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Why Do Platforms Charge Proportional Fees? Commitment and Seller Participation*

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Abstract

This paper deals with trade platforms whose operators not only allow third party sellers to offer their products to consumers, but also offer products themselves. In this context, the platform operator faces a hold-up problem if he uses classical two-part tariffs only as potential competition between the platform operator and sellers reduces platform attractiveness. Since some sellers refuse to join the platform, some products that are not known to the platform operator will not be offered at all.

We find that revenue-based fees lower the platform operator's incentives to compete with sellers, increasing platform attractiveness. Therefore, charging such proportional fees can be profitable, which may explain why several trade platforms indeed charge proportional fees.

Keywords: Intermediation, Platform Tariff, Hold-Up Problem

JEL classification numbers: D40, L14, L81

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1 Introduction

Sellers frequently use marketplaces (or trade platforms) to reach consumers. Before they can offer their products on a particular platform, sellers often have to sink platform-specific investment costs, such as development costs. In turn, a platform operator who wants to attract sellers has to guarantee sellers some return on their investment by leaving them a positive margin on sales. However, as the platform operator easily observes sales and, thus, can identify profitable products, he is tempted to cut out the respective sellers, collecting (parts of) their margins just after they established their products on his platform.[1] This generates a particular hold-up problem for platform operators who can offer products themselves.

For example, Amazon is a retailer and, at the same time, provides a platform for sellers to access their customers – the Amazon Marketplace.[2] Similarly, Apple and Google provide their own applications next to third-party applications in their online stores. Using the language of Hagiu (2007), these intermediaries combine the *merchant mode* and the *platform mode*. Therefore, we call this policy "operating under a *dual mode*": for some products, intermediaries act as classical retailers, buying from suppliers and setting prices (merchant mode), while they also allow external sellers access to consumers on their platform for some fee (platform mode).[3]

Interestingly, Amazon primarily charges proportional fees (a fixed share of the revenue) to sellers who use the Amazon Marketplace.[4] Similarly, Apple and Google charge software providers proportional fees for selling their applications in the AppStore and on Google Play.[5] Likewise, proportional fees are usually included in franchising arrangements, where the franchisor offers the franchisee a business model (platform) to reach consumers.[6]

In these examples, the platform operator (franchisor) is also a potential competitor to sellers (franchisees) as he often can serve demand himself.

In this paper, we analyze a model with a monopoly intermediary who provides a platform and can be a merchant at the same time. The intermediary can do cherry-picking, selling profitable goods himself after observing sellers' offers. However, this potential competition makes the platform less attractive to sellers in the first place. By choosing a

[1] This conflict of interest is highlighted with empirical evidence for the Amazon Marketplace by Cure, Hunold, Kesler, Laitenberger and Larrieu (2022) and is also part of the decision by the European Commission Cases AT.40462 - Amazon Marketplace and AT.40703 - Amazon Buy Box, where, in particular in paragraphs 106 and following, the Commission finds that Amazon used data gathered from the marketplace for its marketing decisions.

[2] According to Amazon's reports, sales by third-party sellers reached 36% of unit sales in 2011, recently this has reached more than 50%.

[3] Operating in both modes has more recently been called "hybrid mode" by Anderson and Bedre-Defolie (2022).

[4] Besides a small membership fee and a fixed per-transaction fee, Amazon charges sellers a proportional fee of about 15% (depending on product category).

[5] Apple and Google charge software developers a proportional fee of 30%.

[6] Cf. e.g. Blair and Lafontaine (2010, p. 62ff.).

platform tariff, the intermediary shapes competition between himself and sellers, trading off his gains from cherry-picking against platform attractiveness.

We focus on the case in which sellers have to sink investment costs before offering a new product on the platform. Sellers are better informed about product demand than the intermediary. Production costs can differ between sellers and the intermediary, i.e., market conditions are ex ante unknown. In this framework, we firstly analyze "classical" two-part tariffs consisting of fixed (membership) fees and per-transaction fees. Secondly, we examine tariffs that include proportional (per-revenue) fees.

While the extant economic literature concerned with the pricing of (two-sided) platforms has focussed on linear and classical two-part tariffs, our analysis departs from this classical approach. In line with the studies of Shy and Wang (2011) and Wang and Wright (2017), we thereby account for the fact that proportional fees are often observed in reality. While Shy and Wang (2011) show that proportional fees mitigate double marginalization problems and Wang and Wright (2017) explain that they can be used as a means of price-discrimination, we find that proportional fees allow the intermediary to commit not to compete with sellers, thereby increasing the attractiveness of the platform.

Focussing on classical two-part tariffs first, we find that the intermediary prefers per-transaction fees over membership fees. In contrast to previous results (e.g. Armstrong, 2006), he is no longer indifferent between both kinds of fees as transaction-based fees create a competitive advantage when the intermediary becomes active as a merchant. Regarding platform attractiveness, we find that an intermediary using classical two-part tariffs enters sellers' markets to undercut their prices whenever he has lower costs. This is to the detriment of the platform's attractiveness to sellers; in particular, if the intermediary is always more efficient than sellers, sellers will be undercut with certainty. Hence, sellers do not join the platform and products are not disclosed. In that case the intermediary would always profit from committing himself not to enter product markets. We find that contracts which include proportional fees allow an intermediary to do so: by increasing the opportunity costs of competition, the use of proportional fees makes it less attractive for an intermediary to compete with sellers as a merchant.

Introducing a dual mode of intermediation into the platform literature, our work sheds light on the different impacts of membership fees, per-transaction fees, and proportional fees on market outcomes. It provides a novel explanation why proportional fees are commonly observed in reality.

Related literature

Our paper is most closely related to the literature on platform pricing/two-sided markets and to the work on an intermediary's choice of the optimal intermediation mode.

To the best of our knowledge, the only studies that directly address the question whether an intermediary should take an active role as a (pure) merchant, buying products himself and reselling them to buyers, or a more passive role as a (pure) platform, enabling other sellers to reach potential buyers, are Hagiu (2007) and Hagiu and Wright (2013). Hagiu (2007) finds that under many circumstances a monopoly intermediary prefers the 'merchant mode' to the 'platform mode'. However, he also identifies several factors that affect the intermediary's choice towards the platform mode, e.g. consumers' demand for variety or asymmetric information about product quality between the intermediary and sellers.[7] Hagiu and Wright (2013) illustrate that an intermediary's decision on which intermediation mode to choose may also be driven by a trade-off between coordinating marketing activities as a merchant (taking into account potential externalities across products) and benefiting from sellers internalizing more precise information on individual demand as a platform.

We extend both analyses by explicitly allowing for endogenous seller pricing when the intermediary can become active as a merchant while offering a platform at the same time.

Similar to our work, Jiang, Jerath and Srinivasan (2011) examine the case of an intermediary who both offers a platform and can serve demand himself (dual mode), crowding out sellers. In their framework, the intermediary has to incur fixed costs to enter a market. Better informed sellers fear that the intermediary serves markets with high demand himself to avoid double marginalization. However, by choosing a low service level, sellers can pretend to offer a product whose demand does not suffice to cover the intermediary's fixed costs. Accordingly, the setting also includes moral hazard. Although proportional fees would tackle both the double marginalization problem and the hold-up problem that arises due to screening, Jiang et al. analyze pure per-unit fees only.

There are several seminal studies on platform pricing/two-sided markets (cf. e.g.[8] Rochet & Tirole, 2006; Armstrong, 2006). that focus on intermediaries featuring the 'platform mode' and analyze tariff choices in presence of (indirect) network effects under various circumstances. Most studies on platform pricing focus on membership fees, per-transaction fees, or two-part tariffs as a combination of both. Furthermore, they usually abstract away explicit payments between the two sides of a market or price setting by sellers. Accordingly, proportional (revenue-based) fees are not discussed.

However, there are several important exceptions who do examine proportional fees. Shy and Wang (2011) analyze a model of a payment card network. They find that profits of the card network are higher under proportional fees than under per-transaction fees as the network faces a double marginalization problem which is mitigated by proportional fees. In their framework, sellers earn lower profits under proportional fees, but consumers are better off and social welfare is higher than under per-transaction fees. Miao (2011) extends the model of Shy and Wang (2011). Allowing for an endogenous number of

[7]Differently from our model, Hagiu assumes that the merchant has to buy products from a seller who would otherwise sell them on the intermediary's platform (at an exogenous price).

[8]Jullien (2012) offers a comprehensive survey on two-sided (B2B) platforms, including a general introduction to two-sided markets.

sellers, he shows that the use of proportional fees results in less seller participation. Consequently, consumer surplus and social welfare may be lower under proportional fees. Wang and Wright (2017) examine the case of an intermediary who facilitates trade of products that differ in both costs and valuations. They illustrate that a combination of a per-transaction fee and a fee which linearly depends on price can achieve the same profit as third-degree price discrimination, even if the intermediary is uninformed about product attributes.

Hagiu (2006) studies commitment of two-sided platforms to a tariff system. In contrast to previous studies (which assume that sellers and buyers take their decisions on joining a platform simultaneously), Hagiu analyzes a sequential time structure: he assumes that all sellers arrive at the platform before the first buyer does. He shows that a platform prefers to commit to the access price charged to buyers instead of setting or adapting it after sellers joined the platform under certain circumstances. Although Hagiu does not mention how commitment could be achieved, he points out that platform commitment is an important issue.

Hagiu (2009) analyzes a platform's tariff decision when sellers compete and consumers value variety. In an extension, he explains that charging variable (proportional) fees can mitigate the aforementioned commitment problem.[9] Belleflamme and Peitz (2010) analyze how intermediation affects manufacturers' investment incentives. In their model, sellers have to invest in innovation *before* the platforms set their prices. They show that sellers my overinvest in setting where platforms compete. Differing from our model, sellers anticipate the platforms' tariff choices, but, due to the suggested timing in the game, platforms cannot affect investment incentives with their tariff choice. Furthermore, the study has a different focus in comparing open platforms (no fees) and for-profit platforms that charge *membership* fees only.

Recently, there has been more interest in the theoretical literature in the conflict of interest between the platform and third-party sellers in the context of the dual mode by Etro (2021), Hagiu, Teh and Wright (2022), and Anderson and Bedre-Defolie (2022). The focus of that literature is on the the regulation of the dual mode. They find mixed results on the welfare effects of the dual mode depending on the wider market structure.

Note that the present article was written in parallel and mostly earlier than that literature and has a different focus on the investment incentives of sellers and the platform's fee structure.

Our work may also be seen as a contribution to the literature on franchising:[10] by

[9]However, note that in Hagiu's framework transaction-based fees can create a commitment not to change the buyer fee if buyers join the platform after sellers, while we find that proportional fees relax (potential) competition between the intermediary and sellers.

[10]Blair and Lafontaine (2010) provide a good introduction into the economics of franchising.

allowing a 'dual mode' of intermediation and analyzing a framework of asymmetric information on demand between sellers (franchisees) and intermediary (franchisor), we provide additional insights into a franchisor's decision on dual distribution/partial vertical integration (cf. e.g. Minkler, 1992; Scott, 1995; Hendrikse & Jiang, 2011) and on the frequent use of sales revenue royalties.

Taken together, we contribute to the economic literature firstly by introducing a "dual mode" of intermediation. Secondly, in contrast to the majority of the extant studies on two-sided markets, we explicitly account for trade between sellers and buyers, allowing for endogenous seller pricing. Thirdly, we show that an intermediary operating under the dual mode is no longer indifferent between membership fees and transaction-based fees. Fourthly, we identify a hold-up problem created by the threat of competition between the intermediary and sellers which impairs platform attractiveness. Finally, we find that platform tariffs that include proportional fees mitigate this problem, in contrast to "classical" two-part tariffs which previous literature focussed on.

Outline

The remainder of the paper is organized as follows: in section 2 we set up a model of a monopoly intermediary who offers a platform to connect sellers and buyers. In section 3 we solve the model for classical two-part tariffs which consist of membership fees and per-transaction fees. In section 4 we discuss existence and conditions of the intermediary's hold-up problem, starting with the decisions a social planer would take. Within section 5 we analyze proportional fees as part of multi-part tariffs. In section 6 we summarize our findings and discuss the results.

2 Framework

We consider a market with a monopoly intermediary who offers sellers a platform to reach potential buyers and, at the same time, can offer products himself.

There is a unit mass of sellers. For being able to list a new product on the marketplace, a seller has to incur fixed investment costs I which are sunk after investment. These costs may be interpreted as costs of developing the respective product, or as general costs of sales preparation (e.g. market research, designing an attractive product illustration, or establishing capacities to ensure immediate supply). They are distributed among sellers according to a uniform distribution function $I \sim U[0,1]$. We assume products offered by different sellers to be completely independent. Hence, there is no competition between sellers. Taken together, there is a continuum of independent product markets which are characterized by their respective investment costs.[11] For selling their products, sellers incur constant marginal costs $c \in (0, r)$, incorporating all per-unit costs except

[11]Note that our framework also covers the situation of a single seller with unknown investment costs if the cumulative distribution of I is interpreted as a probability instead of the share of the mass of sellers having investment costs below I.

for fees charged by the intermediary. In the following, we simply refer to c as (marginal) *production costs*, although c could also represent costs of purchasing the product from some wholesaler, retailing or transaction costs like payment charges, or the expected costs of product failure. To guarantee interior solutions for the participation level of sellers we assume that $r - c \leq 1$, the gross margin does not cover the highest level of investment costs.

We assume that each buyer purchases at most one unit of each product. Buyers' gross utilities from consuming a unit of a good are constant over buyers and products and given by $r > c$. Accordingly, we abstract from double marginalization problems and buyer heterogeneity. Hence, the intermediary's tariff decision is neither driven by the effect of mitigating double marginalization (unlike Shy & Wang, 2011), nor by any price discrimination attempts (unlike Wang & Wright, 2017).[12] The mass of buyers is normalized to one. Buyers' (as well as sellers') outside options are normalized to zero. Hence, not joining the platform yields a zero payoff to either side. As we will assume that buyers do not have to pay a membership fee, it is a dominant strategy for buyers to join the platform.[13] Hence, for each product the demand function is given as[14]

$$D(p) = \begin{cases} 1, & p \leq r \\ 0, & p > r \end{cases} .$$

The intermediary chooses a platform tariff system which can comprise different forms of payments by sellers: a membership fee A, a per-transaction fee a, or a proportional fee. For the latter a fixed share α of seller revenues accrues to the platform. All platform costs are normalized to zero.

Additionally, the intermediary can decide to compete with sellers who joined his platform, becoming active as a *merchant* in the respective product markets. In doing so, he either starts selling the same product, purchasing it from some supplier, or he imitates the product that is offered by a seller. More precisely, each product offered by the merchant is not differentiated from the corresponding seller's product.

We assume that the intermediary cannot offer a product if the respective seller did not join the platform.[15] In particular, this assumption captures the following situation: the intermediary is ex ante uninformed about existence of new products or corresponding demand. In contrast, more specialized sellers are (perfectly) informed about existence of demand for products which they may offer. By joining the intermediary's platform, they disclose information. Thereby, the intermediary can easily learn existence of demand for

[12] Our results would also generalize to cases of heterogenous product categories with varying market sizes or different gross utilities across markets.

[13] We implicitly rule out trivial equilibria in which no buyer and no seller joins.

[14] We assume that the demand structure for new products is common knowledge. This seems reasonable at least within smaller product categories since the intermediary is supposed to be informed about typical market characteristics, but not about existence of specific products. Note that this might be a rationale for Amazon's discriminating practice of charging different fees across well-defined product categories.

[15] This assumption could be interpreted as search cost advantages of sellers, cf. e.g. Minkler (1992).

each specific product as platform operator. We emphasize the role of sellers' demand information as we do not include product markets in our model for which the intermediary is informed about demand.

After sellers joined the intermediary's platform, he observes his constant marginal production costs and may pick profitable products, entering markets.[16] We assume that these marginal costs ζ are drawn from a distribution represented by a differentiable distribution function $H(\zeta)$ with support $[\underline{\zeta}, \overline{\zeta}]$. A draw of ζ captures the intermediary's relative bargaining position towards suppliers or his ability in imitating sellers' products; he may have higher or lower production costs than sellers, i.e., $c \in (\underline{\zeta}, \overline{\zeta})$. We assume that the merchant's marginal costs are determined by one single draw, and, hence, are the same for all products. For entering a market that was disclosed by a seller, the intermediary faces infinitesimally small (but positive) costs $\varepsilon > 0$. This assumption is made for two reasons: firstly, the asymmetry between the intermediary's and merchants' investment costs accounts for the fact that the intermediary becomes informed about important product characteristics without bearing any costs. Once a seller disclosed demand and established her product on the platform, it is much less costly to simply imitate the product. Secondly, positive investment costs solve the tie situation that the intermediary would face if he was indifferent with respect to market entry, i.e., in cases he faces higher production costs than the respective seller, and, hence, is not willing to serve any demand.

As the intermediary attains an (exclusive) information advantage about profitable product markets compared to sellers who are active in other markets, his imitation incentives are much stronger than those ones faced by other sellers. Therefore, we do not allow for sellers imitating each other but focus on potential competition between the intermediary and each individual seller.

Timing

The game has four stages, the timing is given as follows:[17]

1. The intermediary sets the platform tariff.[18]

2. Sellers' investment costs are realized. Sellers & buyers decide on joining the platform.

3. The intermediary learns the existence of each sellers product, the respective production costs are realized. The intermediary decides whether to enter product markets.

[16] Again, we use the term "production costs" as representative for any kind of per-transaction costs.

[17] It may be natural to include another period of sales between the second and third stage. In this period, sellers who joined the platform could be active as monopolists. However, this would not affect any of our results.

[18] We implicitly assume that the tariff is contractible, or, at least, that commitment to a tariff system is feasible. Commitment seems plausible: As the tariff system is publicly observable, a reputation for not changing it can be obtained.

4. In each product market that the intermediary entered he competes with the respective seller in prices; otherwise, sellers take their monopoly pricing decisions.

We assume that the structure of demand as well as all costs, once realized, are common knowledge to sellers and the intermediary. Both sellers and the intermediary are assumed to maximize their expected profits, i.e., they are risk neutral.

In the following, we firstly analyze tariffs that consist of a membership fee and a per-transaction fee charged to sellers. Secondly, we elaborate on the hold-up problem which emerges under those classical two-part tariffs. Finally, we discuss the case of a proportional fee, i.e., revenue sharing between the intermediary and each seller, as a special case of three-part tariffs.

3 Classical two-part tariffs charged to sellers

In this section we consider classical two-part tariffs charged to sellers only. These tariffs combine a membership fee A as fixed transfer and a transaction-based per-unit fee a which increases each seller's perceived marginal costs. We restrict our analysis to non-negative fees: we rule out negative membership fees since they induce a moral hazard problem.[19] Similarly, negative per-transaction fees would create incentives for fictitious transactions.[20]

We solve the game described before by backward induction.

3.1 Stage 4: Product pricing decisions

We firstly look at the pricing decisions in one representative product market that a seller disclosed before. The seller paid the membership fee A up front. Hence, A are sunk costs at this stage. However, the seller pays the per-transaction fee a for each unit sold which increases her marginal costs to $a + c$. We can exclude cases where $a > r - c$ as then this stage would never be reached (zero seller participation).

If the intermediary did not enter the market, the seller is a monopolist, charging a price of

$$p^{mon} = r.$$

In this case, the seller's profit (before investment costs and membership fee) equals $\pi_s^{mon} = r - (c + a)$.

If the intermediary entered the market in stage 3, he and the seller compete à la Bertrand, with asymmetric costs. However, contrary to standard price competition, the intermediary receives a transfer of a for each unit sold by the seller.

[19] With a negative A, sellers would list products they do not want to sell. In our setting the platform operator cannot distinguish good products from worthless ones before they are listed; hence, he would have to pay $|A|$ to the seller indiscriminate of the listing value.

[20] We abstract from the provision of free goodies (which could be interpreted as negative fees).

If the intermediary undercuts the seller[21] by setting a price of

$$p_m^{comp}(a) = c + a,$$

his (merchant) profit from this market equals

$$\pi_m(a) = (c + a) - \zeta.$$

If he does not undercut the seller, the (variable) platform revenue that he receives from the seller equals

$$\pi_p(a) = a.$$

He prefers undercutting the seller if and only if

$$\pi_m(a) > \pi_p(a) \;\Leftrightarrow\; \zeta < c. \tag{1}$$

Hence, if production costs turn out to be below the seller's costs ($\zeta < c$), the intermediary serves demand himself as a merchant.

If $\zeta > c$, the
seller serves the market at a price of

$$p_s^{comp}(a) = \min\{\zeta + a, r\}.$$

The intermediary does not undercut $p_s^{comp}(a)$ by any amount $k > 0$ as he would lose a in platform fees while only gaining merchant profits of $(\zeta + a - k) - \zeta < a$ (assuming that $\zeta + a \leq r$). Charging prices above r is dominated as it results in zero demand. Finally, the case that both are equally efficient ($\zeta = c$) happens with zero probability as the distribution of ζ is atomless.

Lemma 1 (Product pricing under a classical two-part tariff)**.**
Under a classical two part tariff (A, a), if the intermediary did not enter a market, the respective seller is a monopolist, setting a price of r. If the intermediary entered a market and has lower production costs than the seller ($\zeta < c$), he undercuts the seller by setting a price of $c + a$. If he faces higher production costs ($\zeta > c$), the seller serves demand at a price of $\min\{\zeta + a, r\}$*.*

Note that competitive prices increase in the per-transaction fee as the increase in seller's perceived marginal costs relaxes competition.

3.2 Stage 3: Intermediary's entry decision

In stage 3, the intermediary decides on entering markets that sellers disclosed by joining the platform, anticipating the pricing decisions just discussed.

[21] As is standard in the literature on Bertrand competition, we rule out prices below marginal costs (which would lead to "implausible" equilibria of the pricing game) because they are not limits of undominated strategies in discrete approximations of the strategy space.

The intermediary decides on entry contingent on his production costs. He enters markets only if he serves demand, which is the case when he has lower production costs ($\zeta < c$), as then his merchant profit exceeds his foregone platform revenues, cf. condition (1).

If he entered without serving demand, he would lose exactly his entry costs $\varepsilon > 0$, without any gains.

Lemma 2 (Intermediary's entry decision under classical two-part tariffs). *Under a classical two-part tariff (A, a), the intermediary enters product markets if and only if his production costs are lower than sellers' costs ($\zeta < c$).*

Note that neither the fixed membership fee nor the per-transaction fee affects the intermediary's entry decision. This is intuitive for the membership fee, but more surprising for the per-transaction fee. The latter increases the platform revenue by a per unit. However, it also increases the competitive price and thus the merchant profit by a per unit. Hence, the per-transaction fee a does not affect the intermediary's trade-off between platform revenue and merchant profit.

3.3 Stage 2: Decisions on joining the platform

In stage 2, sellers and buyers simultaneously decide whether to join the platform.

Recall that for buyers joining is a dominant strategy. Hence, all buyers join the platform.[22] Sellers join the platform if they expect to be able to at least recoup their investment costs I.

As argued before, each seller will be a monopolist in her respective product market if $\zeta > c$, but will be undercut if $\zeta < c$. Hence, each seller's expected profit from joining the platform under a two-part tariff (A, a) is given by

$$\pi_s^e(A, a, I) = Pr(\zeta > c) \cdot \{r - (c + a)\} - I - A,$$

where $Pr(\zeta > c) = 1 - H(c)$ represents the probability that the intermediary does not enter as he is less efficient. Defining the critical level of investment costs

$$\widetilde{I}(A, a) \equiv \{1 - H(c)\} \cdot \{r - (c + a)\} - A, \tag{2}$$

we achieve the following result:

Lemma 3 (Decisions on joining the platform under classical two-part tariffs). *Under a classical two-part tariff (A, a), all buyers join the platform. Sellers join if their investment costs are below $\widetilde{I}(A, a)$ as defined in (2). The mass of sellers joining the platform equals $\widetilde{I}(A, a))$ and is decreases in both A and a.*

[22] Note that the joining decision would still be homogeneous if buyers had to pay fees as there is no buyer heterogeneity and, hence, each buyer faces the same trade-off. Consequently, there is either zero or full buyer participation, and zero participation can never occur in equilibrium as the intermediary could increase his profit by lowering fees.

Seller participation decreases in the membership fee A and in the per-transaction fee a as both fees decrease seller rents which lowers the maximum level of investment costs that sellers can cover without expecting a negative surplus from joining the platform.

We elaborate on the hold-up problem that evolves from the threat of entry (captured by the probability $1-H(c)$) in more detail within the next section. Beforehand, we solve the model under two-part tariffs, analyzing the intermediary's tariff decision in the first stage.

3.4 Stage 1: Optimal classical two-part tariff

In stage 1 the intermediary sets the membership fee A and the per-transaction fee a.

Recall that under any two-part tariff (A, a) the intermediary will enter product markets as merchant if and only if he has lower production costs than sellers. The respective probability for ζ being below c is given by $H(c)$. Therefore, for each product listed on the marketplace, the intermediary's expected platform profit equals

$$\pi_p^e(A, a) = A + (1 - H(c)) \cdot a, \tag{3}$$

and his expected per-product merchant profit (which is independent of the membership fee A) is given by

$$\pi_m^e(a) = H(c) \cdot \{c + a - E[\zeta|\zeta < c]\}. \tag{4}$$

His expected overall profit is given by the sum of his platform profit $\pi_p^e(A, a)$ and his merchant profit $\pi_m^e(a)$, times the mass of sellers who joined the platform:

$$\Pi^e(A, a) = \widetilde{I}(A, a) \cdot \{\pi_p^e(A, a) + \pi_m^e(a)\}. \tag{5}$$

We observe that if we define the merchant's expected realized cost advantage as

$$\Delta^e(c) \equiv H(c) \cdot \left(c - \frac{1}{H(c)} \int_{\underline{\zeta}}^{c} x dH(x)\right), \tag{6}$$

we can rewrite the intermediary's expected overall profit (5), inserting (3) and (4), as

$$\Pi^e(A, a) = \widetilde{I}(A, a) \cdot \{A + (a + \Delta^e(c))\}. \tag{7}$$

While the first factor, $\widetilde{I}(A, a)$, is decreasing in A and a (cf. Lemma 3), the second factor, i.e., the intermediary's expected profit per market, is increasing in both fees. Solving the intermediary's first order condition for a yields:

$$a^* = \max\left(\frac{r - c - \Delta^e(c)}{2}, 0\right). \tag{8}$$

Proposition 4 (Optimal classical two-part tariff).
The optimal two-part tariff consists of a zero membership fee and a positive per-transaction fee a^*, as defined in (8). The intermediaries equilibrium profit is given by

$$\Pi^e(a^*) = \begin{cases} (1 - H(c))\frac{1}{4}(r - c + \Delta^e)^2, & \Delta^e < r - c \\ (1 - H(c))(r - c)\Delta^e, & \Delta^e \geq r - c \end{cases} \tag{9}$$

Proof. See appendix, p. 21. □

The intuition why the intermediary prefers the per-transaction fee to the membership fee is the following: Starting from any combination of a membership fee and a per-transaction fee that generates the same platform revenue (and the same seller participation), increasing the per-transaction fee increases the expected merchant profit $\pi_m^e(\cdot)$ by creating by raising the competitive price. Note that it can be optimal for the intermediary to charge no fees, i.e. $(A, a) = (0, 0)$. This is the case if $r - c$ is low compared to $\Delta^e(c)$. In that case the intermediary prefers not to charge sellers in order to make more profits on those products sold by the intermediary with a cost advantage, due to larger seller participation.

4 Hold-up problem and commitment

In this section we provide a result showing that with two-part tariffs a hold-up problem always exist. The intermediary offers too many products himself which reduces the incentives for sellers to join the platform. We also define and discuss *full* and *partial commitment*.

First, let us illustrate the hold up problem, by showing that the intermediary would always profit if he were able to commit to his entry threshold, measured in his costs ζ. We call this commitment partial commitment, i.e. committing only to enter if the cost advantage $c - \zeta$ is strictly positive. While committing directly to an entry threshold is not realistic, it provides for a clear benchmark. In the next section, we show that proportional fees imply and indirect commitment to such a threshold.

Proposition 5 (Profitability of commitment to less entry).
Under any classical two-part tariff (A, a), the intermediary benefits from committing not to enter with costs above a threshold $\hat{\zeta} < c$.

Proof. See appendix, p. 21. □

The reason, why it is always profitable to marginally lower the entry threshold, is that at the margin the intermediary has no cost advantage and thus no loss, but increases seller participation.

With classical two-part tariffs, the intermediary therefore faces a hold-up problem: he would like to commit to enter markets in less cases. However, as he decides on entry when sellers have already joined the platform, he will enter markets whenever he is more efficient (see Lemma 5). Hence, we arrive at the following result:

Corollary 6 (Intermediary's hold-up problem under classical two-part tariffs).
Under any two-part tariff consisting of a membership fee and a per-transaction fee, the intermediary faces a hold-up problem: his excessive entry behavior leads to insufficient

seller investment incentives as well as poor seller participation and impedes him to open up all profitable product markets.

In some cases the intermediary would even profit from a commitment never to enter, which we call *full commitment*. One form of full commitment can be achieved by being a platform only. E-Bay, for example, seems to have committed to the platform only business model. Full commitment is profitable, if the expected foregone profit of not entering is small. To compare the platform only profit to the profit under the dual mode, we substitute the optimal fees (8) into the profit function of the intermediary (7). Under the pure platform mode $H(c)$ and Δ^e are zero, which gives the LHS of the following inequality, while the LHS is the profit under the dual mode.

$$\left(\frac{r-c}{2}\right)^2 > (1-H(c))\left(\frac{r-c+\Delta^e}{2}\right)^2. \tag{10}$$

Inspecting the above inequality gives us:

Proposition 7.
The intermediary profits from full commitment under two-part tariffs, if inequality (10) holds.

Intuitively, full commitment is profitable, if it is likely for the intermediary to have lower costs, but the expected cost advantage is small.

However, the intermediary would often prefer to enter markets only if he is much more efficient, while committing not to enter only when his cost advantage is small.

5 Proportional fees mitigate the hold-up problem

We have shown that for any classical two-part tariff the intermediary always enters a seller's market when he has lower marginal costs than the seller.

Nevertheless, we have argued that an intermediary using only classical two-part tariffs would profit if he committed not to compete with sellers in cases he is more efficient. However, we have not explained *how* an intermediary could achieve such commitment – in fact committing not to compete seems to be hard to achieve (i) in a credible way and (ii) by legal means.[23]

We now consider an intermediary using proportional fees, i.e., tariffs that comprise revenue sharing where the intermediary earns a fraction α of the revenues that sellers realize on his platform. We find that proportional fees allow the intermediary to credibly commit not to compete with sellers even in cases he has lower marginal costs. Therefore, proportional fees help the intermediary to attract more sellers, mitigating the hold-up

[23] Note that platforms like Amazon often already have a reputation for acting under the dual mode, i.e., competing with sellers in a variety of existing product markets. Therefore, credible commitment on *not* competing might not be feasible. Furthermore, an announcement not to compete with other sellers may be interpreted as a horizontal collusive agreement.

problem. Furthermore, we show that even if full commitment not to compete with sellers could be achieved without using proportional fees, the intermediary would prefer not to use this option under certain circumstances, while the introduction of a proportional fee is profitable to him.

In the following, we analyze three-part tariffs as combinations of classical two-part tariffs and proportional fees. We again proceed by backward induction. The key insight regarding the intermediary's entry behavior (which is decisive for the hold-up problem) will be given in the second subsection (analysis of third stage). Furthermore, we identify conditions under which the inclusion of an additional proportional fee improves the optimal classical two-part tariff. This gives an explanation for the use of proportional fees by platforms and similar businesses.

5.1 Stage 4: Product pricing decisions under a three-part tariff

Along the lines of the analysis under classical two-part tariffs, we have to consider two cases to determine price setting within a (representative) product market that a seller disclosed under a three-part tariff (A, a, α).

If the intermediary did not enter the market, the seller is a monopolist and earns a profit (before investment costs and membership fee) of $\{(1-\alpha)\cdot r-(c+a)\}$ by setting a price of

$$p^{mon} = r.$$

If the intermediary entered the market as merchant, he competes with the seller in Bertrand fashion. Nevertheless, he might prefer not to serve any demand, even if he earned a positive margin by undercutting the seller, as he would lose the transfer $a+\alpha p$ that he earns for each transaction conducted by the seller at a price of p.

As before, once entered the market, the intermediary still prefers to serve demand whenever he has lower costs than the seller. This can be seen as follows: at any price p chosen by the seller, the intermediary is tempted to undercut the seller if his merchant profit $M\cdot(p-\zeta)$ exceeds his variable platform profit $M\cdot(a+\alpha\cdot p)$. Accordingly, serving demand himself at a given price p is more profitable than acting as platform operator if

$$p-\zeta > a+\alpha p \;\Leftrightarrow\; p > \frac{\zeta+a}{1-\alpha}.$$

As the lowest price the seller can offer without obtaining a negative margin equals $\frac{c+a}{1-\alpha}$, the intermediary indeed prefers to undercut the seller by charging a price of

$$p_m^{comp}(a,\alpha) = \frac{c+a}{1-\alpha}$$

if $\zeta < c$. Then, the intermediary achieves a profit of $M\cdot\left(\frac{c+a}{1-\alpha}-\zeta\right)$.[24]

If the merchant faces higher production costs than the seller ($\zeta \geq c$), the seller serves demand at a price of

$$p_s^{comp}(a,\alpha) = \min\left\{\frac{\zeta+a}{1-\alpha}, r\right\}.$$

[24]Again, our analysis excludes cases where $\frac{c+a}{1-\alpha} > r$ as these cannot occur (no seller participation).

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We summarize our findings in the following result:

Lemma 8 (Pricing decisions under a three-part tariff).
Under a three-part tariff (A, a, α)*, if the intermediary did not enter, the seller serves demand at a price equal to* r*. If the intermediary entered the product market as merchant, he serves demand at a price of* $\frac{c+a}{1-\alpha}$ *if and only if he has lower costs than sellers* ($\zeta < c$)*; otherwise* ($\zeta \geq c$)*, the seller serves demand at a price of* $\min\left\{\frac{\zeta+a}{1-\alpha}, r\right\}$.

Both the per-transaction fee a and the proportional fee α increase competitive prices.

5.2 Stage 3: Intermediary's entry decision under a three-part tariff

After the intermediary's production costs have been realized, he decides on entering product markets. If he faces higher production costs than a (representative) seller ($\zeta \geq c$), he does not enter the market, anticipating the decisions in stage 4: if he entered, he would not serve any demand, but incur entry costs $\varepsilon > 0$. Furthermore, entry would drive down the seller's price by $r - \frac{\zeta+a}{1-\alpha}$. Hence, if the intermediary's tariff includes a positive proportional fee α, the intermediary in addition loses parts of his platform profit by entering the market, even though he does not serve any demand.

The latter logic also applies to the case when the intermediary's production costs turn out to be below the seller's costs: if the intermediary charges a proportional fee, he incurs a direct loss from the reduction in prices which is induced by his market entry. Therefore, the intermediary prefers not to enter even if he has a (small) cost advantage. This can be formalized as follows: the intermediary prefers entry if his merchant profit from undercutting the seller,

$$\pi_m(a, \alpha) = p_m^{comp}(a, \alpha) - \zeta,$$

exceeds his variable platform profit

$$\pi_p(a, \alpha) = a + \alpha \cdot p^{mon};$$

this is the case if

$$\pi_m(a, \alpha) > \pi_p(a, \alpha) \;\Leftrightarrow\; \zeta < \frac{c+a}{1-\alpha} - \alpha \cdot r - a \equiv \widetilde{\zeta}(a, \alpha). \tag{11}$$

The critical threshold $\widetilde{\zeta}(a, \alpha)$ of merchant's production costs generally differs from the seller's marginal costs c. Differently from the analysis under classical two-part tariffs, his entry decision now depends on the difference of production costs, the level of production costs, and the transaction-based tariff components a and α.

Lemma 9 (Intermediary's entry decision under a three-part tariff).
Under a three-part tariff (A, a, α)*, the intermediary enters product markets if and only if* $\zeta < \widetilde{\zeta}(a, \alpha)$.

For a more intuitive illustration of the intermediary's tradeoff, we define $\Delta c \equiv c - \zeta$ as the merchant's cost advantage. Then, we have $\pi_m(a, \alpha) = \Delta c + a + \alpha \cdot \left(\frac{c+a}{1-\alpha}\right)$, and condition (11) for entry being profitable can be written as

$$\Delta c > \alpha \cdot \left(r - \frac{c+a}{1-\alpha}\right). \tag{12}$$

This inequality exactly corresponds to the reasoning that we made above: if the intermediary enters the market, he incurs a loss from the price reduction caused by competition which is captured by the right-hand side. He only enters if this loss is overcompensated by his cost advantage Δc.

Taking a closer look at the right-hand side of inequality (12), we can state the following result:

Proposition 10 (Intermediary's entry decision under a three-part tariff)**.**
Under any three-part tariff that yields positive seller participation and comprises a proportional fee $\alpha > 0$, the intermediary only enters product markets if his cost advantage exceeds a strictly positive threshold, i.e., $c - \widetilde{\zeta}(a, \alpha) > 0$.

Proof. See appendix, p. 22. □

Accordingly, under three-part tariffs that include a positive proportional fee, the intermediary always enters in fewer cases than under any classical two-part tariff. The use of proportional fees creates a credible commitment not to enter product markets for cost advantages $\Delta c < c - \widetilde{\zeta}(a, \alpha)$, and, therefore, mitigates the hold-up problem by reducing the threat of competition.

5.3 Stage 2: Sellers' joining decisions under a three-part tariff

Given the critical level of merchant's production costs $\widetilde{\zeta}(a, \alpha)$, a seller's expected profit from joining the intermediary's platform can be written as

$$\pi_s^e(A, a, \alpha, I) = Pr(\zeta \geq \widetilde{\zeta}(a, \alpha)) \cdot \{(1-\alpha) \cdot r - c - a\} - A - I,$$

where $Pr(\zeta \geq \widetilde{\zeta}(a, \alpha))$ denotes the probability of the intermediary not entering the respective product market, which equals $1 - H(\widetilde{\zeta}(a, \alpha))$. A seller joins the platform if her expected profit $\pi_s^e(A, a, \alpha, I)$ is positive, i.e., if her investment costs are below the critical level

$$\widetilde{I}(A, a, \alpha) \equiv \{1 - H(\widetilde{\zeta}(a, \alpha))\} \cdot \{(1-\alpha) \cdot r - c - a\} - A. \tag{13}$$

Interestingly, while $\widetilde{I}(A, a, \alpha)$ is strictly decreasing in both A and a, it is increasing in the proportional fee α under certain conditions. For $\alpha = 0$, i.e., classical two-part tariffs, seller participation increases in α if and only if

$$\frac{h(c)}{1 - H(c)} \cdot (r - c - a) > \frac{r}{r - c - a}.\text{[25]} \tag{14}$$

[25] The condition for $\frac{\partial \widetilde{I}}{\partial \alpha}$ being positive in case of $\alpha \neq 0$ can be found in the remark on Lemma 11, cf. p. 22.

While all tariff components, i.e., A, a, and α, strictly reduce sellers' margins from selling their products, the proportional fee α in addition reduces the intermediary's entry incentives, and, in turn, makes sellers more likely to sell their products themselves.

The results are summarized in the following lemma:

Lemma 11 (Sellers' decision to join the platform under a three-part tariff)**.** *Under a three-part tariff (A, a, α), the mass of sellers that join the platform equals $\widetilde{I}(A, a, \alpha)$. It decreases in A and a, but the effect of a change in α is ambiguous.*

Note that the intermediary's platform profit is increasing in α if seller participation increases in α. Furthermore, the increase in platform profits under condition (14) overcompensates the reduction of merchant profits, and introducing a proportional fee is profitable to the intermediary, cf. our analysis below.

5.4 Stage 1: Intermediary's decision on proportional fees

Given the results derived before, the intermediary's expected per-product platform profit under a three-part tariff (A, a, α) equals

$$\pi_p^e(A, a, \alpha) = A + M \cdot \{1 - H(\widetilde{\zeta}(a, \alpha))\} \cdot (a + \alpha \cdot r), \tag{15}$$

and his expected per-product merchant profit is given by

$$\pi_m^e(a, \alpha) = H(\widetilde{\zeta}(a, \alpha)) \cdot \left\{ \frac{c + a}{1 - \alpha} - E[\zeta | \zeta < \widetilde{\zeta}(a, \alpha)] \right\}. \tag{16}$$

His expected overall profit equals the sum of his platform profit $\pi_p^e(A, a, \alpha)$ and his merchant profit $\pi_m^e(a, \alpha)$, multiplied by the mass of sellers who joined the platform:

$$\Pi^e(A, a, \alpha) = \widetilde{I}(A, a, \alpha) \cdot \{\pi_p^e(A, a, \alpha) + \pi_m^e(a, \alpha)\}. \tag{17}$$

Substituting (15) and (16) into (17) leads to

$$\Pi^e(A, a, \alpha) = \widetilde{I}(A, a, \alpha) \cdot \left\{ A + \left[a + \alpha \cdot r + \Delta^e\left(\widetilde{\zeta}(a, \alpha)\right) \right] \right\}, \tag{18}$$

where

$$\Delta^e\left(\widetilde{\zeta}(a, \alpha)\right) = H(\widetilde{\zeta}(a, \alpha)) \cdot \widetilde{\zeta}(a, \alpha) - \int_{\underline{\zeta}}^{\widetilde{\zeta}(a,\alpha)} x dH(x)$$

as defined in (6).[26] Evaluating the partial derivative of the intermediary's profit $\Pi^e(A, a, \alpha)$ with respect to α at the optimal two-part tariff leads to the following result:

Proposition 12 (Proportional fees improve optimal classical two-part tariff)**.** *The inclusion of an additional positive proportional fee improves the optimal classical two-part tariff $(0, a^*)$ if*

$$\frac{r - c + \Delta^e(c)}{2} > \frac{H(c)(1 - H(c))}{h(c)}. \tag{19}$$

[26] Note that $\Delta^e(x)$ can only be interpreted as the merchant's expected cost advantage if $x = c$.

Proof. See appendix, p. 23. □

Introducing a proportional fee is profitable, if (new) markets are sufficiently profitable, i.e., $r - c + \Delta^e(c)$ is large enough, and reducing the entry threshold opens up sufficiently many new markets, $h(c)$ is large enough. Hence, if the H is such that it is very likely for the intermediary to only have a small cost advantage (H has a low variance or is very dense around c) then it is usually profitable to forego the merchant profit and commit to not entering, thereby providing additional incentives to to join the platform.

Most likely the intermediary can choose his tariff system, and if revenue can be contracted on use proportional fees. This gives him partial commitment and is often profitable.[27] Alternatively, the intermediary may be able to fully commit not to enter. In that case proportional tariffs are not necessary as two part tariffs are already profit maximizing. We can show that there are cases in which the use of proportional fees yields higher profits than full commitment. To illustrate this consider the following case, full commitment is not profitable, while the use of proportional fees is, i.e. condition (10) does not hold, while (19) holds:

$$\left(\frac{r-c}{2}\right)^2 < (1 - H(c))\left(\frac{r-c+\Delta^e}{2}\right)^2, \tag{20}$$

$$\frac{r-c+\Delta^e(c)}{2} > \frac{H(c)(1-H(c))}{h(c)} \tag{21}$$

Clearly, both inequalities can be met if $h(c)$ is large enough and at the same time $\Delta^e(c)$ is also not to small. Intuitively. in such cases the partial commitment provided by proportional fees is particularly profitable if $h(c)$ is large, as then partial commitment strongly decreases the likelihood to compete with sellers, at the same time Δ^e the expected cost advantage could still be large. On the contrary if Δ^e is small than full commitment has low opportunity costs. In summary:

Proposition 13.
If full commitment is possible, it can still be more profitable not to fully commit, but to use proportional fees.

6 Conclusion

While real world platforms use a mixture of tariff forms, including proportional (per-revenue) fees, the great majority of the economic literature on platform markets has focussed on membership fees and per-transaction fees. The extant studies on proportional platform fees highlight the reduction of the double marginalization problem and the ability to price discriminate by using a proportional fee. Analyzing a dual mode of

[27]Note that we constructed the model such that the only benefit of proportional fees is commitment, in case of double marginalization or price discrimination there are additional benefits.

intermediation, we identify the effects of the intermediary's tariff system on competition between sellers and the intermediary and on sellers' investment incentives.

Firstly, we identify a *competition-relaxing effect* of transaction-based fees. Abstracting from double marginalization, the intermediary strictly prefers transaction-based fees to membership fees. The reason is that transaction-based fees increase sellers' marginal costs and, thus, increase prices in case the intermediary competes with a seller. This effect does not occur for a pure platform, and, hence, the operator of a pure platform is indifferent between membership-based and transaction-based tariffs (in line with Armstrong, 2006).[28]

If sellers have to sink costs before joining the platform, the threat of competition leads to a hold-up problem: profitable product markets remain unexplored. Sellers' investment incentives are insufficient as sellers do not internalize the profits that the intermediary achieves due to their product. Therefore, the intermediary would like to commit not to compete, forgoing (parts of) his merchant profits to increase investment incentives.

However, even if credible commitment never to enter sellers' markets was feasible, it would not always be profitable. The intermediary would prefer to commit not to enter if his cost advantage is small, but he wants to exercise his merchant option in case of a large cost advantage.[29] We show that proportional (revenue-based) fees can achieve this partial commitment as they change the intermediary's opportunity costs of competition. In particular, the *commitment effect* of proportional fees is such that the intermediary only enters product markets if his cost advantage exceeds a strictly positive threshold. In contrast, under classical two-part tariffs, the intermediary enters if and only if he faces lower production costs than sellers. The reason is that the level of the per-transaction fee does not affect the intermediary's incentives to enter as a change in this platform fee results in an equal change of sellers' perceived costs, affecting merchant profits to the same extent as platform profits.

However, the commitment effect of proportional fees comes at the cost of foregoing cost advantages and a potential reduction of the competitive price. Although proportional fees mitigate the hold-up problem, their profitability depends on the distribution of the intermediary's costs relative to the sellers' costs. If the probability of the intermediary facing costs slightly below sellers' costs c is large, the introduction of a small proportional fee is always profitable as it significantly reduces the hold-up problem.[30]

Our analysis sheds light on the economics of intermediated markets, in particular markets in which the intermediary does not only organize a marketplace, but can become active in it himself. In addition, the effects we identify could also play a role in the context of franchising and licensing.

[28] The canonical two-sided market models like Armstrong (2006) abstract from price-setting by sellers and, thereby, also abstract from double marginalization problems.

[29] As the intermediary's costs are rarely verifiable, such behavior seems not to be contractible directly.

[30] Furthermore, if the intermediary's maximal cost advantage is relatively small, the intermediary can achieve credible commitment *never* to enter sellers' markets by charging a proportional fee that implies that the entry threshold $\widetilde{\zeta}(\cdot)$ equals $\underline{\zeta}$.

Appendix: Proofs

Proof of Proposition 4

Recall that the intermediary's expected overall profit under a two-part tariff (A, a) can be written as

$$\Pi^e(A, a) = \widetilde{I}(A, a)\{A + a + \Delta^e(c)\}, \tag{22}$$

with $\Delta^e(c)$ being independent of both A and a.

We show that it is always more profitable to charge a higher per-transaction fee instead of a membership fee: a 'compensated' increase in the per-transaction fee a which does not affect seller participation leads to an increase in the intermediary's per-product profit. Starting from an arbitrary tariff scheme (A, a) with $A > 0$, we firstly determine how to adapt the membership fee A such that the critical level of investment costs $\widetilde{I}(A, a)$ remains constant while changing a. Secondly, given this compensation, we show that the effect of a change in the per-transaction fee a overcompensates the effect of the corresponding adaption of the membership fee A.

(i) Given the definition

$$\widetilde{I}(A, a) \equiv \{1 - H(c)\}\{r - (a + c)\} - A$$

from Lemma 3, we have $\frac{\partial \widetilde{I}(A,a)}{\partial A} = -1$. By implicit function theorem it follows that the compensation $A(a)$ has to fulfill $\frac{\partial A(a)}{\partial a} = -\frac{\partial \widetilde{I}/\partial a}{\partial \widetilde{I}/\partial A} = \frac{\partial \widetilde{I}(A,a)}{\partial a}$. Substituting $\frac{\partial \widetilde{I}}{\partial a}$ yields $\frac{\partial A(a)}{\partial a} = -(1 - H(c))$.

(ii) Define $\pi(A, a) \equiv A + a + \Delta^e(c)$. Then, we obtain $\frac{\partial \pi}{\partial A} = \frac{\partial \pi}{\partial a} = 1$. Substituting these derivatives and $\frac{\partial A(a)}{\partial a}$ into the definition of the total differential

$$d\pi = \frac{\partial \pi}{\partial A} dA + \frac{\partial \pi}{\partial a} da$$

leads to $\frac{d\pi}{da} = H(c) > 0$, and the loss from a decrease in A is overcompensated by the corresponding increase in a as the latter creates an additional advantage for the merchant in case of competition (that occurs with probability $H(c)$).

Now, we can focus on pure per-transaction fee tariffs as the optimal membership fee is zero. Differentiating equation (7) with respect to a and plugging in $A = 0$ yields the first order condition

$$\frac{\partial \Pi^e(0, a)}{\partial a} = \widetilde{I}(0, a) - \cdot\{1 - H(c)\} \cdot (a^* + \Delta^e(c)) = 0.$$

Solving this for a^* yields (8).

Note that $\Pi^e(0, a)$ is strictly concave in a. Hence, the first order condition is sufficient for a maximum.

Proof of Proposition 5

The intermediary's expected overall profit under commitment not to enter with production costs above $\hat{\zeta}$ is given as follows:

$$\widehat{\Pi}^e(A,a,\hat{\zeta}) = \begin{cases} \hat{I}(A,a,\hat{\zeta}) \cdot \{A + (a + \Delta^e(c,\hat{\zeta}))\}, & \hat{\zeta} \leq c \\ \hat{I}(A,a,\hat{\zeta}) \cdot \{A + (a + \Delta^e(c,c))\}, & \hat{\zeta} > c \end{cases}, \tag{23}$$

where

$$\hat{I}(A,a,\hat{\zeta}) = \{1 - H(\hat{\zeta})\} \cdot (r - (c+a)) - A,$$

and

$$\Delta^e(c,\hat{\zeta}) \equiv H(\hat{\zeta}) \cdot c - \int_{\underline{\zeta}}^{\hat{\zeta}} x dH(x).$$

Firstly, note that $\hat{\zeta} > c$ are dominated by $\hat{\zeta} = c$. This can be seen as follows: if $\hat{\zeta} > c$, $\hat{\zeta}$ affects the intermediary's profit only through the change in seller participation captured by $F(\cdot)$ because it is never profitable for the intermediary to enter with costs $\zeta \in (c, \hat{\zeta})$ (i.e., $\Delta^e(c,c)$ does not depend on $\hat{\zeta}$). For any $\hat{\zeta} > c$, $\hat{I}(A,a,c) > \hat{I}(A,a,\hat{\zeta})$ holds.

Differentiating $\widehat{\Pi}^e(A,a,\hat{\zeta})$ from below c yields

$$\left.\frac{\partial \widehat{\Pi}^e(A,a,\hat{\zeta})}{\partial \hat{\zeta}}\right|_{\hat{\zeta} \leq c} = \{-h(\hat{\zeta}) \cdot M \cdot (r - (c+a)\} \cdot \{A + M \cdot (a + \Delta^e(c,\hat{\zeta}))\} + \hat{I}(A,a,\hat{\zeta}) \cdot \{h(\hat{\zeta}) \cdot (c - \hat{\zeta})\}.$$

For $\hat{\zeta} = c$, the first term is negative, while the second term equals zero. Hence,

$$\left.\frac{\partial \widehat{\Pi}^e(A,a,\hat{\zeta})}{\partial \hat{\zeta}}\right|_{\hat{\zeta} = c} < 0,$$

and $c > \arg\max_{\hat{\zeta}} \widehat{\Pi}^e(A,a,\hat{\zeta})$.

Proof of Proposition 10

The condition $\widetilde{\zeta}(a,\alpha) < c$ is equivalent to $\frac{c+a}{1-\alpha} - \alpha r - a < c$, which can also be written as $c - (1-\alpha) \cdot \alpha \cdot r + \alpha \cdot a < (1-\alpha) \cdot c$, or $\alpha \cdot (c+a) < (1-\alpha) \cdot \alpha \cdot r$. Division by $\alpha > 0$ yields $c + a < (1-\alpha) \cdot r$, a necessary condition for positive seller participation.

Proof of Lemma 11

Equation (13) defines the critical level of investment costs under a three-part tariff as

$$\widetilde{I}(A,a,\alpha) \equiv \{1 - H(\widetilde{\zeta}(a,\alpha))\} \cdot M \cdot \{(1-\alpha) \cdot r - c - a\} - A.$$

Since $\widetilde{\zeta}(a,\alpha) \equiv \frac{c+a}{1-\alpha} - \alpha r - a = \frac{c}{1-\alpha} - \alpha r + \frac{\alpha}{1-\alpha} \cdot a$, $\widetilde{I}$ clearly decreases in A and a. Furthermore, we have

$$\frac{\partial \widetilde{I}(A,a,\alpha)}{\partial \alpha} = -M \cdot \left\{ \underbrace{(1 - H(\widetilde{\zeta}(a,\alpha)))r}_{\text{change of revenue share}} - \underbrace{h(\widetilde{\zeta}(a,\alpha)) \left(r - \frac{c+a}{(1-\alpha)^2} \right) \{(1-\alpha)r - (c+a)\}}_{\text{change of entry incentives}} \right\}.$$

This expression is positive if and only if

$$(1 - H(\widetilde{\zeta})) \cdot r < h(\widetilde{\zeta}) \cdot \left(r - \frac{c+a}{(1-\alpha)^2} \right) \cdot \{(1-\alpha) \cdot r - (c+a)\}.$$

Proof of Proposition 12

Firstly, we consider the merchant's expected cost advantage. We observe

$$\begin{aligned}\frac{\partial \Delta^e(\widetilde{\zeta}(a,\alpha))}{\partial \alpha} &= h(\widetilde{\zeta}(a,\alpha)) \cdot \frac{\partial \widetilde{\zeta}(a,\alpha)}{\partial \alpha} \cdot \widetilde{\zeta}(a,\alpha) + H(\widetilde{\zeta}(a,\alpha)) \cdot \frac{\partial \widetilde{\zeta}(a,\alpha)}{\partial \alpha} \\ &\quad - \left[\widetilde{\zeta}(a,\alpha) \cdot h(\widetilde{\zeta}(a,\alpha)) \cdot \frac{\partial \widetilde{\zeta}(a,\alpha)}{\partial \alpha} \right],\end{aligned}$$

where the last term in brackets follows from the Leibniz integral rule. As the first and the last term cancel out, this simplifies to

$$\frac{\partial \Delta^e(\widetilde{\zeta}(a,\alpha))}{\partial \alpha} = H(\widetilde{\zeta}(a,\alpha)) \cdot \frac{\partial \widetilde{\zeta}(a,\alpha)}{\partial \alpha} = H(\widetilde{\zeta}(a,\alpha)) \cdot \left(\frac{c+a}{(1-\alpha)^2} - r \right).$$

Hence, the derivative of the intermediary's expected profit (18) is given by

$$\begin{aligned}\frac{\partial \Pi^e(A,a,\alpha)}{\partial \alpha} &= \widetilde{I}(A,a,\alpha) \cdot \left[r + H(\widetilde{\zeta}(a,\alpha)) \left(\frac{c+a}{(1-\alpha)^2} - r \right) \right] \\ &\quad + \left(\frac{\partial \widetilde{I}(A,a,\alpha)}{\partial \alpha} \right) \cdot \left\{ A + \left[a + \alpha r + \Delta^e \left(\widetilde{\zeta}(a,\alpha) \right) \right] \right\},\end{aligned}$$

with $\frac{\partial \widetilde{I}(A,a,\alpha)}{\partial \alpha}$ as given in the proof of Lemma 11.

Defining

$$\pi(A,a,\alpha) \equiv \left\{ A + \left[a + \alpha r + \Delta^e \left(\widetilde{\zeta}(a,\alpha) \right) \right] \right\},$$

we find that $\frac{\partial \Pi^e(A,a,\alpha)}{\partial \alpha}$ is positive if and only if

$$\widetilde{I}(A,a,\alpha) > \pi(A,a,\alpha) \frac{(1 - H(\widetilde{\zeta}(a,\alpha)))r + h(\widetilde{\zeta}(a,\alpha)) \left(\frac{c+a}{(1-\alpha)^2} - r \right) \{(1-\alpha)r - c - a\}}{r + H(\widetilde{\zeta}(a,\alpha)) \left(\frac{c+a}{(1-\alpha)^2} - r \right)}.$$

From Proposition 4, we know that the optimal per-transaction fee in case of $\alpha = 0$ is defined by

$$\{1 - H(c)\} \cdot \{\underbrace{(a^* + \Delta^e(c))}_{=\pi(0,a^*,0)}\} = \widetilde{I}(0,a^*,0).$$

Hence, by envelope theorem, $\frac{\partial \Pi^e(0,a^*,0)}{\partial \alpha} > 0$ holds at the optimal two-part tariff if

$$\begin{aligned} 1 - H(c) &> \frac{(1-H(c))r - h(c)\{r - c - a^*\}^2}{r - H(c)\{r - c - a^*\}} \\ \Leftrightarrow -H(c)\{r - c - a^*\} &> \frac{-h(c)\{r - c - a^*\}^2}{1 - H(c)} \\ \Leftrightarrow \qquad \frac{h(c)}{1-H(c)} &> \frac{H(c)}{r - c - a^*}.\end{aligned}$$

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