incentive to foster sellers' coordination on prices. Moreover, the platform may want to internalize its pricing decisions entirely to avoid potential problems of double marginalization. Such instances should appear more frequently on product categories facing price sensitive demand or on a platform with a well-grounded user base.

In the next version, we plan to extend this paper in several ways. First and foremost, we intend to derive welfare implications as well as further implications for regulators with our model. So far, we have only looked at implications for seller competition. As one might suspect, seller collusion replicates the general welfare result of monopolies by minimizing overall welfare. However, the effects on welfare stemming from different ways of governing competition can be more nuanced, especially when the platform uses additional tools to design its marketplace.

Second, even though already derived, we plan to incorporate other pricing strategies of the platform into our paper. In particular, we will show that our results remain unchanged once the platform employs a pricing strategy featuring revenue-sharing. Moreover, we also plan to extend our results to the use of fixed membership fees and two-part tariffs.

Third, we intend to include the possibility that platforms can also charge buyers. Currently, our analysis is restricted to retail platforms or platforms where buyers cannot observe charged fees. However, to underline the "two-sidedness" of online marketplaces, including this possibility would make our results more general.

Fourth, we will augment our model to allow the platform to influence transportation costs as well as the stand-alone benefit for users. Including these tools opens novel channels for the platform to govern competition, and it will direct the focus of our paper closer to design features in the marketplace.

Fifth, we plan to derive implications when the timeline of the game is modified. In particular, we plan to alter the game's structure in such a way that the platform may choose what product category equilibrium will arise. This would reinforce our results and make the platform's incentives more explicit.

Finally, we also plan to relax our assumption about sellers' outside options. So far, their outside option is assumed to be normalized to zero for all sellers. However, similarly to the possibility for the platform to charge buyers, a non-homogeneous outside option for sellers would stress once more the nature of two-sided markets by making indirect network effects on the sellers' side more present. This can be done by either assuming that the sellers' outside option follows a similar distribution as for buyers, or by introducing a second platform. In general, one might suspect that the introduction of platform competition would limit the scope of our results; however, they should not vanish. Moreover, indirect network effects on the sellers' side provide the potential to stabilize seller cartels. In that, the effects of platform competition could be a priori ambiguous.

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A Extensions

Below, we provide a set of extensions to our baseline model, as discussed in Section 6. Although most our results are quite robust to these considerations, we discuss how alternative pricing strategies and types of competition as well as the Folk Theorem relate our findings, and how to introduce supply-sided network effects as well as platform competition.

A.1 Other Pricing Strategies

Our main analysis studied a platform's pricing behavior and incentives to encourage collusion among sellers when it employs a per-unit fee structure. In this section, we look how our results relate to alternative pricing strategies. Especially, we show that our results remain qualitatively unchanged when the platform sets a royalty fee, a fixed membership fee, and a two-part tariff.

A.1.1 Royalty Fees

In this section, we show that our results from the transaction fee model can also be extrapolated to a model of royalty fees. More specifically, the generality of our results also hold when the platform generates profits through a revenue-sharing scheme.

Formally, denote by $f_R \in [0, 1]$ the share of revenue whose value is retained by the platform. Also, let its profits be characterized by

$$\Pi^P = f_R * \pi^\ell * N^B(p^\ell, N) * N, \tag{33}$$

where $\ell = \{com, mon\}$. Sellers' prices and profits, on the other hand, are thus equal to $p_R^{com} = \tau/N$ and $\pi_R^{com} = (1 - f_R)\tau/N^2$, respectively, when sellers compete, and $p^{mon} = v$ and $\pi_R^{mon} = (1 - f_R)v/N$ when they collude. As a result, Lemma 1 as well as Corollaries 1 and 2 remain unchanged.

The next proposition shows that under royalty fees, a monopoly platform can eliminate double marginalization when sellers compete:

Proposition 5 (Royalties – Platform Pricing (No Collusion)). *Suppose Lemma 1 holds and that sellers compete. Then, the monopoly platform's profit maximizing fee satisfies* $f_R^{com} = 1$.

Proof. The platform's optimization problem reads

$$\begin{aligned} \max_{f_R}\ \Pi^P =& f_R * \pi_R^{com} * N^B(p_R^{com}, N) * N \\ \text{s.t.}\ \ & 0 \geq (1 - f_R)\frac{\tau}{N^2}, \end{aligned} \tag{34}$$

which is maximized at $f_R^{com} \equiv f_R = 1$. □

As the Proposition above shows, when sellers compete, the platform charges a royalty fee that extracts all the surplus from the sellers.

We next study a seller collusion game as outlined in Section 4.3. The following Proposition shows that also under royalty fees, a deviating seller charges a price that is between the competitve and the collusive price, thus gets a larger market share and therefore higher profits:

Proposition 6 (Royalties – Deviator strategy)**.** *Suppose all sellers coordinate to play p^{mon}. Now, if one seller deviates from the collusive agreement by playing p_R^{Dev}, the deviator then obtains a market share d_R^{Dev} and generates profits π_R^{Dev} such that*

$$p_R^{Dev} = p^{mon} - \frac{p^{mon} - p_R^{com}}{2} \;\; ; \;\; d_R^{Dev} = \frac{1}{N} + \frac{v - \tau/N}{2\tau} \;\; ; \;\; \pi_R^{Dev} = \pi_R^{mon} + \frac{(\pi_R^{mon} - \pi_R^{com})^2}{4\pi_R^{com}}. \quad (35)$$

Proof. This proof is analogous to the proof of Proposition 2. □

And even though also sellers' competitive profits p_R^{com} depend now on the level of the transaction fee (in contrast to proportional fees), sellers' incentives to collude increase in the level of the imposed royalty fees as well:

Lemma 5 (Royalties – Collusion Incentives)**.** *Denote δ_R^* the critical discount factor for which collusion is sustained. For π_R^{Dev}, π_R^{mon}, and π_R^{com}, it holds that $\delta_R^*(f_R)$ is monotonically decreasing in f_R.*

Proof. This proof is analogous to the proof of Lemma 2. □

Finally, the next two Propositions show the platform's optimal pricing strategy once sellers collude, and its preferred conduct. In particular, our results remain qualitatively unchanged if the platform charges royalty fees instead of transaction fees:

Proposition 7 (Royalties – Platform Pricing (Collusion))**.** *Suppose Lemma 2 holds and that sellers collude. Then, for any $\epsilon \in \mathbb{R}_{++}$, the platform's profit maximizing royalty fee is $f_R^{coll} = 1 - \epsilon$.*

Proof. From Lemma 2, a necessary condition for seller collusion is $\pi_R^{coll} > \pi_R^{com}$. Further, it follows from Proposition 5 that $\pi_R^{com} = 0$. Hence, the profit-maximizing fee must satisfy $\pi_R^{coll} = (1 - f_R^{coll})v/N > 0$, hence $f_R^{coll} < 1$. Moreover, since $v/N > 0$, this implies that there exists an $\epsilon \in \mathbb{R}_{++}$ such that $f_R^{coll} = 1 - \epsilon$. □

Proposition 8 (Royalties – Preferred Conduct (IC))**.** *Given that seller's incentive compatibility constraint for collusion (Corollary 2) is satisfied, the platform's preferred condict is seller collusion iff*

$$v \;>\; \frac{\tau}{N}\frac{N^B(p_R^{com}, N)}{N^B(p_R^{mon}, N)}\frac{1}{1-\epsilon}. \quad (36)$$

Proof. This proof is analogous to the proof of Proposition 4. In particular, $\Pi_P^{coll} > \Pi_P^{com} \iff$

$$(1-\epsilon) * \pi_R^{coll} * N^B(p_R^{mon}, N) \ > \ \pi_R^{com} * N^B(p_R^{com}, N), \tag{37}$$

, which, after rearranging terms, yields the inequality in the above Proposition. □

A.1.2 Fixed Membership Fees

The main result of this section is that under fixed membership fees, the platform will virtually always prefer seller collusion. The reason is that in contrast to transaction fees and royalty fees, the platform's profit do not depend on the total volume in its marketplace, but only on the total number of sellers. Thus, it limits the platform's focus on revenue generated via the sellers. However, to support this claim, we first characterize sellers' strategies when the platform levies a fixed fee. Next, we show that the platform can charge a higher fee to colluding sellers.

Suppose first that the platform charges a fixed fee f_m. The next lemma characterizes seller prices and profits:

Lemma 6 (Fixed Fee – Competition)**.** *If the platform charges a fixed membership fee F and sellers compete, then sellers charge $p_F^{com} = \tau/N$. The platform charges $f_F^{com} = \tau/N^2$ and sellers obtain $\pi_F^{com} = 0$.*

Proof. From Lemma 1, $p^{com} = f + \tau/N$, where f is the proportional fee levied by the platform. Hence for our purpose, $f = 0$ such that $p_F^{com} = \tau/N$. Moreover, also from Lemma 1, $\pi_F^{com} = \tau/N^2$, thus total profits under fixed fees become $\pi_F^{com} = \tau/N^2 - F$. □

Since sellers provide horizontally differentiated goods, they can charge a mark-up to achieve prices above marginal costs (zero here) – extracting some of the surplus from the buyers. But since a fixed fee represents a fixed cost for sellers, the platform can re-extract this surplus via its fee from the sellers to maximize profits.

On the other hand, when seller collude, they can charge the monopoly price $p^{mon} = v$ (as seen in Lemma 1). Thus, seller profits are equal to $\pi_F^{mon} = v/N - f_F^{mon}$. Again, the platform may set its fee to re-extract all the surplus that sellers have captured from consumers, i.e., $f_F^{mon} = (v-c)/N$. Thus $\pi_F^{mon} = 0$. However, this would violate sellers' participation constraint to collude. Thus, the platform needs to set f_F^{mon} such that $\pi_F^{mon} = \epsilon_F > 0$. The next lemma summarizes these results:

Lemma 7 (Fixed Fee – Collusion)**.** *If the platform charges a fixed membership fee F and sellers collude, then sellers charge $p^{mon} = v$. Then, there exists an $\epsilon_F \in \mathbb{R}_{++}$ such that the platform charges $f_F^{mon} = (v - \epsilon_F)/N$ and sellers obtain $\pi_F^{mon} = \epsilon_F$ for any $v - \tau/N > \epsilon_F > 0$.*

Proof. We structure this proof in two parts. The first part derives the optimal prices irrespective of the participation constraint for sellers to collude and is analog to the proof of Lemma 6. The second part adjusts these findings with respect to the participation constraint. For this, notice that collusion requires that $\pi_F^{mon} > \pi_F^{com} = 0$. Thus $f_F^{mon} < v/N$ because else $\pi_F^{mon} = 0$. This implies that there exists $\epsilon_F > 0$ and $f_F^{mon} = v/N - \epsilon_F/N$. Note that the platform sets f_F^{mon} as long as $f_F^{mon} > f_F^{com} \iff v - \tau/n > \epsilon_F$. $\square$

Notice that Lemma 7 is conditional on the size of ϵ_F. But given Assumption A2, this condition is always satisfied.

Finally, since we study retail platforms, it can charge only the seller side. Thus, the platform takes only the total number of sellers into account (and ignores network effects). Therefore, under fixed membership fees, the platform's profits are given by

$$\Pi^P = F * N. \tag{38}$$

Therefore, the platform only cares about the total number of sellers and the fee it charges to them. But since both the charged fee and the numbers of sellers are greater under collusion (because $\pi_F^{mon} > \pi_F^{com}$), the platform can generate greater profits under collusion. Hence, whenever the platform employs fixed fees, it will prefer seller collusion.

Proposition 9 (Fixed Fee – Platform preferences)**.** *Under fixed membership fees, the platform always prefers seller collusion.*

Proof. Given it charges a fixed membership fee, a monopoly platform's profits are characterized by

$$\Pi^P = F * N.$$

Moreover, from Lemma 7, it holds that $f_F^{mon} > f_F^{com}$. Hence, holding the number of (colluding) sellers constant, $\Pi^P(f_F^{mon}) > \Pi^P(f_F^{com})$. $\square$

A.1.3 Two-part tariff

Employing a two-part tariff fee structure, the platform levies both a fixed fee and a proportional fee. Denote the fixed fee and the proportional fee of the two-part tariff by $F_{TPT} \in \mathbb{R}_{++}$ and $f_{TPT} \in \mathbb{R}_{++}$, respectively. As established previously, a fixed fee is a more efficient tool to extract surplus from sellers compared to a proportional fee. And given that a two-part tariff involves a fixed fee, also the results remain qualitatively unchanged. Hence, also under a two-part tariff, the platform would prefer collusive prices.

In contrast to a fixed fee, however, the platform does not need to incentivize sellers to collude to reach such an outcome: instead, the platform can achieve collusive prices by setting proportional fees such that sellers' prices parallel the collusive price v, and then set the fixed fee to eliminate any double marginalization. As a result, for the platform employing a two-part tariff is an even more efficient tool to extract rents, but also the worst outcome in terms of welfare. Together, this implies that a two-part tariff with collusive prices is always the most preferred pricing scheme for the platform because it can fully extract both buyer and seller surplus. The following two Propositions summarizes these findings:

Proposition 10 (Two-Part Tariff – Platform Pricing). *Under a two-part tariff, the platform's optimal per-unit fee and fixed fee are $f_{TPT} = v - \tau/N$ and $F_{TPT} = \tau/N^2$, respectively. Moreover, seller profits are $\pi^{com}_{TPT} = 0$ and buyer surplus is minimized.*

Proof. From Lemma 1, $p^{com}_{TPT} = f_{TPT} + \tau/N$ and $p^{mon} = v$. Suppose now the platform charges a two-part tariff. Then, it can set the variable part of the tariff f_{TPT} such that $p^{com}_{TPT} = p^{mon}_{TPT} \iff f_{TPT} + \tau/N = v \iff f_{TPT} = v - \tau/N$, which minimizes buyer demand and, hence, buyer surplus.

Sellers profit margin then equals $\pi^{com}_{TPT} = \tau/N^2 - F_{TPT}$, from which it follows that $F_{TPT} = \tau/N^2$ eliminates double marginalization and maximizes the platform's profits. $\square$

Proposition 11 (Two-Part Tariff – Platform Preferences). *When the platform can employ a two-part tariff, it will prefer to set prices as in Proposition 10.*

Proof. We prove this statement by contraposition. Before starting, however, notice that from Propositions 6 and 7, it follows that the optimal fixed fees are and $F = \pi^{mon}_F$ under seller competition and $f^c_m = \pi^c$ under seller collusion, respectively.

Suppose now that the platform does not play according to pricing strategy outlined in Proposition 10. Then, the platform can set variable fees to parallel either f^{com}_{TPT} when sellers compete, or f^{mon}_{TPT} when sellers collude (notice that from Propositions 1 and 3, it follows that f^{mon}_{TPT} is never optimal once sellers compete, and f^{com}_{TPT} is never optimal once they collude).

Thus, potential candidates for an optimal strategy are the two-part tariffs $(F_{TPT} = F^{mon}, f_{TPT} = f^{mon})$ and $(F_{TPT} = F^{com}, f_{TPT} = f^{com})$. Now, if the statement in Proposition 11 is false, then

$$\Pi^P_{com} > \Pi^P_{coll} \iff \pi^{com} * N + f^{com} * N * N^B(p^{com}, N) > \pi^{coll} * N + f^{mon} * N * N^B(p^{mon}, N), \tag{39}$$

which can be rearranged to

$$\pi^{mon} - \pi^{com} < f^{com} * N^B(p^{com}, N) - f^{mon} * N^B(p^{mon}, N). \tag{40}$$

Notice that the left-hand side is positive. Moreover, notice that $N^B(p^{com}, N) > N^B(p^{mon}, N)$, hence there exist a $z \in \mathbb{R}_{++}$ such that $N^B(p^{com}, N) = N^B(p^{mon}, N) + z$. Thus, the expression above can be rewritten as

$$\pi^{mon} - \pi^{com} < N^B(p^{com}, N) * (f^{com} - f^{mon}) - f^{mon} z, \tag{41}$$

where the right-hand side is negative. But since, $\pi^{mon} - \pi^{com} > 0$, this is a contradiction. Hence, offering a two-part tariff of $(F_{TPT} = F^{mon}, f_{TPT} = f^{mon})$ must be optimal. $\square$

A.2 Cournot Competition

Although our baseline model considers sellers who provide horizontally differentiated goods, we can extend this model to a setting that features homogeneous goods where sellers compete in quantities instead of prices. To see this, suppose that sellers compete à la Cournot. Formally, suppose there is a finite number of sellers N, where each seller $i \in N$ produces a quantity $q_i \in \mathbb{R}_+$ and $Q = \sum_{i=1}^{N} q_i$. For the sake of simplicity, assume that sellers are symmetric and face no marginal costs. Further, let the inverse demand function of buyers be

$$P(Q) = A - bQ, \tag{42}$$

where $A \in \mathbb{R}{++}$ is the reservation price and $b \in \mathbb{R}{++}$ a parameter for demand sensitivity.

Then, in the Cournot equilibrium sellers charge $p = (A + Nf)/(N + 1)$, sell units of $q_i = (A - f)/(b(N + 1))$ and make profits equal to $\pi_i = (1/b) * [(A - f)/(N + 1)]^2$.

In relation to Proposition 1, the following Lemma shows that when a platform employs a transaction fee f, results from the competitive equilibrium remain qualitatively unchanged:

Proposition 12 (Cournot – Platform's Best response (Competition))**.** *Suppose that sellers compete à la Cournot. Then, the monopoly platform's best response to maximize profits is*

$$f^{com}_{Cournot} = \frac{N^B}{-dN^B/df} \quad \textit{and} \quad \eta^B = -\frac{f^{com}_{Cournot}}{N^B}\frac{dN^B}{df}. \tag{43}$$

Proof. This proof is analogous to the proof of Proposition 1. $\square$

In addition, if sellers collude, they maximize joint profits. In particular, they agree on the monopoly price and commonly sell the associated quantity:

Lemma 8 (Cournot – Collusive Equilibrium)**.** *In the Cournot model, if sellers collude, their prices $p^{coll}_{Cournot}$, quantities $q^{coll}_{Cournot}$ and profits $\pi^{coll}_{Cournot}$ are, respectively:*

$$p^{coll}_{Cournot} = \frac{A+f}{2} \quad ; \quad q^{coll}_{Cournot} = \frac{A-f}{2bN} \quad ; \quad \pi^{coll}_{Cournot} = \left(\frac{A-f}{2}\right)^2 \frac{1}{bN}. \tag{44}$$

Proof. Colluding sellers act like a single monopoly and maximize joint profits with respect to the price. Hence, given the inverse demand function $p = A - bQ$, the first order condition yields prices, quantities and profits equal to the one in the proposition above. $\square$

In contrast to the model with horizontal differentiation, however, a deviator chooses a price that is slightly below the collusive price and caters the entire market. To see this, let $\epsilon \in \mathbb{R}_{++}$ be the increase in sold united with respect to the total quantity from collusion. The following Proposition outlines the deviator's strategy:

Proposition 13 (Cournot – Deviator Strategy)**.** *In the Cournot model, if a seller deviates from the collusive agreement, its price, quantity and profits, respectively, are:*

$$p^{Dev}_{Cournot} = \frac{A+f}{2} - \epsilon b \quad ; \quad q^{Dev}_{Cournot} = \frac{A-f}{2b} - \epsilon \quad ; \quad \pi^{Dev}_{Cournot} = \left(\frac{A-f}{2}\right)^2 \frac{1}{b} - \epsilon^2 b. \tag{45}$$

Moreover, a seller has an incentive to deviate as long as $\epsilon < (N-1)(q^{coll}_{Cournot})^2$.

Proof. Suppose a seller deviates and sets the price $p^{Dev}_{Cournot}$, which is slightly below $p^{coll}_{Cournot}$. Then, it follows from the inverse demand function that the sold quantity is equal to $q^{Dev}_{Cournot}$. Together, this implies that a deviator's profits are equal to $\pi^{Dev}_{Cournot} = (A - f0^2/(4b) - \epsilon^2 b$.

Finally, it is easily verified that $\epsilon < (N-1)(q^{coll}_{Cournot})^2$ implies $\pi^{Dev}_{Cournot} > \pi^{coll}_{Cournot}$. This concludes the proof. □

Next, we show that also Lemma 2 and Proposition remains qualitatively unchanged when switching to the Cournot model. In particular:

Lemma 9 (Cournot – Collusion Incentives)**.** *Denote δ^* the critical discount factor δ that enables collusion. For $\pi^{Dev}_{Cournot}$, $\pi^{coll}_{Cournot}$ and $\pi^{com}_{Cournot}$ as defined above, it holds that $\delta^*(f)$ is monotonically decreasing in f.*

Proof. The critical discount factor for the Cournot model is defined as

$$\delta^* = \frac{\pi^{Dev}_{Cournot} - \pi^{coll}_{Cournot}}{\pi^{Dev}_{Cournot} - \pi^{com}_{Cournot}}, \tag{46}$$

which, when plugging in $\pi^{Dev}_{Cournot}$, $\pi^{coll}_{Cournot}$ and $\pi^{com}_{Cournot}$, yields

$$\frac{\left(\frac{A-f}{2}\right)^2 \frac{N-1}{N} - (\epsilon b)^2}{\left(\frac{A-f}{2}\right)^2 \frac{(N+1)^2-4}{(N+1)^2} - (\epsilon b)^2}.$$

Moreover, its derivative with respect to f is

$$\frac{\partial \delta^*(f)}{\partial f} = -\left(\frac{A-f}{2}\epsilon b\right)^2 \frac{\frac{(N-1)^2-4}{(N-1)^2} - \frac{N-1}{N}}{(\pi^{Dev}_{Cournot} - \pi^{com}_{Cournot})^2}, \tag{47}$$

where the first term is negative and the denominator of second term is positive. Moreover, also the second term's enumerator is positive since $N(2+N) > 1$, so $\partial\delta^*/\partial f < 0$. □

Given that sellers collude, we next characterize the platform's best response to seller collusion. Notice, however, that when sellers compete in quantities, they take the imposed fee into account when jointly maximizing their profits and setting their prices. As a result, it is possible that even under the monopoly price, buyer demand is not minimized in Cournot competition.[16] Thus, a higher platform fee may crowd out further demand, which may force the platform to reduce its fee:

Proposition 14 (Cournot – Platform's Best Response (Collusion))**.** *Suppose sellers collude. Then, the monopoly platform's best response to maximize profits is*

$$f^{coll}_{Cournot} = \frac{N^B_{coll}}{-dN^B/df} \quad \text{and} \quad \eta^B_{coll} = -\frac{f^{coll}_{Cournot}}{N^B_{coll}} * \frac{dN^B}{df}. \tag{48}$$

Additionally, in comparison to Lemma 12, it holds that $f^{coll}_{Cournot} < f^{com}_{Cournot}$ whenever $N^B_{coll}/N^B_{com} < (N+1)/(2N)$.

Proof. When sellers collude, the platform's profits are

$$\Pi^P = f * N^S * N^B_{coll}(p^{coll}_{Cournot}(f)). \tag{49}$$

Taking its derivative with respect to f yields the first order condition, which after rearranging terms, leads to

$$f^{coll}_{Cournot} = \frac{N^B_{coll}}{-dN^B/df}. \tag{50}$$

Lastly, notice that $N^B_{com} > N^B_{coll}$ and that $\frac{-dN^B_{coll}/dp^{coll}_{Cournot}}{-dN^B_{com}/dp^{com}_{Cournot}} = \frac{n+1}{2n} < 1$. Hence,

$$f^{coll}_{Cournot} > f^{coll}_{Cournot} \iff \frac{N^B_{coll}}{N^B_{com}} > \frac{N+1}{2N}. \tag{51}$$

□

Finally, also the platform's preferences over collusion remain mostly unchanged. However, since the difference between the fees in the collusive and the competitive equilibrium depends now on the number of sellers, also the platform's preference over the competition structure now depends on the number of sellers in the marketplace:

Proposition 15 (Cournot – Equilibrium Selection)**.** *Let N^B_{coll} and N^B_{com} be the number of buyers in the collusive and the competitive equilibrium, respectively, and N the number of sellers. The platform prefers seller collusion over seller competition iff $2N/(N+1) > (N^B_{com}/N^B_{coll})^2$.*

[16] That is to say, a higher price leads to a finite decrease in buyer demand. Hence, $dN^B_{coll}/dp \neq -\infty$, which is in contrast to the model with horizontally differentiated goods.

Proof. The platform prefers seller collusion over competition whenever $\Pi^P_{coll} > \Pi^P_{coll}$. Substituting the results for $f^{com}_{Cournot}$ and $f^{coll}_{Cournot}$ from Propositions 12 and 14, respectively, we can rewrite this condition as

$$f^{coll}_{Cournot} * N * N^B_{coll} > f^{com}_{Cournot} * N * N^B_{com} \iff \frac{2N}{N+1} > \left(\frac{N^B_{com}}{N^B_{coll}}\right)^2. \tag{52}$$

□

A.3 Folk Theorem

Generally, sellers can coordinate on any price $p^{coll} \in [p^c, p^m]$ when colluding. Consequently, there are infinite collusive equilibria, as suggested by Folk Theorem [Friedman, 1971]. While we conveniently assumed in the main part of our paper that when sellers collude, they coordinate on the monopoly price p^m, the following lemma establishes that the results of Proposition 2 can be generalized to hold under the Folk Theorem.

Lemma 10 (Folk Theorem)**.** *Suppose sellers can coordinate on prices $p^{coll} \in [p^c, p^m]$. Then there exists an $\alpha \in [0,1]$ such that collusive price and profits are given by*

$$p^{coll} = \alpha p^m + (1-\alpha)p^c \quad ; \quad d^{coll} = \frac{1}{N} \quad ; \quad \pi^{coll} = \alpha\pi^m + (1-\alpha)\pi^c. \tag{53}$$

Moreover, a deviator's price, demand, and profits, respectively, are given by

$$p^D = p^c + \alpha\frac{p^m - p^c}{2} \quad ; \quad d^D = \frac{1}{N} + \alpha\frac{p^m - p^c}{2\tau} \quad ; \quad \pi^D = \pi^{coll} + \alpha^2\frac{(\pi^m - \pi^c)^2}{4\pi^c}. \tag{54}$$

Proof. Colluding sellers can charge any price $p^{coll} \in [p^c, p^m]$. If all sellers collude to play p^{coll}, there exist $\alpha \in [0,1]$ such that

$$p^{coll} = \alpha p^m + (1-\alpha)p^c \quad ; \quad d^{coll} = \frac{1}{N} \quad ; \quad \pi^{coll} = \alpha\pi^m + (1-\alpha)\pi^c. \tag{55}$$

Suppose now that while $-i$ sellers collude while i deviates to play p^D. Then, i's best response reads

$$\pi^D = (p^D - c - t) * \left(\frac{1}{N} + \frac{p^{coll} - p^D}{\tau}\right), \tag{56}$$

which yields

$$p^D = p^c + \alpha\frac{p^m - p^c}{2} \quad ; \quad d^D = \frac{1}{N} + \alpha\frac{p^m - p^c}{2\tau} \quad ; \quad \pi^D = \pi^{coll} + \alpha^2\frac{(\pi^m - \pi^c)^2}{4\pi^c}. \tag{57}$$

□

A.4 Indirect Network Effects and Idiosyncratic Outside Option for Sellers

The main part of the analysis focused on a retail platform absent of network effects on the supply side for the sake of simplicity. However, we can easily embed indirect network effects of the supply side in this framework by allowing for two additional features: first, seller's profits must be increasing in the total number of buyers on the platform, and second, sellers have an idiosyncratic outside option or face an individual cost to set up their business.

First, seller profits need to increase in the total number of buyers. Hence, sellers benefit from the presence of more buyers. In fact, our model is able to capture this if we let buyers' transportation cost τ be monotonically increasing in the number of buyers N^B who join the platform in equilibrium. Thus, buyers' updated transportation costs are then equal to τN^B.[17] Due to the fact that N^B enters only as a multiplicative factor to the transportation cost τ, most of our initial results remain unchanged (in particular, Lemma 1 and Corollaries 1 and 2).

Second, we assume that each seller i has an idiosyncratic outside option $F_i \in \mathbb{R}$ following a continuous distribution with support over $[\underline{F}, \overline{F}]$ where $\underline{F}, \overline{F} \in \mathbb{R}$ and $\underline{F} < \overline{F}$. Hence, one can interpret F_i as another distribution channel for sellers, like a brick and mortar store or another platform. Although we are going to call F_i as seller i's idiosyncratic outside option for the remaining part of the analysis, one can also think of it as a seller specific cost to set up their business. Given that third-party online sellers oftentimes reside in countries different from the platform or consumers, F_i may thus reflect different requirements that happen in the background of a buyer's purchasing process.[18] Hence, a necessary condition for sellers to join the platform is that their profits (which now depend on N^B) are greater than F_i for all i.

Finally, denote sellers' cost of joining the platform by $F \in [\underline{F}, \overline{F}]$. Then, sellers' updated utility from joining the platform is equal to

$$U^S = \pi * N^B - F, \tag{58}$$

so they join the platform as long as $F_i \geq F$. To see this, notice that since each seller's outside option is idiosyncratic and either above $\underline{F}$ or below $\overline{F}$, sellers can be ordered along their individual F_i. Thus, by the Intermediate Value Theorem, there exist an $F \in [\underline{F}, \overline{F}]$ such that $F_i \geq F \in [\underline{F}, \overline{F}]$ for some sellers and below for others.

In the following, we show that also the other main results of our analysis can be imported to a framework where sellers have an idiosyncratic outside option and their total number is subject to indirect network effects. The only difference to our previous findings, however, is that now, due to indirect network effect, the platform also takes

[17] In other words, the perimeter of the Salop circle can be "scaled" by N^B.

[18] For instance, these requirements can be country-specific (e.g., warehousing and storing), contract related (e.g., shipping and reselling), or internal (e.g., organizational procedures).

the price elasticity of sellers into account when setting its fees. In particular, one can show that most of the intuition and the results of Proposition 1 remains valid, and similar to Rochet and Tirole [2003], it also reflects indirect network effects on on the seller side:

Proposition 16 (NE – Platform pricing (No Collusion)). *Suppose Lemma 1 holds and that sellers compete. Then, the monopoly platform's profit maximizing fee is*

$$f_{NE}^{com} = \frac{1}{\frac{dN^B/df}{N^B} + \frac{dN/df}{N}} \quad \text{where} \quad \eta_{NE}^B = \frac{f^{com}}{N^B}\frac{dN^B}{df} \quad \text{and} \quad \eta_{NE}^S = \frac{f^{com}}{N}\frac{dN}{df}. \tag{59}$$

Proof. □

Proposition 16 reflects that in a competitive equilibrium, the platform charges a relative markup equal to $1/(\eta_{NE}^B + \eta_{NE}^S)$. Thus, in addition to the elasticity of buyer demand, the platform also takes the elasticity of the number of sellers into account when supply-side network effects are present.

What is the platform's optimal fee level when sellers collude? Unchanged in the presence of seller network effects, colluding sellers charge a price $p^{mon} = v$. Then, due to network effects, both the number of sellers and the number of buyers is reduced to a minimum, which remains unchanged

A.5 Platform Competition

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