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# Stricter Margin Squeeze Regulation to Achieve Nondiscrimination in Digital Markets

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*Prosjektet har mottatt midler fra det alminnelige prisreguleringsfondet.*

# Stricter margin squeeze regulation to achieve nondiscrimination in digital markets*

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**Abstract**

Once more, non-discrimination clauses are in focus within digital markets, echoing the debates of the 1990s during the liberalization of telecommunications and resurfacing two decades later in discussions about net neutrality. In essence, these clauses often manifest as regulations addressing margin squeeze when dealing with vertically integrated incumbents. Margin squeeze regulation mandates that a vertically integrated firm offer wholesale access at a minimum margin between retail and wholesale prices. The size of this margin defines the regulation's "strictness". We show that a binding margin squeeze constraint softens downstream competition, leading to a tradeoff between product variety and retail prices concerning total and consumer welfare. Furthermore, we demonstrate that the regulation's strictness does not incentivize wholesale competition, unlike direct regulation through the imposititon of wholesale price ceilings. These results have implications for telecom regulation and digital markets, where the regulation of "gatekeepers" is becoming increasingly stringent.

**Keywords:** Nondiscrimination; margin squeeze; access regulation; infrastructure competition

**JEL codes:** L13; L40; L51.

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# 1 Introduction

Vertically integrated firms in digital markets often operate in "dual mode" and both serve consumers and provide access to rivals. Such markets are typically characterized by high entry barriers and at risk of exclusionary practices, therefore often being subject to regulatory scrutiny. Recently, digital industries have received particular attention. A possible regulatory intervention is the price structure of the vertically integrated firm becoming subject to a margin squeeze constraint. This type of constraint specifies a minimum difference between the downstream retail price and the upstream wholesale price.

This kind of regulation is a candidate remedy under the Digital Markets Act (DMA) recently adopted by the European Union. Moreover, a prohibition against margin squeeze is used as a method for regulating access pricing in the telecommunications sector. Finally, under European competition law (TFEU 102), any vertically integrated and dominant dual mode firm is subject to a de facto prohibition against imposing a margin squeeze (Jullien et al., 2014).

A prohibition against margin squeeze is a partial rule (see e.g., Baumol et al., 1997). On the one hand, entry is facilitated, but on the other hand, the integrated firm can still charge monopoly prices unless the firm is subject to competition (or direct price regulation). Competition in both the upstream and downstream segments results in a constraint on the retail price charged by a dominant firm. Nevertheless, imposing margin squeeze regulation on a dominant firm subject to competition has an ambiguous effect on consumer surplus and may result in increased retail prices as compared to the market outcome without margin squeeze regulation (Jullien et al., 2014; Krämer & Schnurr, 2018, among others).

We measure margin regulation strictness as the minimal size of the margin between retail and wholesale prices of the regulated firm. We utilize this measure to address two questions related to the strictness of margin squeeze regulation: 1) how does the strictness of a margin squeeze regulation affect retail prices and consumer surplus? and 2) can a stricter margin squeeze regulation induce more intense wholesale competition?

In short, we find that increased margin regulation strictness has an adverse effect on consumer surplus, and an ambiguous effect on prices, and it is inefficient at inducing wholesale competition.

Our results are derived from a model where the regulated firm faces competition from both a non-integrated firm and a nonregulated vertically integrated firm. This assumption reflects the structure frequently observed in markets with dual mode firms. For example, in markets for broadband access, a regulated provider of fixed broadband may face competition from a provider of broadband based on cellular technology (e.g., 5G). Similarly, under DMA, some firms are designated as “gatekeepers” and therefore regulated. These “gatekeepers” may also face competition from similar services provided by firms that are not regulated under DMA.[1]

An increase in the regulated margin incentivizes downstream entry. However, a binding margin squeeze constraint may also have unintended consequences in terms of softened downstream competition resulting in increased retail prices. Like Krämer and Schnurr (2018), we find that binding margin squeeze regulation may reduce consumer surplus as compared to consumer surplus under foreclosure.[2] One contribution of the present paper is to demonstrate that this result holds also for regulated margins that differ from downstream marginal cost (i.e., for both stricter and more lenient regulation). Moreover, we demonstrate that if the regulated margin increases, the increased strictness in access regulation typically results in further reductions to consumer surplus.[3]

The mechanism resulting in reduced consumer surplus can be decomposed into two effects. We label the first effect as the "wholesale effect". A firm that provides access compete less aggressively on the downstream market because any reduction in the retail price will result in a reduction to wholesale profits (Chen, 2001). The wholesale effect is, accordingly, not due to margin squeeze regulation per se. As long as access is priced above upstream marginal cost, any dual mode firm will take the wholesale effect into account in its downstream pricing decision.

The second effect is labeled "the margin squeeze effect". Since the access price is set at a stage preceding the regulated firms’ retail pricing decisions, a binding margin regulation implies that the retail price set by the firm is bounded downwards by the margin squeeze regulation. Thus, a binding margin squeeze constraint implies that the regulated firm can commit to a high retail price by setting a high access price. The vertically integrated firm becomes akin to a Stackelberg leader.[4]

[1] Examples of services regulated under DMA are Amazon Marketplace and Google Search. Both face competition from services provided by strong "dual mode" rivals.

[2] However, there may be dynamic gains from entry not captured in our model, and in such cases the dynamic gains may outweigh the short run loss.

[3] The statement holds for low and moderate levels of the regulated margin. The marginal effect on consumer surplus of increased strictness may be positive for sufficiently high margins, i.e., for relatively strict regulation.

[4] The term "Stackelberg leader" may be misleading in the present context. Gal-Or (1985) shows

Interestingly, the "margin squeeze effect" reinforces the wholesale effect. This occurs because the commitment device is a high access price, which ensures high wholesale profits from the downstream rival, which translates to weak incentives to compete for customers of the non-integrated downstream rival.[5]

Since prices are strategic complements, the response from downstream rivals is to increase retail prices, further softening competition (coined "the umbrella effect" by Carlton, 2008). Thus, all firms in the market increase their prices when margin squeeze regulation is imposed.

The margin squeeze effect yields a negative shift in consumer surplus for any binding regulated margin. Moreover, in terms of binding margin squeeze regulation, increasing the strictness of the margin squeeze constraint reduces consumer surplus for moderate margins.

We extend the model to also consider wholesale competition. Wholesale competition takes place if the nonregulated vertically integrated rival offers competing access services so that the regulated firm is subject to direct competition in both the upstream and the downstream market. This kind of market structure is analyzed by Bourreau et al. (2011) and subsequent papers. Our results are similar to theirs, in that we find there may be multiple equilibria in the access pricing game. The equilibrium that maximizes profits is where one vertically integrated firm provides access at the monopoly price and the rival abstains from making an offer; i.e., the upstream rival's best response is not to make competing offers in the wholesale market because any profit gains in the wholesale markets will be more than offset by reduced retail profits.

Moreover, Bourreau et al. (2011) demonstrate that if the access price of a vertically integrated firm is directly regulated by a price cap, then Bertrand competition is induced in the access market. Thus, they find that with sufficiently "strict" regulation, competitive dynamics will ensure that access is priced at marginal cost. In contrast with Bourreau et al. (2011), we find that a stricter margin squeeze regulation cannot have the same effect. The monopoly-like equilibrium is not affected by increasing the strictness of the margin squeeze regulation.

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that if firms are free to choose, they would prefer to be followers rather than first movers, given that prices are strategic complements. Our finding is that given a margin squeeze constraint, resulting in the regulated firm committing to a retail price before the other firms, the optimal strategy for the regulated firm is to commit to relatively high prices.

[5] See, e.g., Bergh et al. (2020), who provide methods to quantify price effects of mergers that cut vertical relations between integrated and non-integrated firms, and thus incentivizes the integrated firms to compete more aggressively for the non-integrated firm's customers after the merger.

This paper is organized as follows. In the remainder of this section, we provide an overview of related literature, as well as a description of the institutional framework. In section 2, we present the model. The market outcome in the case of wholesale monopoly is discussed in section 3 and, in section 4, the market outcome under wholesale competition is analyzed. Finally, in section 5, we provide some concluding remarks.

## 1.1 Related literature

A number of questions related to the regulation of digital platforms are discussed in the literature. A ban on dual mode can be considered a corner solution for ensuring nondiscrimination. The effect of banning dual mode is analyzed by both Hagiu et al. (2022) and Anderson and Bedre-Defolie (2022). Under different modeling assumptions, both papers find that the welfare effects of a ban are ambiguous.

Relative to a ban on dual mode, a less intrusive remedy is access price regulation. There is considerable literature on access pricing; see, e.g., the reviews in Armstrong (2002) and Laffont and Tirole (2000). This literature takes as a starting point that a vertically integrated firm that provides rivals with access to a bottleneck may have incentives to foreclose the market or to charge an excessive access price. Several markets within the telecommunications sector provide examples of regulated access prices.

Since regulated firms are typically characterized by increasing returns to scale, straightforward marginal cost pricing is not a viable basis for setting the access price. Ramsey-Boiteux pricing (Boiteux, 1971) is the second-best price structure where markups over marginal costs are inversely proportional to demand elasticities. Laffont and Tirole (1993) adapt Ramsey-Boiteux pricing to situations with asymmetric information. Other, less information-demanding approaches to access price regulation take the accounts of the regulated firm as a starting point (Averch & Johnson, 1962) or the price structure of the regulated firm, in particular the Efficient Component Pricing Rule (ECPR, see Baumol et al. 1997).

The ECPR is structurally very similar to a margin squeeze-based access price. In both cases, the access price is calculated by subtracting a margin[6] from the retail price of the regulated firm. The literature on the ECPR is mainly concerned with conditions for ensuring efficient entry (see, e.g., Armstrong et al., 1996 ). During the 1990s, the ECPR was hotly debated as a basis for setting access prices. It was established that

[6] In Baumol et al. (1997), the margin is specified as "the bottleneck owner's incremental cost of the remaining inputs required to supply the final product", i.e., downstream incremental costs.

the ECPR is a partial rule. A necessary condition for ECPR-based access prices to be optimal is that there is a constraint on the regulated firm's downstream price. The constraint may be due to competition or regulation (Laffont & Tirole, 1996; Baumol et al., 1997). This is a type of "Chicago argument": with an upstream monopoly, the regulated firm can price access at the monopoly price, and then adjust the downstream price in order to satisfy the margin squeeze constraint. Hence, in the presence of an upstream monopoly, the ECPR does not constrain the regulated firm in setting excessive prices and harvesting monopoly profits.[7] Accordingly, in the literature on the ECPR, some form of regulated downstream pricing is assumed (see, e.g., Armstrong et al., 1996, and Laffont & Tirole, 1996). It is noteworthy that the topic of the present paper, effects of increasing the regulated margin, may allow entry by "less efficient suppliers".[8]

However, in both digital markets and telecommunications there are typically (imperfect) substitutes for the potentially regulated upstream service. Thus, regulation may interact with competition. Bourreau et al. (2011) consider competition between two vertically integrated firms where one, or both, may provide access to third party firms. In the unregulated case, they demonstrate the existence of a foreclosure equilibrium, which is also the case when the upstream product from the two firms are perfect substitutes. Moreover, they find that a regulated price ceiling on the access price of one of the vertically integrated firms may induce Bertrand competition in the access market. Accordingly, a key question is whether margin squeeze regulation has a similar effect, i.e., whether imposing a margin squeeze constraint on a vertically integrated firm may induce Bertrand type competition in the wholesale market.

Two papers related to ours are Höffler and Schmidt (2008) and Krämer and Schnurr (2018). As in the present paper, they analyze the effect of imposing margin regulation on a vertically integrated firm in the presence of a vertically integrated rival.[9] However, the analysis in both papers is limited to the case where the permissible margin is exactly equal to the downstream marginal cost. In the present paper we extend the analysis

[7] This result is valid e.g., in a situation with an upstream monopoly and Bertrand type competition downstream. However, similar to other "Chicago type arguments," the result referred to above does not necessarily hold in all cases. Within the literature on ECPR, a number of these special cases are explored.

[8] "A less efficient supplier of the remaining inputs for the final product can win the competition for the business of supplying those inputs" (Baumol et.al., 1997, p. 152).

[9] In the paper by Höffler and Schmidt (2008), there are no explicit references to margin squeeze regulation. They analyze "retail minus" regulation. Retail minus regulation and margin squeeze regulation are structurally identical.

by considering the effect of changing the permissible margin. Krämer and Schnurr (2018) also consider margin squeeze regulation if there is wholesale competition. In contrast with their approach, we assume that one of the regulated firms is designated as subject to margin squeeze regulation prior to wholesale competition.[10] In the paper by Krämer and Schnurr (2018), whichever firm providing access is subject to the regulatory constraint. Thus, in their model, being subject to regulation is a function of the wholesale offerings, whereas in our model the requirement to satisfy a margin test is imposed on one of the firms prior to wholesale competition. Moreover, we analyze the effect of changing the permissible margin under wholesale competition as well.

## 1.2 Institutional background

### 1.2.1 Competition law

Views diverge as to whether or not a margin squeeze should be considered a separate type of abuse under competition law (see the discussion in Jullien et al., 2014). This is reflected in the difference between EU and US competition law. Under EU case law, a margin squeeze may in itself be considered an abuse of market power.[11] This is in contrast with case law in the US, where it is necessary to demonstrate either refusal to deal or predation in order for the margin squeeze to be considered as abuse of market power (Sidak, 2008).

In the European context, a prerequisite for the margin squeeze to be considered abuse is that the undertaking be deemed dominant. Moreover, firms subject to margin squeeze rulings are typically subject to a mandate to provide access. This is illustrated by the fact that most margin squeeze cases in Europe since the year 2000 have been in the telecommunications sector (Bostoen, 2018).

[10] Under the Digital Markets Act firms are designated as digital gatekeepers, and within telecom-regulation firms are designated as having significant market power: "SMP".

[11] See, e.g., EU Court 2011: Judgement of 17. 2. 2011 — CASE C-52/09, paragraph 31: "A margin squeeze, in view of the exclusionary effect which it may create for competitors who are at least as efficient as the dominant undertaking, in the absence of any objective justification, is in itself capable of constituting an abuse within the meaning of Article 102 TFEU." Any dominant firm in Europe serving both wholesale and retail customers in the same value chain is, accordingly, in principle, constrained by margin squeeze regulation. However, cases in Europe have primarily been in the telecom sector, in addition to a few cases within the railway, gas, water, and postal sector (Bostoen, 2018).

### 1.2.2 Digital markets

The European Union adopted the Digital Markets Act (DMA) in October 2022 (European Union, 2022). Article 6 of this act mandates designated gatekeepers[12] to apply fair and non-discriminatory general conditions of access to software application stores, online search engines, and online social networking services (European Union, 2022).[13]

Moreover, gatekeepers providing online search engines are mandated to provide access on fair, reasonable, and nondiscriminatory terms to ranking, query, click and view data.[14]

However, both market structures and business models vary across digital gatekeepers, and margin squeeze regulation will not necessarily be an option in all cases. On the one hand, the margin squeeze framework can be applied directly when there is a given access price per transaction on the platform as well as a strictly positive retail price. On the other hand, the margin squeeze framework may be less well suited when retail services are offered for free and/or when accessing the platform is commission based. Bostoen (2018) argues that margin squeeze is well suited for analyzing abuse by both app stores and online trading platforms, but less suited for search engines.

The European Commission's handling of Amazon's proposed acquisition of iRobot in 2023 highlights this foreclosure concern within e-commerce (one of the sectors covered by the DMA). In its statement of objections to the proposed transaction, the Commission stated, among other things, that Amazon may indirectly increase advertising and selling costs for iRobot's competitors within Amazon's marketplace.[15] This case suggests that ex-ante competition concerns may be alleviated by regulating merchant fees alongside nondiscrimination clauses.

Similar regulations may be relevant within targeted online advertising, where services such asGoogle Ads have a competitive advantage due to access to user data (e.g., search data). To be able to compete efficiently, rival advertising services may require access to data or a service from Google that allows them to deliver an advertising product of comparable quality. Price-based access regulation, akin to margin squeeze regulation, represents one approach to ensuring more competition in online advertising.

[12]In September 2023, 22 services across six companies (Alphabet, Amazon, Apple, ByteDance, Meta, and Microsoft) were designated as gatekeepers.

[13]European Union (2022), article 6, paragraph 12.

[14]European Union (2022), article 6, paragraph 11.

[15]Press release: https://ec.europa.eu/commission/presscorner/detail/en/IP_23_5990

### 1.2.3 Broadband access

Local fiber access is typically a bottleneck in the provision of broadband internet. In Europe, this form of access is regulated based on the economic replicability test, provided that a set of conditions is fulfilled (EU, 2024, point 38). The economic replicability test in effect requires a vertically integrated regulated firm to satisfy a margin squeeze test. A precondition for basing a regulation on the replicability test is the presence of infrastructure-based competitors[16] (EU, 2024, point 38, d).[17] The replicability test implies that the difference between the retail price and the wholesale access price charged by the regulated vertically integrated firm cannot exceed the *"incremental downstream costs and a reasonable percentage of common costs"* (EU 2024, annex 3). Thus, neither the retail price nor the access price is directly regulated. The regulator either decides on or approves the difference between the retail and wholesale price (the margin) and, as long as the difference is sufficiently large, the regulated firm is free to set both the retail and wholesale price.

# 2 The model

Dual mode firms are normally exposed to competition from other vertically integrated firms providing (imperfect) substitutes. Hence, in cases where one of the vertically integrated firms is subject to margin squeeze regulation, the regulation will interact with competitive pressure. Accordingly, we consider a market with three competing firms: two vertically integrated firms, and one firm active only in the downstream market (at the retail level).[18] The upstream and downstream services are strict complements and the downstream firm relies on buying access to the upstream activity from either firm

[16] It can be argued that regulation of a (dominant) access provider is unnecessary if the firm is subject to infrastructure based competition, and indeed, in the context of the ECPR (a margin rule with similarities to the replicability test), Economides and White (1998) argue that *"If the conditions under which the ECPR would be efficient are present, its application is redundant; if they are absent, its application would be a mistake (as compared with a more optimal Ramsey rule)."*

[17] In the absence of infrastructure-based competition, regulators in the EU may deploy a hybrid regulatory regime. In cases where the regulated firm provides more than one access product (e.g., bandwidth-based differentiation), then one access product, "the regulated anchor", is subject to direct (cost-based) price regulation and the other access products are subject to margin squeeze regulation (EU, 2024, point 38).

[18] Recall that the ECPR debate from the nineties identified that a margin squeeze constraint is a partial rule. A monopoly firm can satisfy a margin squeeze constraint without sacrificing monopoly profits. Accordingly, by assuming the presence of a vertically integrated rival, the possibility of obtaining the monopoly outcome is removed by assumption.

1 or firm 2 at the unit price $a_i$. The market structure is illustrated below:

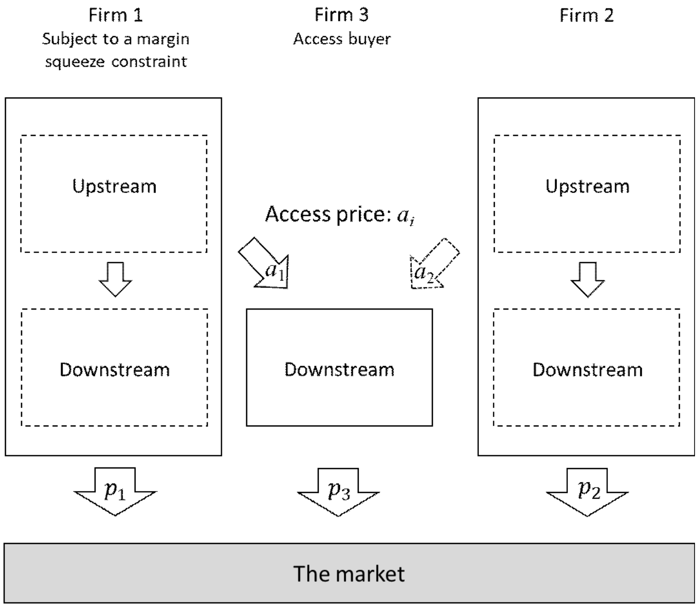



Figure 1: Market structure

In terms of product differentiation, the three firms are assumed to be located equidistant on the Salop circle (Salop, 1979; Vickrey, 1964). A mass 1 of consumers is distributed uniformly on the circle. The circumference of the circle is of length 1 and traveling costs are quadratic. A consumer located at $x$ on the circle is offered utility $v-p_i-3t\,(x-x_i)^2$ by the firm located at $x_i$, where $p_i$,$v$, and $t$ are respectively the retail price, the standalone value of the product, and a measure of product differentiation ("travelling costs"). Accordingly, demand directed towards firm $i$ ($i = 1, 2, 3$) is:

$$D_i = \frac{1}{3} - \frac{2p_i - p_j - p_k}{2t}$$

The three firms are assumed to have zero marginal downstream costs. Marginal upstream costs are normalized to zero. As illustrated above, firms 1 and 2 are vertically integrated. Firm 3 is active downstream and not upstream. Firm 3 buys one unit of the upstream service (access) from either firm 1 or firm 2, per unit sold in the downstream market. Firm 2 is unregulated, whereas firm 1 is subject to access price regulation in the form of a margin squeeze requirement: $a_1 \leq p_1 - m$.

The timing of the game is as follows:

- Stage 1, The regulator designates one of the vertically integrated firms as the regulated firm and imposes a minimum margin, $m$ (i.e. a minimum difference between the retail price and the access price of the regulated firm).

- Stage 2, The regulated firm (firm 1) sets an access price, $a_1$, and as a consequence commits to $p_1 \geq a_1 + m$. The unregulated vertically integrated firm (firm 2) may, or may not, make a competing wholesale offering of $a_2$. If both firms make an offering, firm 3 selects the offering with the lowest price.

- Stage 3, All firms active in the downstream market simultaneously set prices. The regulated firm sets this price subject to the constraint $p_1 \geq a + m$.

In the analysis below, we separately analyze the case where only firm 1 makes an access offering (wholesale monopoly) and the case where both firms 1 and 2 make competing access offerings (wholesale competition).

# 3 Wholesale monopoly

In this section, it is assumed that firm 2 chooses not to make a wholesale offering at stage 2 of the game. In section 4, we will demonstrate that this is a candidate equilibrium under wholesale competition. To save on notation in this section, we have suppressed the footscript on the access price.

Since the focus of the present paper is a situation in which the regulated firm is active in both the upstream and downstream markets, we make the following assumption to ensure a strictly positive downstream market share for the regulated firm:

**Assumption 1:** $m < \frac{35}{54}t$

Below, we will demonstrate that the assumption is necessary in order for the regulated firm to operate profitably.

## 3.1 Stage 3

At stage 3 of the game, firm 2 and firm 3 determine prices knowing that the retail price charged by firm 1 is constrained by the margin regulation and the access charge determined at stage 2 of the game. Firm 2 maximizes $\pi_2 = p_2 \left(\frac{1}{3} - \frac{2p_2 - p_1 - p_3}{2t}\right)$ resulting in the best response function $p_2 = \frac{t}{6} + \frac{p_1 + p_3}{4}$. Firm 3 is only active in the downstream market and has to buy one unit of the access product per unit sold in the downstream market at price $a$, hence the firm maximizes $\pi_3 = (p_3 - a)\left(\frac{1}{3} - \frac{2p_3 - p_1 - p_2}{2t}\right)$ resulting in the best response function $p_3 = \frac{t}{6} + \frac{p_1 + p_2}{4} + \frac{a}{2}$. Finally, the regulated firm has both retail and wholesale profits, and chooses the optimal price subject to the margin constraint. Hence firm 1 solves the following programming problem:

$$L = p_1\left(\frac{1}{3} - \frac{2p_1 - p_2 - p_3}{2t}\right) + a\left(\frac{1}{3} - \frac{2p_3 - p_1 - p_2}{2t}\right) - \lambda\left(p_1 - m - a\right)$$

where $\lambda$ is a nonnegative multiplier. The first order conditions are:

$$\begin{aligned} \frac{\partial L}{\partial p_1}; \frac{1}{3} + \frac{a}{2t} - \frac{4p_1 - p_2 - p_3}{2t} - \lambda &= 0 \\ \lambda\left(p_1 - m - a\right) &= 0 \end{aligned}$$

Suppose the constraint binds ($\lambda > 0$), then $p_1 = m + a$. Suppose it does not bind ($\lambda = 0$), then; $p_1 = \frac{t}{6} + \frac{p_2+p_3}{4} + \frac{a}{4}$. Accordingly, if the constraint binds (topscript $b$) the equilibrium is:

$$\begin{aligned} p_1^b &= a + m \\ p_2^b &= \frac{2}{9}t + \frac{1}{3}m + \frac{7}{15}a \\ p_3^b &= \frac{2}{9}t + \frac{1}{3}m + \frac{13}{15}a \end{aligned}$$

If the constraint is not binding (topscript $nb$):

$$\begin{aligned} p_1^{nb} &= \frac{t}{3} + \frac{1}{2}a \\ p_2^{nb} &= \frac{t}{3} + \frac{3}{10}a \\ p_3^{nb} &= \frac{t}{3} + \frac{7}{10}a \end{aligned}$$

Accoringly, firm 1's best response function is piecewise linear. The figure below illustrates the best response function for firm 1 as a function of the price charged by the two other firms:[19]

[19] By defining $p_{-1} = \frac{p_2+p_3}{2}$, the upward sloping part of the best response for firm 1 can be written: $p_1 = \frac{t}{6} + \frac{a}{4} + \frac{p_{-1}}{2}$

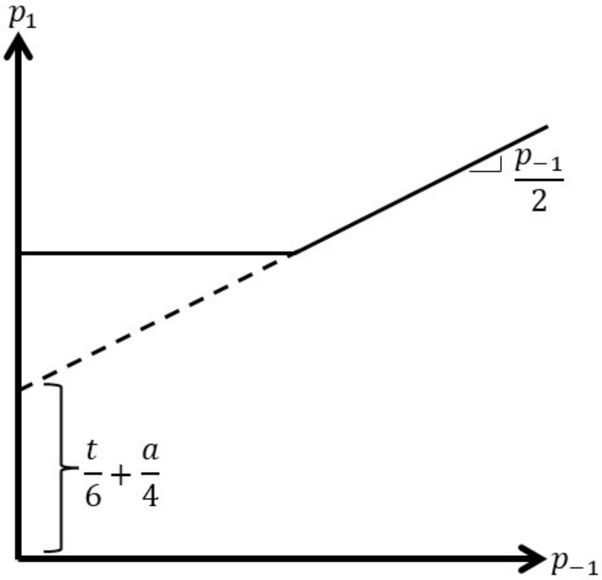



Figure 2: Best response firm 1

When the margin squeeze regulation binds the best response functions of firms 2 and 3 intersect on the horizontal segment of the best response function illustrated above. Intersection is on the horizontal segment if $a > a^{crit}$ where $a^{crit}$ is defined by $p_1^b = p_1^{nb} \Leftrightarrow a^{crit} = 2\left(\frac{t}{3} - m\right)$.[20] It is evident from figure 2 that intersection on the horizontal segment yields higher equilibrium prices, as compared to the intersection on the (dotted) upward sloping best response in the absence of margin squeeze regulation. Hence, for a given access price, a binding margin squeeze constraint results in higher retail prices as compared to the situation without a binding constraint. This effect is implicitly present in earlier analysis of margin squeeze regulation (Krämer & Schnurr, 2018). However, an illustration of this effect as a piecewise linear best response function appears to be novel.

[20]Reassuringly, at the boundary, the binding and nonbinding solutions yield exactly the same prices for the three firms, hence stage 3 prices are continuous functions of the access charge determined at stage 2 of the game.

## 3.2 Stage 2

At stage 2 of the game, firm 1 determines $a$ by maximizing:

$$\pi_1(a) = \left\{ \begin{array}{ccc} p_1^{nb} D_1\left(p_1^{nb}, p_2^{nb}, p_3^{nb}\right) + a D_3\left(p_1^{nb}, p_2^{nb}, p_3^{nb}\right) & \text{if} & a \leq a^{crit} \\ p_1^{b} D_1\left(p_1^{b}, p_2^{b}, p_3^{b}\right) + a D_3\left(p_1^{b}, p_2^{b}, p_3^{b}\right) & \text{if} & a > a^{crit} \end{array} \right\}$$

substituting for prices, and rearranging yields:

$$\pi_1(a) = \left\{ \begin{array}{ccc} \frac{t}{9} + \frac{a(5t-3a)}{10t} & \text{if} & a \leq a^{crit} \\ \frac{7a+5m}{9} - \frac{7a^2+10am+10m^2}{15t} & \text{if} & a > a^{crit} \end{array} \right\}$$

If the optimal $a^* \leq a^{crit}$, then $a^* = \frac{5}{6}t$ otherwise $a^* = \frac{5}{6}t - \frac{5}{7}m$. Assume there exist a margin, $m^{crit}$, such that for margins below that threshold, the optimal $a$ is in the nonbinding region, and for margins above that threshold, the optimal $a$ is in the binding region. Then we can substitute for the optimal access charge in the two regions and write:

$$\pi_1^* = \left\{ \begin{array}{ccc} \frac{23}{72}t & \text{if} & m \leq m^{crit} \\ \frac{35}{108}t - \frac{3}{7t}m^2 & \text{if} & m > m^{crit} \end{array} \right\}$$

Assuming a solution in the nonbinding region, then $a = \frac{5}{6}t$ and $p_1^{nb} = \frac{3}{4}t$. This price structure will satisfy a margin regulation if the difference between the retail price and the access price is larger than the regulated margin: $m < p_1^{nb} - a \iff m < -\frac{1}{12}t$. Hence, any regulated margin above this threshold will result in regulation being binding, i.e., the boundary between the binding and nonbinding regions, $m^{crit}$ must satisfy: $m^{crit} \leq -\frac{1}{12}t$. Consider now the margin $\widetilde{m}$ such that profit in the constrained region is equal to profit in the unconstrained region:[21]

$$\begin{aligned} \frac{23}{72}t &= \frac{35}{108}t - \frac{3}{7t}(\widetilde{m})^2 \\ \widetilde{m} &= -\frac{\sqrt{14}}{36}t \simeq -\frac{t}{10} \end{aligned}$$

With this regulated margin, the firm is indifferent to setting an access charge in the nonbinding region $a^{nb}(\widetilde{m}) = \frac{5}{6}t$ and an access charge in the binding region

[21] There are two solutions for $\widetilde{m}$. Only the relevant one is shown here.

$a^b(\widetilde{m}) = \frac{5}{6}t\left(1+\frac{\sqrt{14}}{42}\right)$. Thus, there is a "jump" in the optimal access charge. The jump represents a percentage change in the access charge equal to $\frac{\sqrt{14}}{42} \simeq 9\%$. A marginal increase in the access charge from $\widetilde{m}-\varepsilon$ to $\widetilde{m}+\varepsilon$ results in an approximately 9 % increase in the access charge. Thus, the critical value $m^{crit}$, where the regulated firm goes from setting an access charge outside the binding region to an access charge in the binding region, is at $\widetilde{m}$. To illustrate this, we provide three plots below. In all plots, profit is considered a function of the access charge. The kink in the profit function is where $a = a^{crit}$. In the left panel, the regulated margin is below the critical level and the regulated firm maximizes profits by choosing an access charge in the nonbinding region. In the middle panel, the regulated margin is exactly at the threshold and there are two optimal access charges. In the right panel, the regulated margin is above the threshold and the optimum is in the binding region.

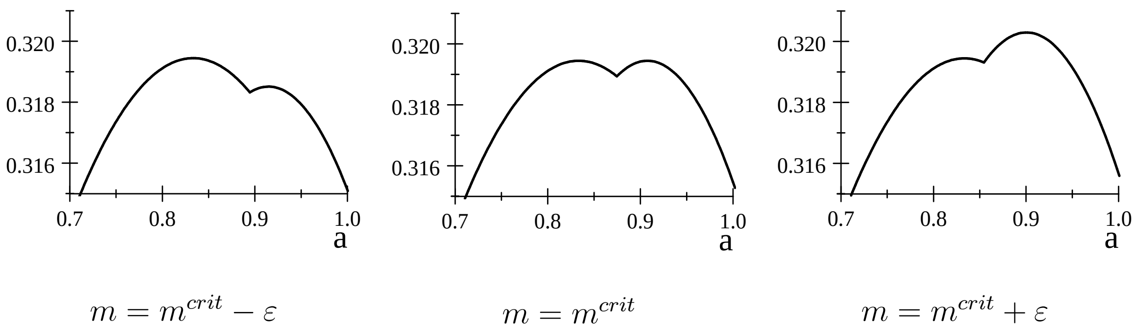



Figure 3, Profit as a function of the access charge, parameter values: $t = 1, \varepsilon = 0.01t$

Substituting for the optimal access charge, equilibrium retail prices in the nonbinding region ($m \leq -\frac{\sqrt{14}}{36}t$) are: $p_1^{nb} = \frac{27}{36}t$, $p_2^{nb} = \frac{21}{36}t$ and $p_3^{nb} = \frac{33}{36}t$. Similarly, in the binding region ($m > -\frac{\sqrt{14}}{36}t$): $p_1^b = \frac{30}{36}t + \frac{2}{7}m$, $p_2^b = \frac{21}{36}t$, and $p_3^b = \frac{34}{36}t - \frac{2}{7}m$.

Equilibrium prices under a binding margin squeeze constraint can be decomposed into three parts:

| | | Hotelling mark-up | + | Wholesale effect | + | Margin squeeze effect |
|---|---|---|---|---|---|---|
| $p_1^b$ | $=$ | $\frac{t}{3}$ | $+$ | $\frac{15}{36}t$ | $+$ | $\frac{3}{36}t + \frac{2}{7}m$ |
| $p_2^b$ | $=$ | $\frac{t}{3}$ | $+$ | $\frac{9}{36}t$ | $+$ | $\frac{1}{36}t$ |
| $p_3^b$ | $=$ | $\frac{t}{3}$ | $+$ | $\frac{21}{36}t$ | $+$ | $\frac{1}{36}t - \frac{2}{7}m$ |

The first price component is the Hotelling mark-up. This is the mark up due to product differentiation, i.e., the mark up we would have if either firm 3 was vertically integrated or if firm 3 could buy access at marginal cost. The second price component is the wholesale effect; in setting a retail price, firm 1 takes into account that increasing prices above the Hotelling price is profitable because some of the lost retail sales are offset by increased wholesale profits. This mechanism was highlighted by Chen (2001). Finally, under a binding margin squeeze constraint, the regulated firm can commit to an increased retail price via setting a high access price.

One feature in the present model is notable: if the strictness of a binding margin squeeze constraint changes, firm 1 and firm 3 will change their retail prices by an equal amount but in opposite directions; firm 2 will not change its price. The market shares of firm 1 and 2 in the binding region are respectively: $D_1 = \frac{5}{18} - \frac{3m}{7t}$ and $D_2 = \frac{11}{18}$. A necessary condition for firm 1 to have a nonnegative market share is accordingly $m \leq \frac{35}{54}t$, which is fulfilled by assumption. Moreover, the market share of firm 2 is independent of $m$ and larger than $\frac{1}{3}$.

In the equilibria derived above, firm 3 obtains a strictly positive market share for any permissible $m$. These equilibria are accordingly characterized by entry accommodation. However, it cannot be ruled out that firm 1 is better off by determining an access price, $a$, sufficiently high such that firm 3 is foreclosed from the market, while still satisfying the regulatory constraint $p_1 \geq a + m$.

**Proposition 1:**

In the absence of any regulatory intervention, firm 3 will be foreclosed from the market. Under margin squeeze regulation and for $m \geq 0$, the market share and profits for firm 3 increase in the regulated margin and for $m < 0$ the market may be foreclosed.

**Proof:**

*Part 1: In the absence of any regulatory intervention, firm 3 will be foreclosed from the market.*

If entry is accommodated, firm 3 obtains market share $D_3 = \frac{1}{30t}(10t - 9a)$ absent regulation. Thus, if firm 1 offers access price $a > \frac{10}{9}t$, firm 3 is foreclosed from the market. Given foreclosure, the market will be equally shared among the two integrated firms. Assuming that the two integrated firms relocate on the Salop circle, the two firms set prices $p^F = \frac{3}{4}t$, and accordingly each firm earns profits $\pi^F = \frac{3t}{8}$. This profit is higher than if entry is accommodated yielding profits $\pi = \frac{23}{72}t$.

*Part 2:For $m \geq 0$, the market share and profits for firm 3 increase in the regulated margin.*

Substituting for prices in the expression for market shares and profits for firm 3 in the binding region yields $D_3 = \frac{2}{18} + \frac{3m}{7t}$ and $\pi_3 = \frac{(27m+7t)^2}{3969t}$, both increasing in $m$.

*Part 3: For $m < 0$, the market may be foreclosed.*

Assume that the two vertically integrated firms relocate to obtain maximum differentiation on the Salop circle if firm 3 is foreclosed from the market.

1. Assume $m \leq -\frac{13}{36}t$. Then all solutions are in the nonbinding region. The solution is accordingly identical to the case in the absence of regulation, and foreclosure is profitable, and achieved by setting $a = \frac{10}{9}t$. This is a permissible solution for $p_1 \geq a + m \Leftrightarrow m \leq -\frac{13}{36}t$. Hence, foreclosure is profitable in this region.

2. Assume next that $m \in \left(-\frac{13}{36}t, -\frac{2}{9}t\right]$. The solution is in the binding region if entry is deterred and in the nonbinding region if entry is accommodated. Thus, the regulated firm obtains profits $\pi_1^* = \frac{23}{72}t$ if entry is accommodated. The condition for foreclosure is $a = \frac{10}{9}t$. Since regulation binds under foreclosure, $p_1 = a + m = \frac{10}{9}t + m$. Under foreclosure, firm 2 maximize: $\pi_2 = p_2 D_2$, with the first order condition: $p_2 = \frac{3t}{8} + \frac{1}{2}p_1$. Thus, equilibrium prices under foreclosure are: $p_1 = \frac{10}{9}t + m$,and $p_2 = \frac{1}{2}m + \frac{67}{72}t$. Firm 1 obtains profits: $p_1 D_1 = \frac{(9m+10t)(41t-36m)}{972t}$. Comparing profits under accommodation to profits under foreclosure $\pi_1^* - \pi_1^f = \frac{23}{72}t - \left(\frac{(9m+10t)(41t-36m)}{972t}\right) = \frac{m(648m-18t)-199t^2}{1944t}$. This expression is negative for $m \in \left(-\frac{13}{36}t, -\frac{2}{9}t\right]$. Hence, foreclosure is profitable in this region.

3. Assume next that $m \in \left(-\frac{2}{9}t, -\frac{\sqrt{14}}{36}t\right]$. The solution is in the binding region if entry is deterred and in the nonbinding region if entry is accommodated. The regulated firm obtains profits $\pi_1^* = \frac{23}{72}t$ if entry is accommodated. The condition for foreclosure is $a \geq a^d = \frac{5}{2}m + \frac{5}{3}t$ (if entry is accommodated the newcomer obtains market share $D_3 = \frac{15m-6a+10t}{45t}$, thus entry is deterred for $a \geq a^d$). Supposing the regulated firm sets a foreclosing access price $a = \frac{5}{2}m + \frac{5}{3}t$, then firm 1 is constrained by margin regulation under foreclosure. The retail price of firm 1 is $p_1 = \frac{5}{3}t + \frac{7}{2}m$. Firm 2 maximizes: $\pi_2 = p_2 D_2$, with first order condition: $p_2 = \frac{3t}{8} + \frac{1}{2}p_1$. Thus, equilibrium prices under foreclosure are $p_1 = \frac{5}{3}t + \frac{7}{2}m, p_2 = \frac{29}{24}t + \frac{7}{4}m$. Accordingly, firm 1 obtains a profit: $\pi_1^f = p_1 D_1 = \frac{7(21m+10t)(t-6m)}{216t}$. Comparing profits under accommodation to profits under foreclosure $\pi_1^* - \pi_1^f = \frac{23}{72}t - \left(\frac{7(21m+10t)(t-6m)}{216t}\right) = \frac{882m^2+273mt-t^2}{216t}$. This expression is negative for $m \in \left(-\frac{2}{9}t, -\frac{\sqrt{14}}{36}t\right]$. Hence, foreclosure is profitable in this region.

4. Finally, assume $m > -\frac{\sqrt{14}}{36}t$. In this case, the solution is in the binding region both if entry is deterred and if entry is accommodated. The regulated firm obtains profits $\pi_1^* = \frac{35}{108}t - \frac{3}{7t}m^2$ if entry is accommodated. Again, the foreclosing access price is $a = \frac{5}{2}m + \frac{5}{3}t$, resulting in retail prices $p_1 = \frac{5}{3}t + \frac{7}{2}m, p_2 = \frac{29}{24}t + \frac{7}{4}m$, in the same way as above. Foreclosure profit for firm 1 is again $\pi_1^f = \frac{7(21m+10t)(t-6m)}{216t}$. Comparing profits under accommodation to profits under foreclosure, $\pi_1^* - \pi_1^f = \left(\frac{35}{108}t - \frac{3}{7t}m^2\right) - \left(\frac{7(21m+10t)(t-6m)}{216t}\right) = \frac{m(1842m+637t)}{504t}$. This expression is positive for $m \geq 0$ and negative for $m \in \left(-\frac{\sqrt{14}}{36}t, 0\right]$. Hence, foreclosure is profitable if $m < 0$.

QED

The profitability of foreclosure is of course a function of the assumptions regarding the market if only firms 1 and 2 are active. In proposition 1, we demonstrate that the relevant accommodation threshold is $m \geq 0$ if firms 1 and 2 relocate on the Salop circle to opposite sides of the circle. If the two firms do not relocate, the foreclosure threshold is lower. It can be demonstrated that without relocation, the threshold is $m \approx -0.082t$. Moreover, it follows from proposition 1 that if the access seeker has some fixed costs, then the threshold is higher. Thus, entry may be deterred also for $m = 0$.

Margin squeeze regulation can be compared to a regime with a price cap ensuring entry accommodation, i.e., $a \leq \frac{10}{9}t$. It follows from the analysis above that given this constraint, firm 1 will set access price $a = \frac{5}{6}t$. Thus, the price cap is not binding in equilibrium. This is accordingly "soft" price cap regulation.[22] The equilibrium under soft price cap regulation is identical to the equilibrium when there are three active firms and nonbinding margin regulation.

[22] Notice that a soft price cap can be considered as the effective constraint on the price structure of a dominant firm under US competition law. Within our model, a wholesale price that does not satisfy a soft price cap results in foreclosure and can be interpreted as a refusal to deal and thus be unlawful. (Sidak, 2008). On the other hand, entry is accommodated if the wholesale price satisfies the soft price cap and evidently the firm is not refusing to deal.

**Proposition 2**:

Given that the available regulatory instrument is to impose a margin squeeze constraint facilitating entry, $m \geq 0$:

- Starting out with $m = 0$, the consumer surplus decreases if the regulated margin is increased.
- Within the feasible region, consumer surplus is minimized for $m = \frac{7}{36}t$.
- Soft price cap regulation $a \leq \frac{10}{9}t$, yields a higher consumer surplus, compared to margin regulation.

**Proof:**

Collecting terms substituting for equilibrium prices and accounting for the horizontal differentiation ("traveling costs"), consumer surplus is:

$$\begin{aligned} CS^B &= v - \frac{253t}{324} - \frac{m(7t - 18m)}{147t} \\ CS^{SC} &= v - \frac{53}{72}t \end{aligned}$$

$CS^B$ is consumer surplus when entry is facilitated, i.e., for $m \geq 0$. $CS^{SC}$ is consumer surplus under soft price cap regulation. Consumer surplus, $CS^B$ decreases at $m = 0$ and has a minimum at $m = \frac{7}{36}t$. Comparing consumer surplus under soft price cap regulation to consumer surplus under margin squeeze regulation when $m \geq 0$: $CS^{SC} - CS^B(m) = \frac{37t}{1296} + \frac{m(7t-18m)}{147t}$ This expression is positive for any $m$ in the relevant region; i.e., where entry is accommodated and firm 1 is active on the retail market: $m \in \left(0, \frac{35}{54}t\right)$. For completeness, the difference is negative for $m \geq \frac{7}{36}t + \frac{7}{27}\sqrt{2}\sqrt{3}t \approx 0.829\,50t$. QED.

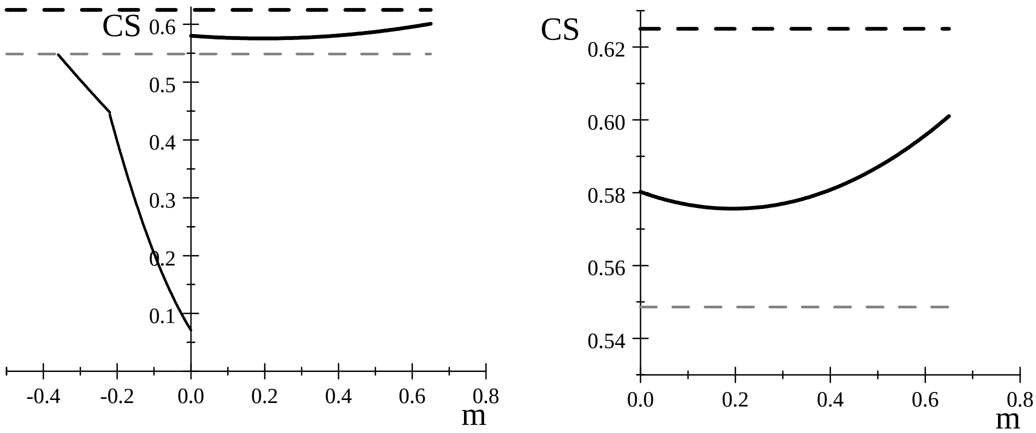
Based on the two propositions above, alternative regulatory regimes can be ranked according to consumer surplus. It follows from the propositions above that consumers prefer price cap regulation over margin squeeze regulation. To be specific, the preferred regime, seen from the consumer's perspective, is facilities-based competition where the three firms have an identical cost structure. This preferred outcome is also obtained with an optimal price cap, where the access price is directly regulated to be equal to marginal cost. The outcome ranked second by consumers is soft price cap regulation where the price cap is nonbinding but sufficiently low such that entry is ensured. The regime ranked third by consumers is margin squeeze regulation, provided that entry is facilitated. Moreover, within this regime consumer surplus is a function of the regulatory strictness. A nonregulated market resulting in entry deterrence is ranked fourth by consumers. Finally, the worst outcome as seen from a consumer perspective is the combination of margin squeeze regulation and entry deterrence.

There is a notable discontinuity in consumer surplus at the boundary where the regulated firm is indifferent to entry facilitation ($m \geq 0$) or entry deterrence ($m < 0$). Entry is deterred by setting a relatively high $a$ and entry is facilitated by setting a relatively low $a$.[23] The regulated firm is constrained by margin squeeze regulation in either case. Thus, a high access price results in an equally high retail price. Firm 2 responds by also setting a high retail price. Hence, if entry is deterred under margin squeeze regulation, consumer surplus is low, due to both less product variety, and high retail prices.

The results are illustrated in figure 4 below. In the figure, parameters are chosen such that the preferred regime (facilities based competition or optimal price cap regulation) yields consumer surplus equal to 1. This is the case for $v = \frac{49}{36}$ and $t = 1$. The solid black line is consumer surplus under margin squeeze regulation.[24] The discontinuity at $m = 0$ is notable. The dashed black line is consumer surplus under soft price cap regulation, and the dashed gray line is consumer surplus under entry deterrence in the absence of regulation.

[23] To be specific, within the present model, for $m = 0$, and given entry accommodation, firm 1 set access price $a = \frac{5}{6}t$, whereas in order to foreclose the entrant, the access price is twice as high: $a = \frac{5}{3}t$.

[24] Consumer surplus under entry deterrence (for $m < 0$) consists of several intervals and some tedious calculations are needed to describe this function. These calculations are provided in appendix A.




$m \in (-0.4t, 0, 6t)$ $\qquad$ $m \geq 0$

Figure 4: Consumer surplus: $v = \frac{49}{36}, t = 1$

It is evident from the illustration above that the gain in consumer surplus by manipulating the regulated margin from a level in the entry deterrence region to a level in the entry-facilitating region has a substantial positive effect on consumer surplus, whereas further increases in the regulated margin have a relatively modest effect. In the entry-facilitating region, the initial effect is negative.

Welfare in the present model without vertical differentiation is only dependent on traveling distances. Hence, the first best outcome is $D_1 = D_2 = D_3 = \frac{1}{3}$. We can directly see that the first best outcome is not feasible under the entry-facilitating margin squeeze regulation since the market share of firm 2 $D_2 = \frac{11}{18}$ is larger than $\frac{1}{3}$ and independent of the regulated margin. Moreover, it can be demonstrated that welfare, as a function of the regulated margin, $m$, is increasing at $m = 0$. Thus, the loss in consumer surplus from increasing the margin is more than offset by an increase in gross profits for the three firms.

In this section, we have assumed that the regulated firm commits to an access price at stage 2 of the game. This can be considered a "Stackelberg contract". The regulated firm commits to a price floor, prior to the price-setting game at stage 3 of the game. An alternative way to satisfy the margin regulation for the regulated firm would be to offer the access buyer a "retail minus contract" at stage 2 of the game. In this case, the regulated firm commits to offering wholesale access at a price equal to the difference between its retail price and the regulated margin, $a = p_1 - m$, without committing to a specific price level. As demonstrated in appendix C, the Stackelberg contract yields higher profits for the regulated firm, and accordingly this contract will be chosen by the regulated firm unless the regulator also specifies the type of contract.

# 4 Wholesale competition

In the previous sections, we assumed that firm 1 is the only supplier of access. In this section, we will explore whether firm 2 has an incentive to compete in the wholesale market and whether a margin regulation imposed on firm 1 has implications for wholesale competition. It is assumed that the timing of the game is the same as in the previous section. Furthermore, the wholesale offerings made by firm 1 and 2 are assumed to be of identical quality, implying that firm 3 simply selects the offering with the lowest price at stage 2 of the game.

Since the wholesale offerings are considered identical, the outcome of stage 2 of this game may be perfectly competitive. However, margin regulation implies a retail price floor and it is not obvious what the outcome will be.

In the following we will analyze a regulatory regime where the regulated firm is constrained by margin regulation only if the firm is active in the wholesale market. If the access buyer chooses to buy access from the nonregulated firm, then the regulated firm is active only in the retail market, and it can be argued that the regulated firm is not constrained by the margin regulation.[25]

Given a winning bid equal to $a_i$, stage 2 profits for firm $i$ is $\pi_i^W(a_i)$ if the firm wins the access contract and $\pi_i^L(a_j)$ if the rival firm win the access contract. Note that this game, where the vertically integrated firms bid for the access contract, is highly asymmetric. Firm 1 is mandated to offer access, and firm 2 may make a counter offer if it is in its interest, or may choose to remain passive.

## 4.1 Nonbinding margin regulation

As a reference point, we will start the analysis of wholesale competition by considering a case similar to the setup in Bourreau et al. (2011) and, by doing so, replicate their results. In this case the regulated firm is mandated to offer access at a price such

[25] In the case where the regulated firm is not active in the access market, the firm has not committed to a specific access price, and it is trivial to argue that the firm satisfies a margin test by postulating a sufficiently low access price.

that firm 3 is not foreclosed (i.e. $a_1 < \frac{10}{9}t$). There is no margin squeeze regulation. Accordingly, competition at stage 3 of the game is identical, irrespective of whether the regulated or nonregulated firm wins the access contract. Let topscript $W$ and $L$ denote respectively the infrastructure firms winning and losing the access contract from stage 2 of the game. From the solution in the nonbinding region derived in section 3.1 above it follows that stage 3 equilibrium prices are: $p_i^W = \frac{t}{3} + \frac{1}{2}a_i$, $p_j^L = \frac{t}{3} + \frac{3}{10}a_i$, and for the access seeker: $p_3 = \frac{t}{3} + \frac{7}{10}a_i$. The resulting market shares are $D_i^W = \frac{1}{3}$, $D_j^L = \frac{1}{3} + \frac{3a_i}{10t}$, $D_3 = \frac{1}{3} - \frac{3a_i}{10t}$.

Profit for the firm winning the access contract is: $\pi_i^W = p_i^W D_i^W + a_i D_3 = \frac{t}{9} + \frac{a_i(5t-3a_i)}{10t}$, with a maximum at $a_i = \frac{5t}{6}$and for the firm not winning the access contract $\pi_j^L = p_j^L D_j^L = \frac{t}{9} + \frac{a_i(20t+9a_i)}{100t}$ which is everywhere increasing in $a_i$. In the plot below we illustrate profits for the three firms as a function of the winning bid.[26] Profits are represented by the solid line for the firm winning the bid, the dashed line for the infrastructure firm not winning the bid, and the lower thin black line profits for firm 3, the access seeker. Finally, profits in the case where the access seeker is foreclosed from the market are represented by the upper horizontal dotted line.

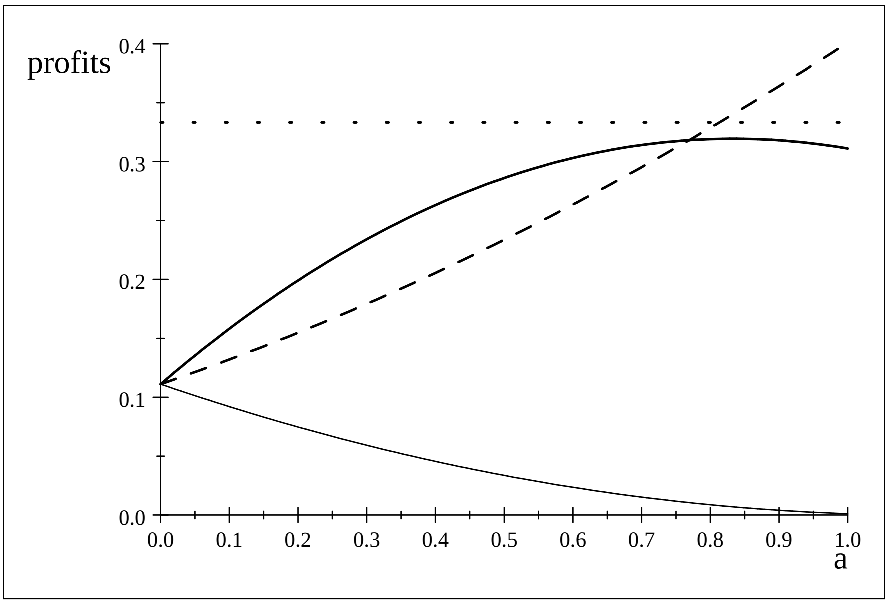



Figure 5: Profits as a function of the winning bid, parameter value: $t = 1$

Note first that in the absence of any form of regulatory intervention, there are three equilibria in this game. First of all, foreclosure: if the rival firm does not make a wholesale offer, the optimal response is to also abstain from making an offer.[27] The

[26] The figure is similar to figure 2 in Bourreau et al. (2011).

[27] The foreclosure profit graphed here assumes that the vertically integrated firms do not relocate. Foreclosure profits are even higher if the firms relocate.

second equilibrium is where the profit functions of the two vertically integrated firms intersect, and thus the two firms are indifferent to winning or loosing. Finally, the perfectly competitive outcome is also a Nash equilibrium. In this case, the access price is competed down to marginal costs, à la Bertrand.

Since we assume regulation such that firm 1 is mandated to make an access offering that firm 3 is willing to accept ($a_1 < \frac{10}{9}t$), the foreclosure equilibrium is eliminated by assumption. If the firm subject to the mandate to provide access offers the monopoly access price $a_1 = \frac{5}{6}t$, the optimal response for the nonregulated firm is to not underbid, since profits are higher for the firm not winning at this access price. This is accordingly an equilibrium candidate. This can be seen from the figure above: in the region where the solid line (profit if winning the contract) has a maximum, profit if losing the contract is higher (dashed line). This result is driven by the wholesale effect; the firm winning the contract competes relatively non-aggressively. This is a replication of the results in Bourreau et al. (2011), who argue that it is reason to expect the two vertically integrated firms to arrive at the equilibrium with a high access price since both firms obtain higher profits compared to the two other equilibrium candidates. Moreover, Bourreau et al. (2011) demonstrate that if the regulator sets a price cap below a threshold (the intersection point in the graph above), Bertrand competition for attracting the access seeker will be induced and the access price will be competed down to zero. This is because, to the left of the intersection point, the winning profit function is above the other function, hence optimal response is to marginally underbid.

The high price equilibrium is identical to the equilibrium in the nonbinding region in the previous section. In the competitive low equilibrium prices become: $p_1 = \frac{t}{3}, p_2 = \frac{t}{3}, p_3 = \frac{t}{3}$, hence consumer surplus is: $CS = v - \frac{13}{36}t$ if the access price is competed down to marginal cost (the "low equilibrium").

## 4.2 Margin regulation

Remember that the game analyzed in the following is highly asymmetric. Firm 1 is mandated to offer access, and firm 2 may make a counteroffer if it is in its interest or may choose to remain passive. If firm 2 wins the access contract, firm 1 is not constrained by margin regulation. This is in contrast with the game analyzed in Krämer and Schnurr (2018). They consider a symmetric game, where the firm winning the access contract is subject to margin squeeze regulation, whether it is firm 1 or firm 2.[28]

Assume $m \geq 0$. Profit, as a function of the access charge in the case where firm 1 wins the access contract, is analyzed in the previous section (topscript "$W$" for winning).

$$\pi_1^W(a_1) = \left\{ \begin{array}{ccc} \frac{t}{9} - \frac{3a_1^2}{10t} + \frac{a}{2} & \text{if} & a_1 \leq a^{crit} \\ \frac{1}{9t}\left(\frac{7a_1(5t-3a_1)}{5} + m\left(5t - 6\left(a_1 + m\right)\right)\right) & \text{if} & a_1 > a^{crit} \end{array} \right\}$$

In this case, profit for firm 2 is:

$$\pi_2^L(a_1) = \left\{ \begin{array}{ccc} \frac{(9a_1+10t)^2}{900t} & \text{if} & a_1 \leq a^{crit} \\ \frac{(21a_1+15m+10t)^2}{2025t} & \text{if} & a_1 > a^{crit} \end{array} \right\}$$

If firm 2 wins the access contract, the equilibrium is identical to the solution in the nonbinding region, where firms 1 and 2 change place, hence:

$$\begin{aligned} \pi_1^L(a_2) &= \frac{(9a_2 + 10t)^2}{900t} \\ \pi_2^W(a_2) &= \frac{t}{9} - \frac{3a_2^2}{10t} + \frac{a_2}{2} \end{aligned}$$

**Proposition 3:**

With margin regulation and $m \geq 0$, the monopoly solution where the regulated firm provides access at $a^m = \frac{5}{6}t - \frac{5}{7}m$ is an equilibrium candidate for any permissible $m$.

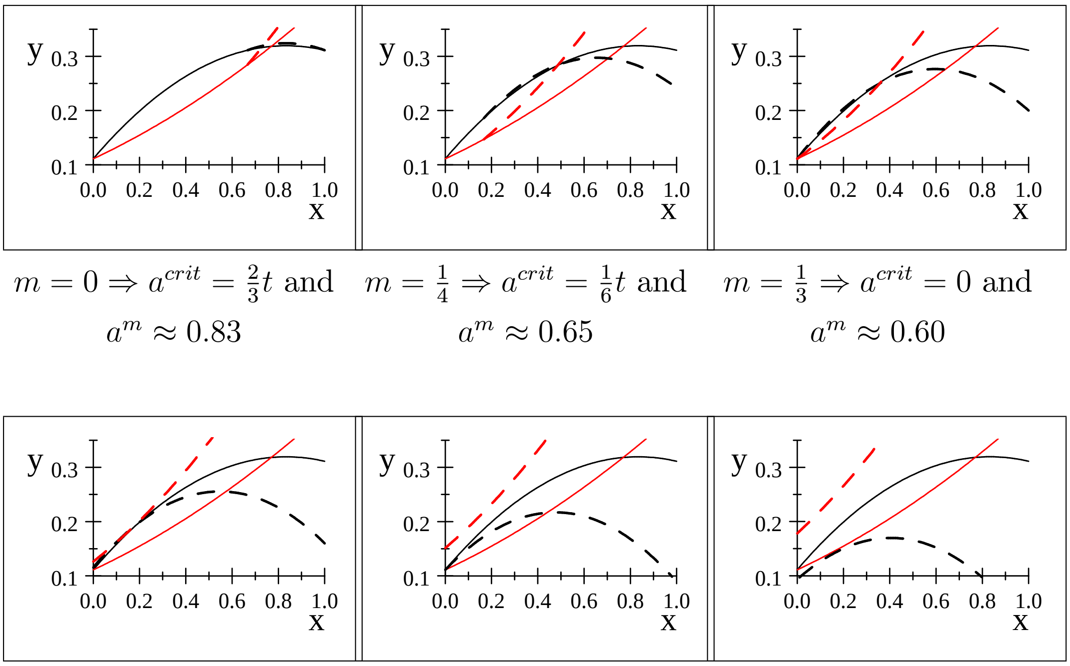
**Proof:**

Assume firm 1 sets the profit maximizing access price: $a_1 = a^m = \frac{5}{6}t - \frac{5}{7}m$, the solution to $\max\limits_{a_1}\left[\frac{1}{9t}\left(\frac{7a_1(5t-3a_1)}{5} + m\left(5t - 6\left(a_1 + m\right)\right)\right)\right]$. If the regulated firm sets the access price at this monopoly level, and assuming it indeed yields a solution in the binding region, firm 2 does not have an incentive to marginally undercut iff $0 < \pi_2^L(a^m) - \pi_2^W(a^m)$. Substituting for equilibrium prices, this expression simplifies

[28] Our assumption is arguably closer to the regulatory set-up under European telecommunications regulation where firms are designated as having a significant market position (SMP) or not having a SMP. Firms designated as SMPs are subject to regulatory constraints; other firms are not. Similarly, the firms subject to the nondiscrimination requirements under the DSM are designated as "gatekeepers". The status as respectively SMP and gatekeeper is typically reviewed every 3 years (see, e.g., European Union 2022 article 4).

to: $0 < \frac{35t}{648} + \frac{15}{98t}m^2$. Hence, if the regulated firm sets the monopoly price, the rival firm does not have an incentive to marginally underbid. Moreover, the profit function for firm 2, if winning, is concave since: $\frac{\partial}{\partial a_2}\left(\frac{\partial}{\partial a_2}\left(\frac{t}{9} - \frac{3a_2^2}{10t} + \frac{a_2}{2}\right)\right) = -\frac{3}{5t}$ and the maximum for this function is at $a_2 = \frac{5}{6}t$ since $\frac{\partial}{\partial a_2}\left(\frac{t}{9} - \frac{3a_2^2}{10t} + \frac{a_2}{2}\right) = -\frac{1}{10t}(6a_2 - 5t)$. Thus, any access offering lower than $a^m = \frac{5}{6}t - \frac{5}{7}m$ is on the upward sloping part of firm 2's profit function, hence firm 2 cannot obtain higher profits by making any counteroffer $a_2 < a^m$. A solution where the access price is $a_1 = \frac{5}{6}t - \frac{5}{7}m$ and where the regulated firm wins the access contract is accordingly a Nash equilibrium. QED

The equilibrium derived above is not necessarily unique, but, similar to the analysis in the previous section, these other equilibria, if they exist, yield lower profits for both firms. Hence, along the same line of argument as above, it is reason to expect the firms to arrive at the monopoly solution. This is illustrated in the six plots below where profits are plotted as a function of the access charge for different levels of the regulated margin. The black and red lines indicate profits for the firms winning and losing the access contract respectively. The solid lines are valid if regulation is nonbinding and the dashed lines are valid if regulation is binding.




$m = 0 \Rightarrow a^{crit} = \frac{2}{3}t$ and $a^m \approx 0.83$

$m = \frac{1}{4} \Rightarrow a^{crit} = \frac{1}{6}t$ and $a^m \approx 0.65$

$m = \frac{1}{3} \Rightarrow a^{crit} = 0$ and $a^m \approx 0.60$

$m = \frac{2}{5} \Rightarrow a^{crit} = 0$ and $a^m \approx 0.55$

$m = \frac{1}{2} \Rightarrow a^{crit} = 0$ and $a^m \approx 0.48$

$m = \frac{3}{5} \Rightarrow a^{crit} = 0$ and $a^m \approx 0.40$

Figure 6

The graphs above illustrate the result for proposition 3. Firm 1 is mandated to make an access offering and the optimal bid is accordingly the monopoly bid $a^m$ (maximum on the dashed black lines above). For all cases graphed above, profit for firm 2, if losing the access contract, (dashed red line) yields higher profits than does making a counteroffer at $a^m$. This is accordingly the equilibrium preferred by both firms.

Moreover, for $m \leq \frac{t}{3}$ the competitive outcome with access price $a = 0$ is also an equilibrium. If a firm offers an access price marginally above zero, the optimal response from the rival is to underbid. Access priced at zero is accordingly a Bertrand type equilibrium. For $m > \frac{t}{3}$ regulation binds, also for $a = 0$ and in such cases firm 2 strictly prefers to lose the access contract at $a = 0$. Thus, there is a continuum of equilibrium candidates $a \in [0, \widetilde{a}]$ where $\widetilde{a}$ is given by the solution to $\pi_2^W = \pi_2^{L\_b}$ (dashed red line intersects solid black line) where the solution exists, otherwise $\widetilde{a} = \frac{5}{2}m + \frac{5}{3}t$.[29] For any $a$ in this interval the nonregulated firm strictly prefer to let the regulated firm win the access contract. Hence, there are no competitive dynamics in this interval and any combination of bids where firm 1 marginally underbids firm 2 is a Nash equilibrium. Of course, both of the vertically integrated firms prefer the monopoly solution, over these other equilibrium candidates.

Note that in the case without margin regulation analyzed above there existed an equilibrium candidate with a relatively high access price, where both firms were indifferent between winning and loosing the contract (the red and black curve intersects). With margin regulation, this equilibrium does not exist due to the asymmetry of the game. With binding margin regulation the two firms are indifferent to winning or losing for different levels of $a$.

Thus, for any permissible $m$ i.e., $m \in \left[0, \frac{35}{54}t\right]$ the two infrastructure-based firms have a common interest in arriving at the monopoly outcome. Accordingly, it is reasonable to expect that they will indeed arrive at this solution rather than some other Nash equilibrium where access is priced at, or close to, marginal costs. The implication of the analysis above is that the regulator cannot induce wholesale competition between the infrastructure-based firms by setting a high (or low) margin. Moreover, the potential for wholesale competition does not have any impact on the market outcome as compared to wholesale monopoly. It follows that analysis of consumer surplus in this case is identical to the case with wholesale monopoly.

[29] $a < \frac{5}{2}m + \frac{5}{3}t$ ensures market share larger than zero for firm 3.

# 5 Concluding remarks

In this paper, we have analyzed the effects of the strictness of margin squeeze regulation in terms of the minimal permissible price-cost margin for an "as efficient" downstream competitor.

Stricter margin regulation stimulates entry, as higher price-cost margins reduce profitability thresholds in terms of, e.g., level of fixed costs or expected market shares for downstream firms. Therefore, strict regulation can potentially benefit consumers by increasing product variety and enhancing competition in the downstream market.

Whereas increased strictness stimulates entry, it also leads to softer competition and higher prices downstream. We identify feedback effects between regulation strictness and downstream competition. First, stricter regulation results in higher prices and softer competition downstream ("margin squeeze effect"). This leads to higher market shares for the downstream rival, leading to higher wholesale profits for the regulated firm. In turn, the regulated firm has a weaker incentive to compete for the downstream firm's customers, because lower market shares for the wholesale customer translate to lower wholesale profits for the regulated firm. This "wholesale effect" further weakens downstream competition.

Hence, the regulator faces a trade-off between facilitating entry and low prices to consumers.

One seemingly intuitive solution for a regulator to ensure both entry and efficient downstream competition is to facilitate wholesale competition between "dual mode" firms (where possible). However, the regulator cannot induce wholesale competition through margin squeeze regulation: a potential "dual mode" wholesale rival would avoid competing with a regulated firm. If the wholesale rival did indeed offer lower wholesale prices, this would intensify wholesale competition, which would subsequently reduce downstream prices and profits. Any gains in wholesale profits would be offset by reduced downstream profits. Foreseeing this, wholesalers refrain from competing at the wholesale level to maintain soft competition downstream.

Our research indicates that regulators need to strike the right balance between encouraging new entrants and promoting effective competition among existing firms. Moreover, if it is a goal to stimulate competition at the wholesale level, regulators should consider measures other than margin squeeze regulation.

The type of access regulation should fit the specific characteristics of the market in question. For instance, in the telecom industry, upstream investments are made possible by substantial infrastructure investments. The return on these investments is critically dependent on the expected profits from both retail and wholesale activities. Access regulations such as wholesale price caps could potentially decrease critical infrastructure investments, which could negatively impact consumers through decreased quality. In such a case, margin squeeze regulation, despite its identified drawbacks, may be a more suitable regulatory tool (if it is not overly strict).

In many digital markets, the primary barrier to entry is not high fixed costs, but network effects (demand-side economies of scale). In these cases, returns on investments are less crucial for ensuring efficient competition and product quality. Under such circumstances, access regulation in the form of price caps may be a preferred measure to promote competition at the wholesale and downstream levels.

# Appendix A: Consumer surplus

In this section, consumer surplus, as a function of retail prices, will be calculated. In the present model without vertical differentiation, costs normalized to zero, and the mass of consumers normalized to one, consumer surplus is simply: $CS() = v - \sum_{i=1}^{3} p_i D_i - TR()$ where $\sum_{i=1}^{3} p_i D_i$ is the transfer from consumers to producers, and $TR()$ is the sum of disutility from not consuming the most preferred variety; the "travelling costs".

Consider customers of firm $j$: The sum of traveling costs is $TR_j = \int_0^{s_{ji}} 3tx^2 dx + \int_0^{s_{jk}} 3tx^2 dx = ts_{ji}^3 + ts_{jk}^3$ where $s_{ji}$ $s_{jk}$ denotes traveling distance for the most distant consumers buying from firm $j$ on each side of firm $j$ on the Salop circle. The location of the most distant consumer is identical to the location of the indifferent consumer, and is a function of prices. Thus $s_{ji} = \frac{1}{6} - \frac{p_j - p_i}{2t}$. The sum of traveling costs across the three firms is accordingly:

$$\begin{aligned} TR &= t\left(s_{12}^3 + s_{13}^3 + s_{21}^3 + s_{23}^3 + s_{32}^3 + s_{31}^3\right) \\ &= t\begin{pmatrix} \left(\frac{1}{6} - \frac{p_1 - p_2}{2t}\right)^3 + \left(\frac{1}{6} - \frac{p_1 - p_3}{2t}\right)^3 + \left(\frac{1}{6} - \frac{p_2 - p_1}{2t}\right)^3 \\ + \left(\frac{1}{6} - \frac{p_2 - p_3}{2t}\right)^3 + \left(\frac{1}{6} - \frac{p_3 - p_2}{2t}\right)^3 + \left(\frac{1}{6} - \frac{p_3 - p_1}{2t}\right)^3 \end{pmatrix} \\ &= \frac{t}{36} + \frac{p_1^2 + p_2^2 + p_3^2 - p_1 p_2 - p_1 p_3 - p_2 p_3}{2t} \end{aligned}$$

Consumer surplus under entry deterrence can be calculated in a similar way:

Assuming that firms relocate if the market is foreclosed, consumer surplus, as a function of retail prices, can be written as $CS = v - \frac{t}{16} + \left[-\frac{p_1 + p_2}{2} + \frac{(p_1 - p_2)^2}{t}\right]$. In the proof to proposition 1 retail prices in the relevant intervals are calculated and it is then it straightforward to substitute them into the expression for consumer surplus as summarized in the table below:

| $m$ | $a$ | $p_1$ | $p_2$ | $CS$ |
|---|---|---|---|---|
| $m \le -\frac{13}{36}t$ | $\frac{10}{9}t$ | $\frac{3}{4}t$ | $\frac{3}{4}t$ | $v - \frac{13}{16}t$ |
| $m \in \left(-\frac{13}{36}t, -\frac{2}{9}t\right]$ | $\frac{10}{9}t$ | $\frac{10}{9}t + m$ | $\frac{1}{2}m + \frac{67}{72}t$ | $v - \frac{t}{16} + \frac{1296m^2 - 2952mt - 5123t^2}{5184t}$ |
| $m \in \left(-\frac{2}{9}t, 0\right)$ | $\frac{5}{2}m + \frac{5}{3}t$ | $\frac{5}{3}t + \frac{7}{2}m$ | $\frac{29}{24}t + \frac{7}{4}m$ | $v - \frac{t}{16} + \frac{7\left(252m^2 - 84mt - 101t^2\right)}{576t}$ |

# Appendix B: Competitive fringe model

In this section we will consider the same market structure as above, but with one notable change. We assume free entry of access-buying firms and that all these firms are located together with firm 3 on the Salop circle. Hence, there is no differentiation among the access buyers and they compete à la Bertrand, whereas the two infrastructure-based firms are horizontally differentiated both towards each other and towards the competitive fringe. It turns out that the condition for firm 1 (the regulated firm) to remain active in the retail market is more restrictive than in the main body of the paper. To be specific, in order to ensure that firm 1 is active in the downstream market we assume:

**Assumption (fringe model):** $m \leq \frac{5}{18}t$.

With homogenous goods and price competition within the competitive fringe, all these downstream firms charge the same competitive price: $p_f = a$ (where footscript $f$ indicate "fringe"). The timing of the game is the same as in the main body of the paper. At stage 1, the regulator sets a margin; at stage 2, the regulated firm sets the access price; and at stage 3, firms set retail prices and compete for customers. Accordingly, the only difference from the game analyzed above is that the best response function of firm 3 is replaced by the price set by the competitive price: $p_f = a$. Hence firm 2 has the response function $p_2 = \frac{t}{6} + \frac{p_1+p_f}{4}$ and firm 1 solves the same programing problem with the best responses $p_1 = m + a$ if margin regulation binds; otherwise the best response function is $p_1 = \frac{t}{6} + \frac{p_2+p_f}{4} + \frac{a}{4}$. Also, accordingly, in this case the best response function of firm 1 is piecewise linear. If the constraint binds (topscript $b$) the equilibrium is:

$$\begin{aligned} p_1^b &= a + m \\ p_2^b &= \frac{t}{6} + \frac{a}{2} + \frac{m}{4} \\ p_f^b &= a \end{aligned}$$

and if the constraint is not binding (topscript $nb$):

$$\begin{aligned} p_1^{nb} &= \frac{2t}{9} + \frac{3}{5}a \\ p_2^{nb} &= \frac{2t}{9} + \frac{2}{5}a \\ p_f^{nb} &= a \end{aligned}$$

Regulation binds if $p_1^{nb} - a \leq m$. Thus, the critical value for $a$ is: $a^{crit} = \frac{5}{9}t - \frac{5}{2}m$
At stage 2 of the game, firm 1 solves

$$\pi_1(a) = \left\{ \begin{array}{ccc} a\left(\frac{160}{225} - \frac{99a}{225t}\right) + \frac{4}{81}t & \text{if} & a \leq a^{crit} \\ a\left(\frac{5}{6} - \frac{2a+m}{4t}\right) + m\left(\frac{5}{12} - \frac{2a+7m}{8t}\right) & \text{if} & a > a^{crit} \end{array} \right\}$$

with the solution:

$$\begin{array}{rcc} a^{nb} = \frac{80}{99}t & \text{if} & a \leq a^{crit} \\ a^b = \frac{5}{6}t - \frac{1}{2}m & \text{if} & a > a^{crit} \end{array}$$

Regulation binds when $a^{nb} \geq a^{crit}$, hence $m \geq -\frac{10}{99}t$. Equilibrium prices in the binding region are:

$$\begin{aligned} a &= \frac{5}{6}t - \frac{1}{2}m \\ p_1 &= \frac{5}{6}t + \frac{1}{2}m \\ p_2 &= \frac{7}{12}t \\ p_f &= \frac{5}{6}t - \frac{1}{2}m \end{aligned}$$

It follows that market shares are: $D_1 = \frac{5}{24} - \frac{3m}{4t}$, $D_2 = \frac{14}{24}$ and $D_f = \frac{5}{24} + \frac{3m}{4t}$. Thus, the assumption above ensures that $D_1 > 0$ in equilibrium.

Firm 1 obtains profit in the nonbinding region:

$$\left[a\left(\frac{160}{225} - \frac{99a}{225t}\right) + \frac{4}{81}t\right]_{a=\frac{80}{99}t} = \frac{100}{297}t$$

This profit can be compared to profits under foreclosure. However foreclosure profits depend on whether the two vertically integrated firms relocate or not (see proposition 1 and footnote 13 in the main body of the paper) With relocation, foreclosure yields higher profits than serving the competitive fringe, and without relocation, serving the competitive fringe yields higher profits.

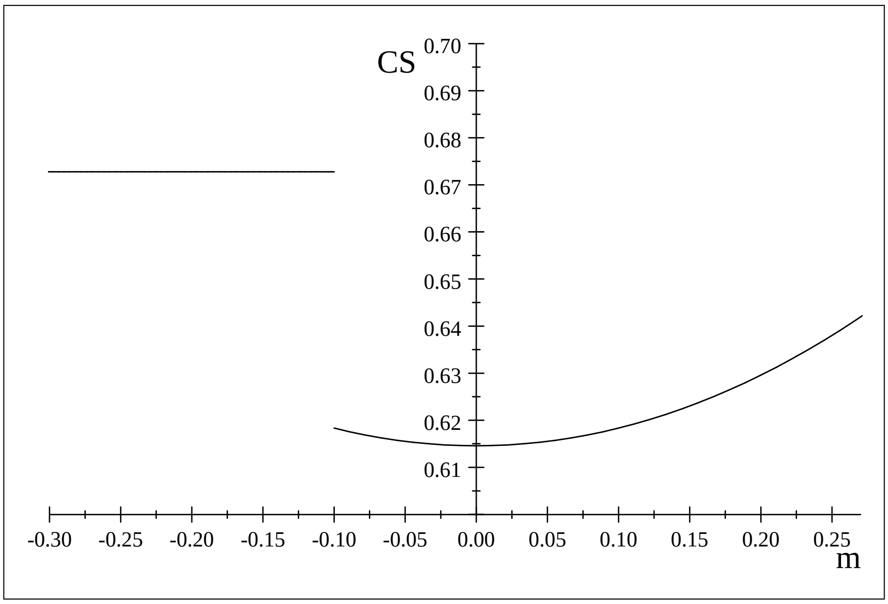
**Proposition (consumer surplus in fringe model)**

Consumer surplus is higher under nonbinding squeeze regulation and surplus has a minimum at $m = c$.

**Proof**

Substituting for prices consumer surplus in the binding region is: $CS^b = v - \frac{t}{36} + \frac{1}{32t}\left(12m^2 - 23t^2\right)$ and in the nonbinding region: $CS^{nb} = v - \frac{8995}{13\,068}t$. Thus, in the permissible region, $m \leq \frac{5}{18}t$, consumer surplus is higher in the nonbinding region. Moreover, we can directly see that, in the binding region, consumer surplus has a minimum at $m = 0$.

QED




Consumer surplus in the fringe model, $t = 1, v = \frac{49}{36}$

# Appendix C: Retail minus version of the model (monopoly)

In the retail minus case, there is no explicit access price in the optimization problem. The access price is always adjusted such that $a = p_1 - m$, i.e., as firm 1 changes its retail price, the access price changes correspondingly

**Proposition (retail minus)**

From the perspective of firm 1, the Stackelberg game yields higher profits than the retail minus game.

**Proof:**

In the retail minus game the best response function of firm 2 is the same as above. Firm 3 solves $0 = \frac{\partial}{\partial p_3}\left((p_3 - (p_1 - m))\left(\frac{1}{3} - \frac{2p_3 - p_1 - p_2}{2t}\right)\right)$, whereas firm 1 is now solving: $0 = \frac{\partial}{\partial p_1}\left(p_1\left(\frac{1}{3} - \frac{2p_1 - p_2 - p_3}{2t}\right) + (p_1 - m)\left(\frac{1}{3} - \frac{2p_3 - p_1 - p_2}{2t}\right)\right)$. The set of best response functions is accordingly:

$$\begin{aligned}
p_1 &= \frac{2}{3}t + p_2 - \frac{1}{2}p_3 - \frac{m}{2} \\
p_2 &= \frac{t}{6} + \frac{p_1 + p_3}{4} \\
p_3 &= \frac{t}{6} - \frac{m}{2} + \frac{3}{4}p_1 + \frac{1}{4}p_2
\end{aligned}$$

Solving the system of best response functions with respect to prices yields a characterization of equilibrium; $p_1 = \frac{70}{87}t - \frac{11m}{29}$, $p_2 = \frac{52}{87}t - \frac{9m}{29}$ and $p_3 = \frac{80}{87}t - \frac{25m}{29}$. Thus market shares become $D_1 = \frac{25}{87} - \frac{6m}{29t}$, $D_2 = \frac{52}{87} - \frac{9m}{29t}$ and $D_3 = \frac{10}{87} + \frac{15m}{29t}$ Profits for firm 1 in the retail minus game is accordingly

$$\pi_1^R = p_1 D_1 + (p_1 - m) D_3 = \frac{2450}{7569}t - \frac{15m}{841} - \frac{534m^2}{841t}$$

This profit level can be compared to profits in the Stackelberg game (in the binding region) $\pi_1^B = \frac{105}{324}t - \frac{3m^2}{7t}$:

$$\begin{aligned}
\pi_1^B - \pi_1^R &= \frac{105}{324}t - \frac{3m^2}{7t} - \left(\frac{2450}{7569}t - \frac{15m}{841} - \frac{534m^2}{841t}\right) \\
&= \frac{5}{635\,796t}(7t + 162m)^2 \geq 0
\end{aligned}$$

Thus, profits are higher in the Stackelberg game than in the retail minus game.

QED.

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