Margin Squeeze Regulation and Infrastructure Competition*

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Abstract

We investigate margin squeeze regulation in a market with infrastructure competition. To this end, we consider two integrated firms and one non-integrated retailer that compete in a horizontally differentiated retail market. The non-integrated firm relies on wholesale access provided by one of the integrated firms. Throughout several model variants we find that margin squeeze regulation lowers consumers' surplus. In reverse, firms are likely to benefit from margin squeeze regulation, because it leads to higher retail prices or facilitates tacit collusion. From a total welfare perspective, margin squeeze regulation is only beneficial if it prevents foreclosure of the retailer, but even then, this is due to increased industry profits and at the expense of consumers' surplus. These results question current European policy initiatives to augment the role of ex ante margin squeeze tests in sector-specific regulation.

Keywords: access regulation; vertical integration; open access; infrastructure competition; margin squeeze regulation; tacit collusion

JEL classification: L13; L40; L51

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1 Introduction

Margin squeezes can occur in markets where non-integrated downstream firms, which supply only retail goods, rely on wholesale access to an upstream good provided by a vertically integrated competitor. In this case, the integrated firm may be able to set the wholesale price such that it exceeds the margin between the retail price and the downstream costs of the non-integrated firm. In particular, by setting the wholesale price close to or even above its own retail price, the integrated firm may *squeeze the margin* of the downstream firm, and thus may ultimately induce its exit from the retail market, i.e., *foreclose* the non-integrated rival. Whether regulators or antitrust authorities should intervene in cases of margin squeeze conduct is controversial. European agencies and courts have qualified margin squeeze conduct as a stand-alone antitrust abuse (see the cases *Deutsche Telekom*, *Telefónica*, and *TeliaSonera*)[1], whereas US courts have dismissed allegations based on the margin squeeze rationale (see the cases *linkLine* and *Trinko*)[2].

Bouckaert and Verboven (2004) identify three types of margin squeezes according to the prevailing regulatory regime: regulatory price squeezes (i.e., if wholesale and retail prices are regulated), predatory price squeezes (i.e., if only wholesale prices are regulated), and foreclosure (i.e., if no prices are regulated). In this study, we consider the latter type, because in industries of competing vertically integrated firms margin squeeze regulation is considered as a potential substitute to access price regulation, and not as a complement to it. This is exemplified by the *ex ante economic replicability test* in the European Commission's (2013) Recommendation on consistent non-discrimination. The economic replicability test has been introduced as a regulatory instrument to fulfill non-

[1]See *Deutsche Telekom* (T-271/03, C-280/08), *Telefónica* (T-336/07, T-398/07 C-295/12) and *TeliaSonera* (C-52/09). Auf'mkolk (2012) reviews these cases and elaborates on the role of margin squeezes in European competition law. Moreover, Gaudin and Saavedra (2014) discuss margin squeezes regulation in European telecommunications markets.

[2]See *Pacific Bell Telephone Co. v. linkLine Communications, Inc.*, 555 U.S. 438 (2009) and *Verizon Communications Inc. v. Law Offices of Curtis V. Trinko, LLP*, 540 U.S. 398 (2004).

discrimination obligations in the context of next-generation access networks and aims at a balance between protecting competition and fostering investment incentives. Thus, the ex ante economic replicability test is more specific with respect to its application context and its implementation parameters (e.g., the relevant cost standard) than the margin squeeze test in ex-post competition law. However, as noted by Jaunaux and Lebourges (2015), "[f]rom an economic point of view [both tests] are based on the same principles" (p. 488). Whereas we focus on these more fundamental principles and abstract from several specific issues (especially we do not consider integrated firms' common costs), we specifically analyze the recommendation's conjecture that margin squeeze regulation is an effective regulatory instrument if applied in the context of infrastructure competition.

To this end, we scrutinize margin squeeze regulation in markets with more than one integrated firm producing the upstream good and consider a retail triopoly with two vertically integrated firms and one non-integrated downstream competitor. This setting captures any industry in which, on the one hand, some downstream firms rely on the input of a vertically integrated competitor, but, on the other hand, there exists more than one vertically integrated firm. In particular, the scenario of infrastructure competition *and* retail competition resembles the current state of many European telecommunications markets, where vertically integrated network operators compete with retailers that rely on network access as an input.

In this setting, we consider two different upstream market structures. First, as is common in European fixed line telecommunications markets, we consider a *wholesale monopoly*, where, despite the presence of two vertically integrated firms (e.g., DSL-based vs. cable-based network operators), only one (e.g., the DSL-based operator) will ever offer the input to the non-integrated retailer.[3] Second, we consider an alternative market structure with

[3]Note that in some countries, cable-based network operators have made wholesale access offers to independent retailers. However, in most fixed line telecommunications markets wholesale access is still provided monopolistically by the incumbent operator.

wholesale competition. This resembles more closely many mobile telecommunications markets, where at least two vertically integrated network operators make competing wholesale offers to mobile virtual network operators that do not operate their own network. gr In both market structures we consider the impact of margin squeeze regulation, which prohibits a vertically integrated firm to set the access price above its own retail price (neglecting marginal and common costs). According to this definition, an integrated firm, irrespective of its cost-efficiency, could not profitably participate in the retail market if it was required to pay its own wholesale price. We find that such regulation would diminish consumers' surplus and, in many cases, total welfare. Indeed, under both, wholesale monopoly and wholesale competition, margin squeeze regulation is never beneficial from a consumer welfare perspective, not even if margin squeeze regulation prevents the foreclosure of the non-integrated retailer. If margin squeeze regulation prevents foreclosure, i.e., for relatively homogeneous retail goods, it may be beneficial from a total welfare perspective. However, this positive effect on total welfare is due to higher industry profits, and at the expense of consumer welfare. Moreover, we show that for a wide range of parameter values, margin squeeze regulation increases the vertically integrated firms' incentives to tacitly collude on wholesale *and* retail prices in the presence of wholesale competition. Overall, our results strongly question the current initiative by the European Commission (2013) to augment the role of ex ante margin squeeze tests in the context of sector-specific regulation of telecommunications markets and infrastructure competition.

The remainder of this article is organized as follows. Next, we relate our study to the extant economic literature. In Section 3 we introduce the general market structure and model that is used to analyze the effect of margin squeeze regulation (MSR) in lieu of no regulation (NR). In Section 4 we study the case of a wholesale monopoly, whereas in Section 5 we investigate the case of wholesale competition. Finally, in Section 6 we conclude by discussing the policy implications and limitations of our model.

2 Related Literature

The extant economic literature on margin squeeze regulation focuses on market structures with a single integrated monopolist under different settings. First, starting from a setting with homogeneous retail goods, Jullien et al. (2014) point to ambiguous effects of banning margin squeezes: although wholesale prices decrease, retail prices may increase. In other words, non-integrated retailers benefit from margin squeeze regulation, whereas consumers may be worse off due to increased double marginalization. Second, Ergas et al. (2010) suggest that retail goods are not likely to be homogeneous and Petulowa and Saavedra (2014) show that with horizontally and vertically differentiated products the single integrated firm will only engage in a margin squeeze if its non-integrated competitor is more efficient. In this setting it is found that a margin squeeze ban induces an increase in the integrated firm's retail price, but nevertheless ultimately benefits consumers, because the retail price of the non-integrated firm decreases, provided that upstream market regulation is non-constraining. Third, in a market setting that resembles a fixed voice telephony market, Briglauer et al. (2011) demonstrate that increasing infrastructure competition from non-strategic rivals may elicit a margin squeeze depending on access price regulation.

In this study, we consider the impact of horizontally differentiated retail goods under infrastructure competition with strategic competitors and show that due to increased competitive pressure in the retail market, margin squeezes occur, also in the case when competitors are equally efficient.

The studies that are most closely related to ours are Höffler and Schmidt (2008) and Bourreau et al. (2011). On the one hand, Höffler and Schmidt (2008) also consider strategic interaction between infrastructure operators and retailers and show that, with differentiated retail goods, consumers' surplus decreases under *retail minus X* regulation, which is akin to a margin squeeze ban. However, when examining such regulation, they focus on a market structure with a wholesale monopoly. Moreover, unlike this paper, they do not consider the possibility of foreclosure, which, however, can constitute an equilibrium outcome, as noted by Bourreau et al. (2011) as well as Atiyas et al. (2015). Indeed, as highlighted by Bouckaert and Verboven (2004) and Gaudin and Mantzari (2016), foreclosure is a central concern with regard to margin squeeze conduct. That is, vertically integrated firms may strategically set excessive access prices, which induces negative profits of the non-integrated downstream firms and consequently their market exit. Therefore, our analysis will distinguish between this more severe *exclusionary* behavior (i.e., foreclosure) and simple *exploitative* margin squeeze conduct (Jullien et al., 2014), where the retailer remains active in the market.[4]

On the other hand, Bourreau et al. (2011) consider the same market structure as we do for the case of wholesale competition, but do not investigate the impact of margin squeeze regulation, which is our focus. Moreover, in addition to Bourreau et al. (2011) we also consider incentives to tacitly collude (on retail and wholesale prices) under wholesale competition both with and without margin squeeze regulation. Thus, our analysis is also related to Nocke and White (2007) and Normann (2009), who study the impact of vertical integration on firms' incentives to collude. Whereas both studies show that vertical integration increases collusion incentives compared to vertical separation, they do not study how such incentives may be affected by regulation. In markets where only few competitors are able to provide access to a wholesale resource, coordinated behavior may constitute a particular relevant issue (see, e.g., Ivaldi et al., 2003).

[4]We do not consider exclusionary strategies by vertically integrated firms which would require loss-making in the short run. Whereas such strategies could still be profitable in the long run (similar to a predatory pricing conduct), we focus on firms' strategies that are profitable without requiring any recoupment period.

3 The model

Consider the industry depicted in Figure 1 with two vertically integrated firms $i \in \{A, B\}$ and a non-integrated firm, D, which operates only in the downstream market. For each unit of its retail good, firm D is required to purchase a unit of the homogeneous upstream good, which firm i offers at price a_i. Without loss of generality, we denote the access provider as firm A and the non-access provider as firm B. In case of a wholesale monopoly, only firm A will make a wholesale offer a_A, whereas in case of wholesale competition, both firms make a wholesale offer, but firm D will always choose that firm as the access provider that offers the lower wholesale price.[5] Whenever differentiation between a_A and a_B is not necessary, we will simply refer to the access price as a. The retail price of firm $k \in \{A, B, D\}$ is p_k and its demand is denoted by q_k. In our analysis, we do not consider common costs and normalize firms' marginal costs to zero. Thus, a vertically integrated firm obtains a profit of

$$\pi_i = \begin{cases} p_i q_i + a_i q_D, & \text{if access provider,} \\ p_i q_i, & \text{if non-access provider,} \end{cases}$$

whereas the retailer obtains a profit of

$$\pi_D = \begin{cases} (p_D - a)\, q_D, & \text{if active,} \\ 0, & \text{if not active.} \end{cases}$$

We consider the representative consumer model suggested by Shubik and Levitan

[5]In case both integrated firms make the same wholesale offer, we assume that the retailer splits its demand equally between the integrated firms. Bourreau et al. (2011) show in their Online Appendix that this assumption yields the same results as under the alternative assumption that the retailer chooses one of the integrated firms as the sole access provider with equal probability. This is also true in our model with MSR, if one additionally assumes that the margin squeeze condition is binding for all integrated firms that offer the lowest retail price ex ante, i.e., independent of whether the integrated firm is chosen ex post.

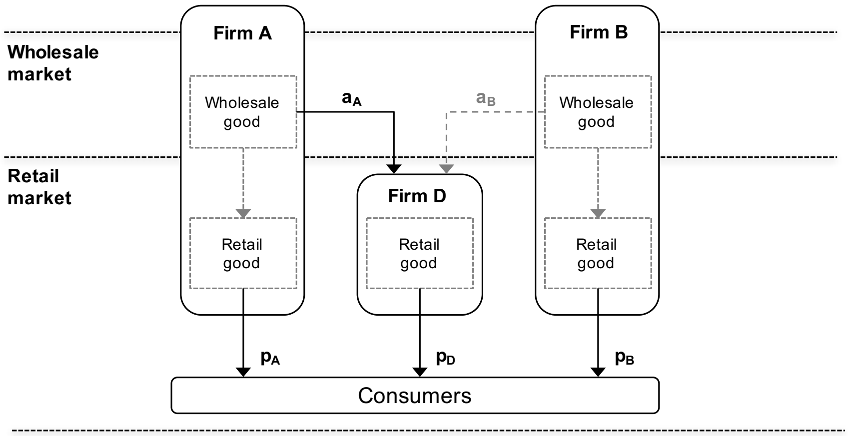


Figure 1: Market structure (based on Bourreau et al., 2011, p. 683).

(1980), so that retail goods are horizontally differentiated and demand for firm k's retail good is given by

$$q_k = \frac{1}{3}(1 - p_k - \gamma(p_k - \frac{p_A + p_B + p_D}{3}),$$

provided that none of the firms exits the downstream market (Höffler, 2008). Thereby, $\gamma \geq 0$ denotes the degree of substitutability so that high values indicate less differentiated retail goods. In contrast to the case of homogeneous retail goods, competition in differentiated goods requires to distinguish between a *margin squeeze* and *foreclosure* of the downstream firm. More specifically, even if firm A engages in a margin squeeze, i.e., $\Delta := p_A - a < 0$, firm D may still make a positive profit, because consumers value variety.[6] This allows firm D to set a price $p_D > a > p_A$ at which it still receives a positive demand and profit. If, however, the spread between firm A's wholesale and retail price exceeds a certain threshold that depends on the degree of substitutability, i.e., $\Delta < \underline{\Delta}(\gamma)$, firm D cannot make a positive profit and therefore exits the market, i.e., it is effectively foreclosed. In what follows, we also consider the integrated firms' incentives to strategically foreclose the downstream

[6]Note that in the case of infrastructure competition, there are additional measures of the retail price, such as the (demand-weighted) market average, which could serve as a reference point for the margin squeeze test. Yet, in this analysis, we follow the extant literature and current regulatory practice and base the margin squeeze rule on the integrated firms' own retail price (see, e.g., Gaudin and Saavedra, 2014; Jaunaux and Lebourges, 2015).

retailer, firm D, through a margin squeeze of $\Delta < \underline{\Delta}$. As will be seen later, whether this can be part of a subgame-perfect Nash equilibrium strategy also depends on the degree of substitutability, γ.[7]

In this vein, margin squeeze regulation serves two objectives: (i) to establish a level playing field by prescribing that no firm sets its retail price below its own wholesale price and (ii) to safeguard product variety by ensuring that non-integrated firms are not foreclosed from the market.

4 Wholesale monopoly

In this section, we consider the setting where only one of the vertically integrated firms may provide access to the retailer. This setting has previously been investigated in the context of MSR by Höffler and Schmidt (2008), but in our analysis we additionally consider possible foreclosure of the retailer. In practice, a wholesale monopoly may exist despite infrastructure competition, because only one infrastructure-based competitor is able to provide wholesale access due to technical constraints. For example, in fixed-line telecommunications markets, access to a DSL-based incumbent operator was deemed feasible based on physical unbundling of the local loop. Although, cable-based competitors can provide competing retail communications services, they do not offer wholesale access in most markets, because physical unbundling is deemed infeasible.

Under the assumption of a wholesale monopoly, the timing of the model is as follows:

Stage 1: Firm A sets the wholesale price a.

Stage 2: Firms A, B and D simultaneously set their retail prices p_A, p_B and p_D.[8]

[7] In practice, a retailer may exit the market even in cases, where short-run profits $\pi_D > 0$, but profits are too small, e.g., to absorb external shocks or to recover fixed costs. However, note that the presence of fixed costs does not change the incentive of the vertically integrated firm to strategically foreclose the entrant. Therefore, the threshold $\overline{\gamma}$, which we derive in Section 4 and 5 would not be affected by fixed costs or external profit shocks.

[8] In Appendix A.2 we consider quantity competition in Stage 2 instead of price competition, and show

The subgame-perfect equilibrium of this game is determined by backward induction for the case of NR, where firm A can set its prices freely, and for the case of MSR, where firm A must adhere to the constraint $\Delta \geq 0$.

For a welfare analysis of MSR in lieu of NR we do not only compare firms' prices p_k, quantities q_k, and profits π_k, but also producers' surplus, i.e., the sum of firms' profits,

$$PS = \sum_k \pi_k,$$

consumers' surplus, i.e., the representative consumer's net utility (Bouckaert and Kort, 2014)

$$CS = \sum_k q_k - \frac{3}{2(1+\gamma)}(\sum_k q_k^2 + \frac{\gamma}{3}(\sum_k q_k)^2) - \sum_k q_k p_k,$$

and total surplus $TS = PS + CS$.

In order to assess MSR relative to NR, we either report ratios $\phi X_k = \frac{X_k^{MSR}}{X_k^{NR}}$, or differences $\Delta X_k = X_k^{MSR} - X_k^{NR}$, where X is the market variable under investigation. In the following, we offer a sketch of the analysis and some intuition for the results, while the technical details are relegated to Appendix A.1.

Under NR, in Stage 2 all firms choose their retail prices given the wholesale price. In Stage 1, firm A decides on its wholesale price by trading off its profits when it does or does not make a viable wholesale offer to firm D. This trade-off is largely determined by the degree of differentiation, γ, in the retail market. If γ is low, i.e., the retail products of the access provider, A, and the access seeker, D, are very differentiated, then firm A benefits relatively more from selling wholesale access to firm D (*wholesale revenue effect*) than

that this yields similar results. Moreover, in Appendix B we explore an alternative timing with price competition, where firm D acts as a Stackelberg follower, setting its retail price subsequent to the retail prices of the vertically integrated incumbents. Under this timing the competitive position of firm D is weakened and thus, while firm A still engages in margin squeezes, it has no incentive to foreclose firm D. Thus, the role of MSR is more limited in this setting compared to the model presented in the main text, because there is no threat of market foreclosure.

it suffers from the increased competition by firm D in the downstream market (*business stealing effect*). Thus, for low γ, firm A has no incentive to foreclose firm D from the downstream market. On the contrary, Bourreau et al. (2011) and Atiyas et al. (2015) show that firm A prefers foreclosure of firm D if $\gamma > \overline{\gamma} := 26.77$. In this case, firm A sets a foreclosure wholesale price of $a^{NR} > \frac{5\gamma+6}{\gamma^2+7\gamma+6}$. Moreover, whenever firm A provides access to firm D, the non-access providing firm B will set a lower retail price than firm A. This is due to the *softening effect* (Bourreau et al., 2011; Fudenberg and Tirole, 1984), which occurs because firm B can be more aggressive in the retail market as it does not need to trade off wholesale revenues against retail revenues like firm A. Hence, the softening effect disappears for $\gamma > \overline{\gamma}$ when firm D is foreclosed, and both integrated firms charge identical retail prices.

The left panel of Figure 2 depicts ensuing equilibrium retail prices. In particular, notice that even if firm A makes a viable wholesale offer, it will engage in a margin squeeze for $\gamma \in (3, \overline{\gamma}]$. Moreover, it can be shown (see Appendix A.1) that for $\gamma \leq 3$ under NR neither foreclosure nor margin squeeze occurs. Consequently, under MSR the margin squeeze condition is binding iff $\gamma > 3$. Also note that MSR effectively prevents foreclosure of firm D for $\gamma > \overline{\gamma}$, because firm A is now required to make a viable wholesale offer. The resulting equilibrium prices under MSR are shown in the right panel of Figure 2.

Figure 3a depicts the net effect of MSR relative to NR on prices, quantities, and profits. Three cases must be differentiated here. First, if retail goods are highly differentiated (i.e., $\gamma \leq 3$), margin squeeze does not occur in equilibrium, and hence MSR has evidently no effect. Second, in the intermediate case when $3 < \gamma \leq \overline{\gamma}$ and foreclosure is not an equilibrium, MSR induces the access provider A to reduce its wholesale price relative to NR. However, notice that in this case all firms, and in particular also firm D ultimately increase their retail price. This is because in order to meet the MSR firm A does not only lower its wholesale price, but also increases its retail price. This in turn induces firm B and firm D

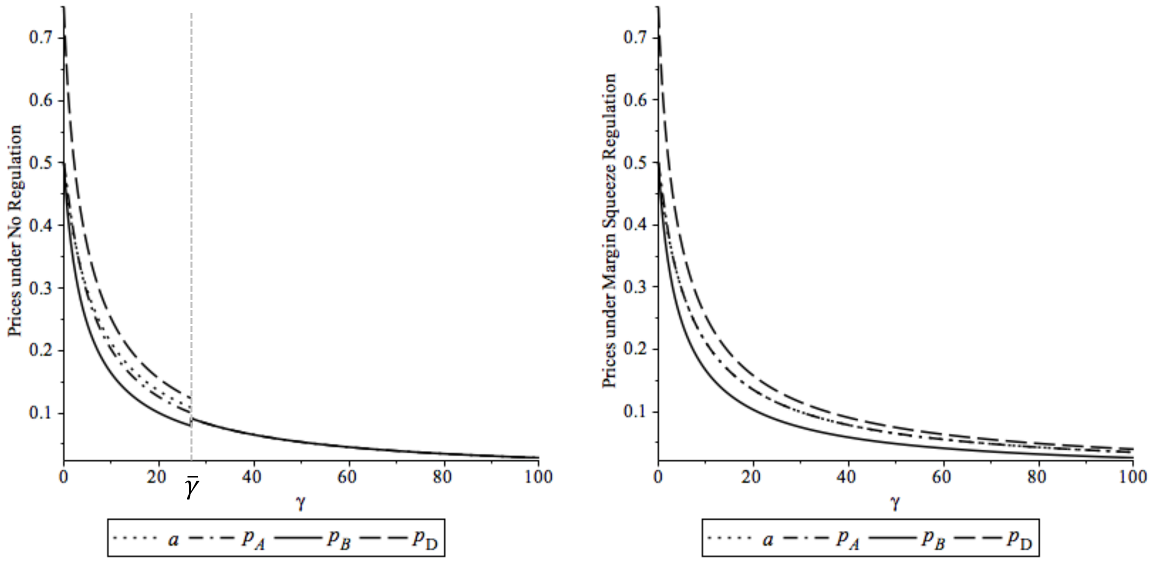
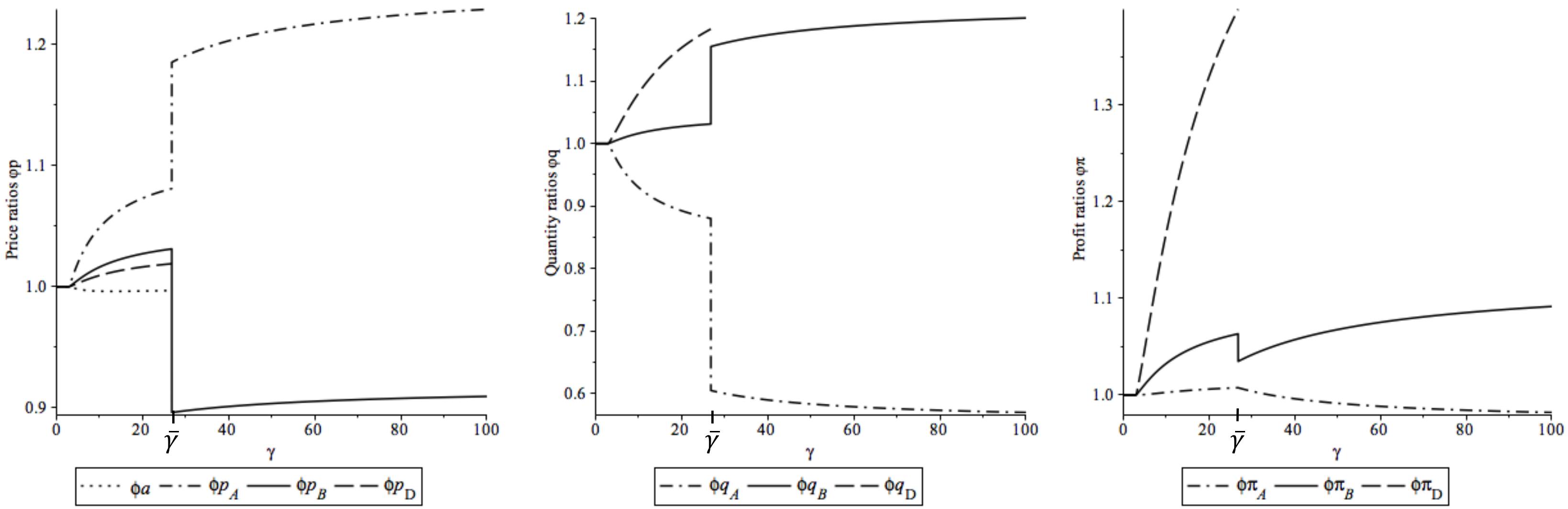


Figure 2: Equilibrium prices under NR and MSR. Under NR a margin squeeze occurs for $\gamma \in (3, \overline{\gamma}]$, and the retailer is strategically foreclosed for $\gamma > \overline{\gamma} = 26.77$. Under MSR, by definition, neither margin squeeze nor foreclosure can occur.

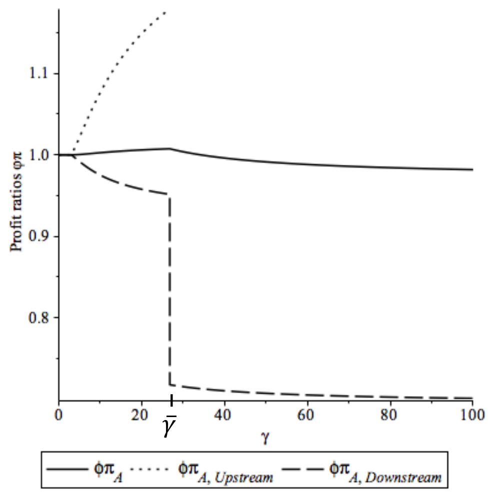
to increase their retail prices as well, because downstream prices of the integrated firms are strategic complements. This demonstrates that MSR can even allow *all* firms to attain higher prices and profits. Third, if retail goods are even less differentiated, i.e., $\gamma > \overline{\gamma}$, the MSR prevents foreclosure. Again, in an effort to meet the MSR, firm A increases its retail price relative to NR, yet firm B will eventually lower its retail price, because, unlike under NR, firm D now remains in the market. In terms of absolute retail price levels, the wholesale profit, business stealing, and softening effects are qualitatively the same as under NR and therefore the order of equilibrium prices is preserved (see the right panel of Figure 2).

For relatively differentiated retail goods, MSR unambiguously increases firms' profits. Since MSR prevents firm D's foreclosure or allows it to set a higher retail price, it is strictly better off under MSR. Likewise firm B, the non-access provider, benefits from the fact that firm A is less aggressive in the retail market under MSR, even in those cases where firm D would have been foreclosed under NR. For firm A, its increased wholesale profit under

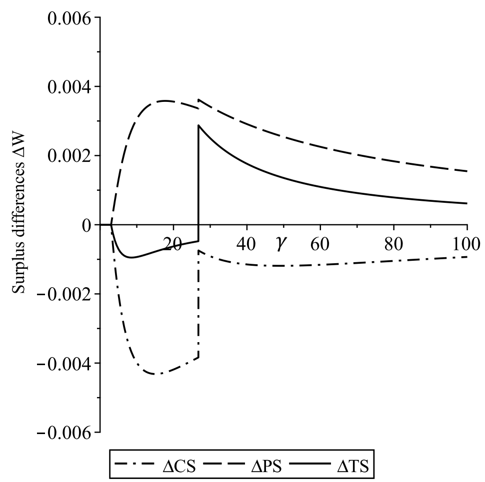
Figure 3: MSR effect on market variables under infrastructure competition with wholesale monopoly.



(a) Firms' prices, quantities, and profits.



(b) Firm A's total, upstream, and downstream profits.



(c) Consumers' surplus, producers' surplus, and total surplus.

MSR outweighs its loss in retail profit if $\gamma \in (3, 34.20)$. However, if $\gamma > 34.20$ and retail goods are very close substitutes, increased competition by firm D leads to overall lower profits for firm A (see Figure 3b). Against this backdrop, it is therefore not surprising that overall producers' surplus increases, whereas consumers' surplus decreases over the whole range of $\gamma > 3$, where the MSR is binding (see Figure 3c). Remarkably, the increase in producers' surplus compensates the loss in consumers' surplus, yielding an increase in total surplus for $\gamma > \overline{\gamma}$. Thus, MSR is beneficial from a total welfare perspective in case of foreclosure—however, this effect emerges from increased producers' surplus, and not from increased consumers' surplus.

5 Wholesale competition

Under the assumption that both vertically integrated firms potentially make viable wholesale offers, the timing of the model is as follows:

Stage 1: Firm A and firm B simultaneously set their wholesale prices a_A and a_B. Then firm D chooses its wholesale provider.

Stage 2: Firms A, B and D simultaneously set their retail prices p_A, p_B and p_D.

In order to follow the extant literature we distinguish between the case where the retailer firm D must always be supplied by at least one integrated firm (as assumed by Bourreau et al., 2011), and the case where foreclosure is possible (as assumed by Atiyas et al., 2015).

5.1 No foreclosure of the retailer

When firm D is not foreclosed Bourreau et al. (2011) show that wholesale competition under NR does not necessarily lead to a perfectly competitive wholesale price, i.e., $a_A = a_B = 0$ in our case. This is remarkable, because the integrated firms are assumed to offer

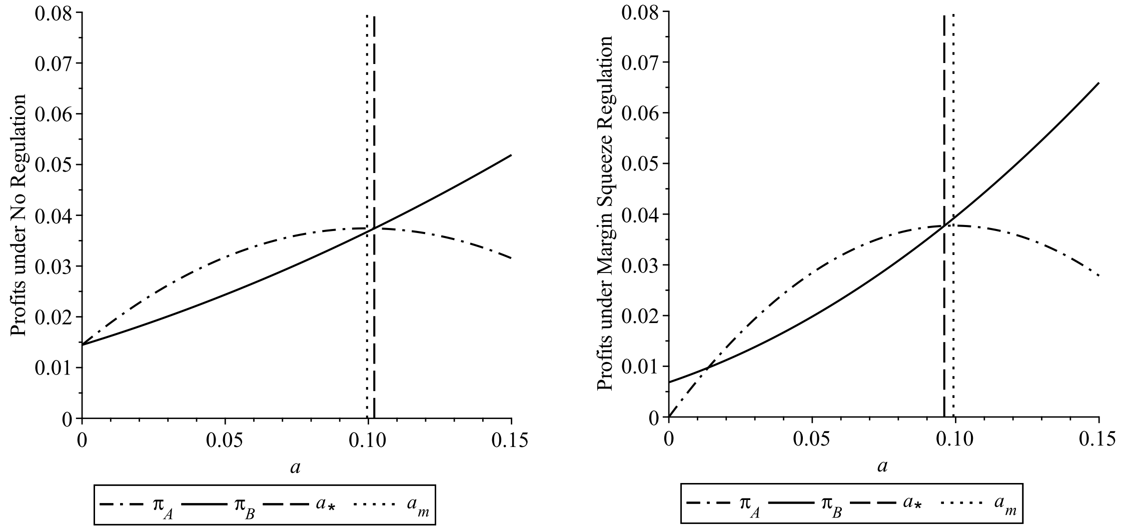


Figure 4: Profits of integrated firms depending on the access price under NR and MSR for $\gamma = 30$, assuming that firm A is the sole access provider. Under NR only the competitive wholesale equilibrium at $a_0 = 0$ exists, because $a_*^{NR} > a_m^{NR}$. In contrast, under MSR $a_*^{MSR} < a_m^{MSR}$, so that additionally the matching-like equilibrium at a_*^{MSR} as well as the monopoly-like equilibrium at a_m^{MSR} exist.

a homogeneous wholesale good and compete à la Bertrand. Specifically, if retail goods are relatively homogeneous, i.e., $\gamma \geq \widetilde{\gamma}^{NR} := 40.97$, two other types of equilibria may arise in addition to the competitive equilibrium, denoted by $a_0 = 0$: First, a matching-like equilibrium, a_*^{NR}, with $a_A = a_B > 0$ can occur, which is characterized by the fact that the access provider and the non-access provider make the same equilibrium profit. Second, two monopoly-like equilibria, a_m^{NR}, with $a_A > a_*^{NR}$ and $a_B > a_*^{NR}$ can occur, where only one integrated firm seeks to supply the retailer at the monopoly wholesale price a_m^{NR} and the other integrated firm is not willing to undercut this wholesale price. Bourreau et al. (2011) also show that, when monopoly-like equilibria exist, they Pareto-dominate all other equilibria in terms of the integrated firms' profits. Therefore, like Bourreau et al. (2011), we assume that the integrated firms choose one of the monopoly-like equilibria if they exist. Yet, since other equilibria do exist, this can be seen as a reasonable worst-case assumption.

Based on these insights, we now investigate the equilibria that may arise under MSR. In particular, we are interested whether monopoly-like equilibria can still arise under MSR. Following the logic of Bourreau et al. (2011), monopoly-like and matching-like equilibria under MSR can only exist if $a_*^{MSR} < a_m^{MSR}$, where a_*^{MSR} is the access price for which an integrated firm is indifferent between providing access and not providing access under MSR, and a_m^{MSR} is the monopoly wholesale price under MSR. Solving this inequality for γ yields that monopoly-like and matching-like equilbria exist for $\gamma \geq \widetilde{\gamma}^{MSR} := 20.55$. Notice that $\widetilde{\gamma}^{MSR} < \widetilde{\gamma}^{NR}$, which means that monopoly-like and matching-like equilibria emerge already for lower degrees of substitution under MSR than under NR. In other words, the application of MSR renders larger support for the emergence of other subgame-perfect equilibria, and specifically the monopoly-like equilibrium, in addition to the competitive equilibrium. This is illustrated in Figure 4, which displays the integrated firms' profits under NR (left panel) and MSR (right panel) for $\gamma = 30$ when there is a single access provider (here firm A). In the left panel, at $\gamma = 30$ it follows that $a_*^{NR} > a_m^{NR}$ so that only the competitive wholesale equilibrium at $a_0^{NR} = 0$ exists. In the right panel, for the same value of γ, it follows that $a_*^{MSR} < a_m^{MSR}$ such that all three types of equilibria, and in particular the monopoly-like equilibria exist.

Figure 5 depicts equilibrium prices under NR and MSR assuming that the monopoly-like equilibria are chosen, if they exist. For $\gamma < \widetilde{\gamma}$ only the competitive equilibrium exists, so that integrated firms do not make any profits in the wholesale market. Consequently, there are no wholesale revenue or softening effects, such that all three firms set identical retail prices. For $\gamma \geq \widetilde{\gamma}$, the access provider sets a monopoly access price (constrained by the margin squeeze condition in case of MSR), and thus the wholesale revenue and softening effects emerge, such that the usual order of prices prevails.

Comparing the net effect of MSR relative to NR in terms of firms' prices, quantities and profits as well as welfare differences, three parameter regions for γ must be differentiated.

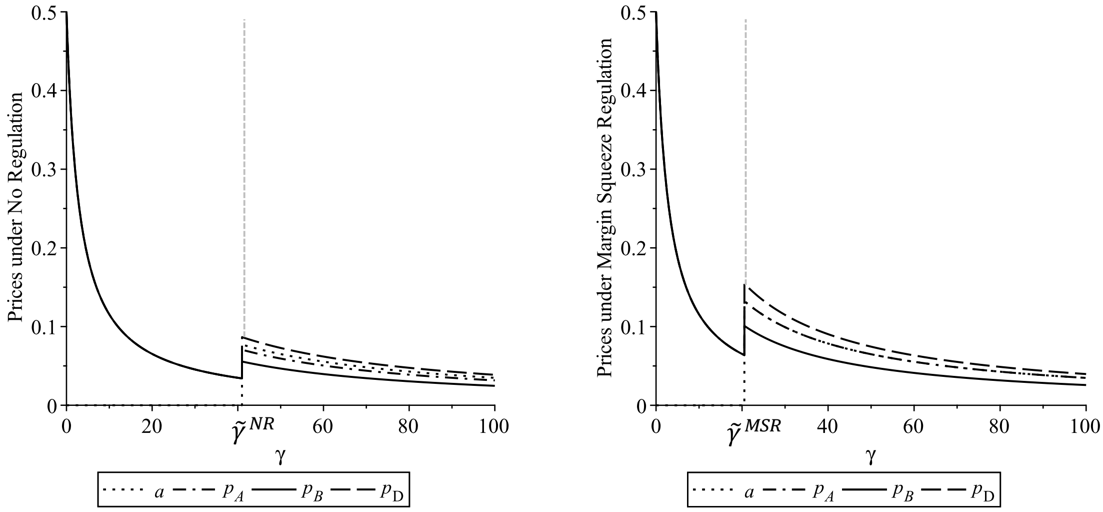
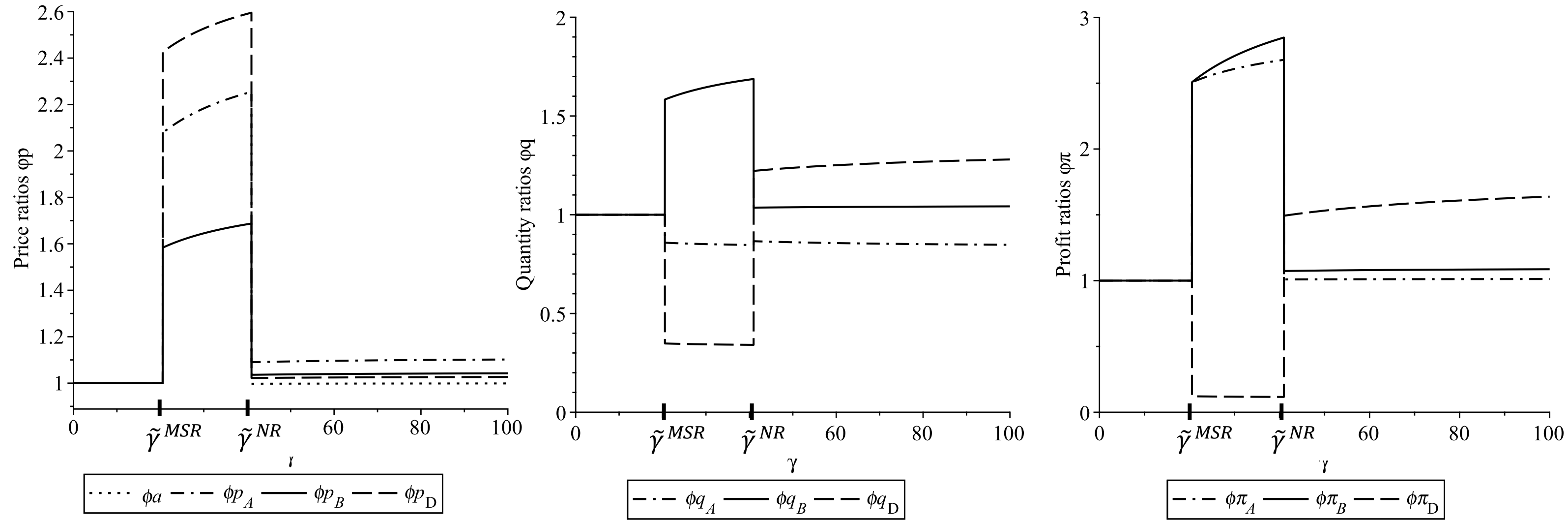


Figure 5: Equilibrium prices under NR and MSR in case of wholesale competition without foreclosure. For $\gamma > \widetilde{\gamma}$ monopoly-like equilibria exist and are assumed to be chosen by the integrated firms.

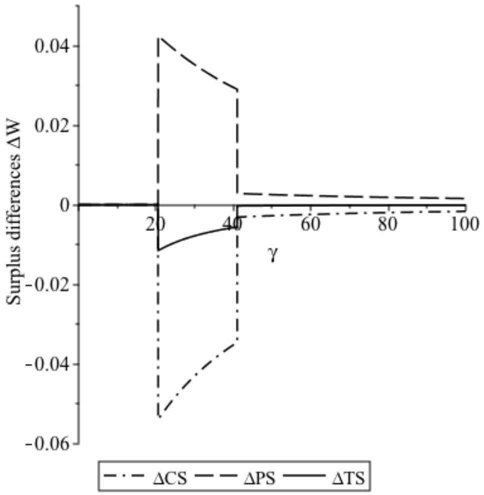
First, for $\gamma < \widetilde{\gamma}^{MSR}$, MSR has no effect, because only the competitive equilibrium exists under both regimes, such that no margin squeezes occur. Second, for $\widetilde{\gamma}^{MSR} \leq \gamma < \widetilde{\gamma}^{NR}$ MSR allows monopoly-like wholesale equilibria to emerge, although these were not equilibrium outcomes under NR. Consequently, in this parameter region, MSR raises retail prices (see Figure 6a), and increases producers' surplus to the detriment of consumers' surplus (see Figure 6b and, for a close-up, Figure 6c). Third, for $\gamma \geq \widetilde{\gamma}^{NR}$ both under NR and MSR monopoly-like wholesale equilibria exist. Not surprisingly, here the effect of MSR is similar as under wholesale monopoly studied in Section 4. In order to meet the MSR, the access provider, firm A, slightly lowers its wholesale price, but also increases its retail price. In this parameter region, the net effect of the MSR on total surplus is negative.

In summary, across all values for γ, MSR either has no effect, or tends to increase prices and producers' surplus, while it lowers consumers' and total surplus.

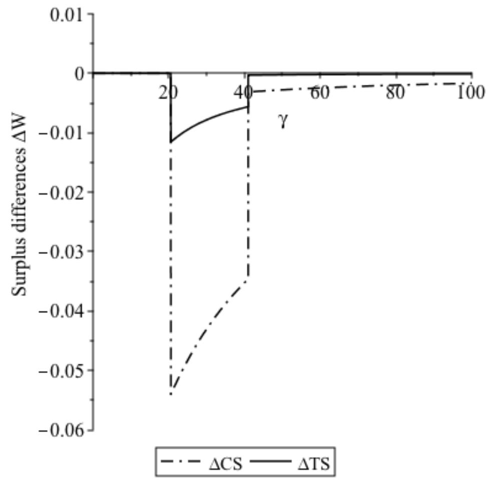
Figure 6: MSR effect on market variables under wholesale competition without foreclosure.



(a) Firms' prices, quantities, and profits.



(b) Consumers' surplus, producers' surplus, and total surplus.



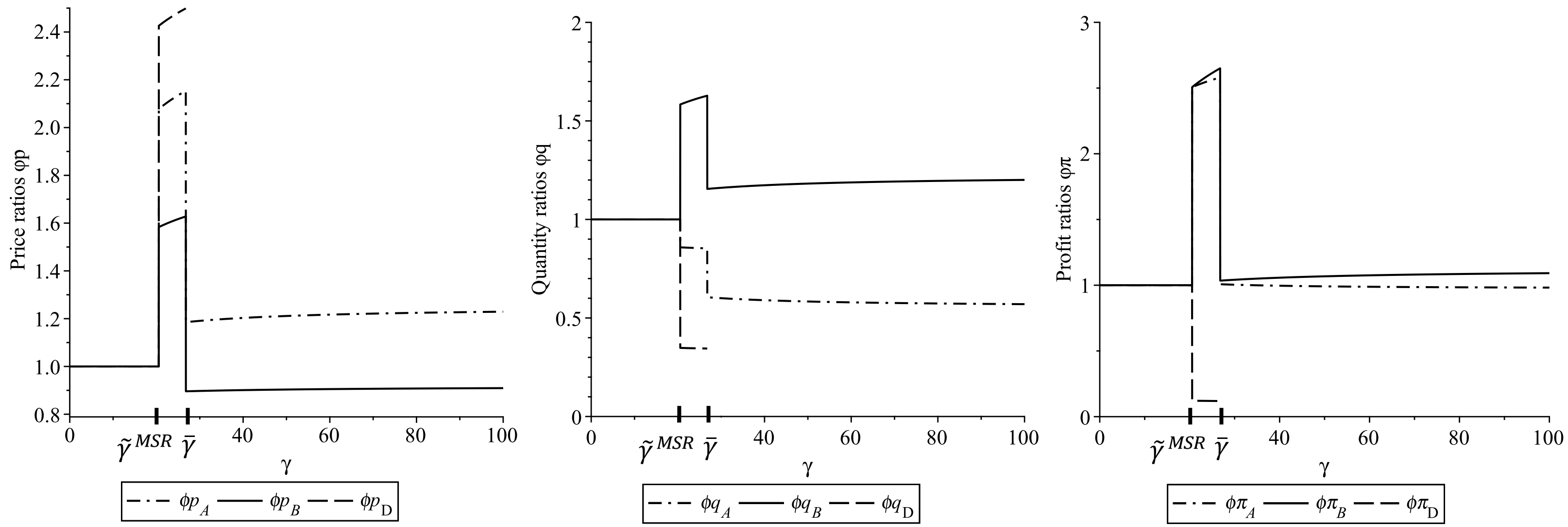
(c) Consumers' surplus and total surplus.

5.2 Possible foreclosure of the retailer

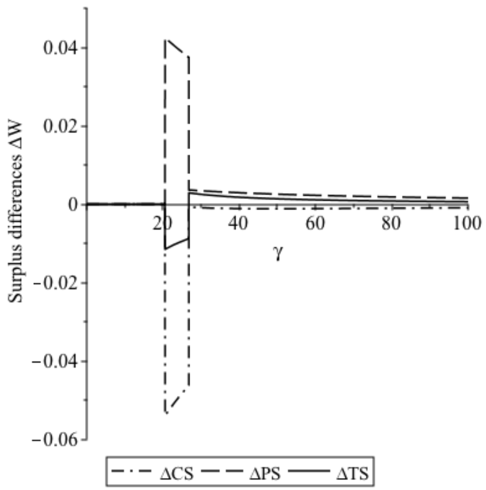
As shown in Section 4, under infrastructure competition with wholesale monopoly, the access provider prefers to foreclose the non-integrated downstream retailer whenever $\gamma > \overline{\gamma} = 26.77$. Evidently, in the case of wholesale competition, foreclosure implies that, provided one of the integrated firms does not make a viable wholesale offer, the other integrated firm also does not wish to make a viable wholesale offer. Consequently, the same rationale as under a wholesale monopoly (see Section 4) also applies here, and therefore, foreclosure under wholesale competition occurs precisely at the same threshold $\gamma > \overline{\gamma} = 26.77$ as under a wholesale monopoly. Moreover, recall that under MSR, monopoly-like equilibria emerge already for $\gamma \in [\widetilde{\gamma}^{MSR}, \overline{\gamma}]$ with $\widetilde{\gamma}^{MSR} = 20.55$.

The effect of MSR can now be readily deduced from our previous insights. Again, we must differentiate three parameter regions for γ and the results are summarized in Figure 7. First, as in Section 5.1, MSR has no effect if retail goods are relatively differentiated, i.e., $\gamma < \widetilde{\gamma}^{MSR} = 20.55$. Second, for $\widetilde{\gamma}^{MSR} \leq \gamma \leq \overline{\gamma}$, MSR facilitates the emergence of monopoly-like equilibria and leads to an increase in prices and producers' surplus, and to a decrease in consumers' and total surplus. Third, for $\gamma > \overline{\gamma}$, MSR prevents foreclosure of the retailer. Here, the effect is the same as in Section 4 and MSR indeed leads to an increase in total surplus, but to a decrease in consumers' surplus (cf. also Figure 3c in the same parameter region). In conclusion, as in the previous scenarios, MSR may only improve total surplus if otherwise, under NR, the retailer would have been foreclosed. This again, may only occur if retail goods are relatively homogeneous, i.e., $\gamma > \overline{\gamma} = 26.77$. In contrast, consumers are always worse off due to higher prices under MSR, even if regulation prevents foreclosure of the retailer.

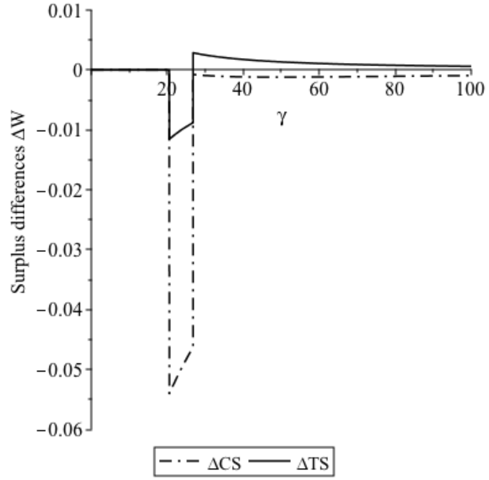
Figure 7: MSR effect on market variables in the scenario with wholesale competition and possible foreclosure.



(a) Firms' prices, quantities, and profits.



(b) Consumers' surplus, producers' surplus, and total surplus.



(c) Consumers' surplus and total surplus.

5.3 Tacit collusion between integrated firms

We conclude our analysis by studying the incentives of the vertically integrated firms to tacitly collude on wholesale and retail prices based on the critical discount factor δ (as in Nocke and White, 2007; Normann, 2009). Specifically, we study an integrated firm's incentives to deviate from a collusive outcome in case the above detailed two-stage game would be infinitely repeated. Thereby, as in Friedman (1971), we assume grim trigger strategies in which a firm punishes the other firm's deviation from a collusive state with reversion to the competitive Nash equilibrium ad infinitum. Then, firms' individual critical discount factors that support collusive behavior as a subgame-perfect Nash equilibrium can be computed as $\delta_i = \frac{\pi_i^{Dev} - \pi_i^{Collusion}}{\pi_i^{Dev} - \pi_i^{Punish}}$, where $\pi_i^{Collusion}$ denotes firm i's collusive profit, π_i^{Dev} is the maximum profit that an integrated firm can achieve by unilateral deviation from the collusive state, and π_i^{Punish} is an integrated firm's profit in periods after deviation. Then, the critical discount factor is $\delta = min\{\delta_A, \delta_B\}$. Note that a lower critical discount factor c.p. signifies a higher incentive for tacit collusion.

Again, we only discuss the main insights here and relegate all technical details to Appendix C. In the collusive outcome, firm A and firm B maximize their joint profit by setting wholesale and retail prices like a single multi-product monopolist with two retail goods. We denote these collusive prices by $a_i^{Collusion}$ and $p_i^{Collusion}$, respectively. It can be shown that $a_i^{Collusion} < p_i^{Collusion}$ for $\gamma > 0$, so that the collusive profits are identical under NR and MSR.

Moreover, note that both under NR and MSR the most severe punishment that is supported in a Nash equilibrium is given by playing the competitive wholesale equilibrium, where $a_A = a_B = 0$, which renders firms symmetric in the retail market. Thus, under NR and MSR every firm obtains the same punishment profit.

However, as we will show next, the deviation profits differ under NR and MSR. In general, an integrated firm can deviate from the collusive state either in the first stage, by lowering the wholesale price, or in the second stage, by lowering the retail price. In the former case, the vertically integrated rival will react already in the second stage of the same supergame period by setting the retail price according to its non-cooperative best response price, and will then execute the punishment action (i.e., play the competitive Nash equilibrium) in every supergame period that follows. In the latter case, the punishment can only begin in the first stage of the subsequent supergame period, i.e., when setting the wholesale price.

It can be shown that under NR, *if* a firm chooses to deviate, it will do so in the wholesale stage (Stage 1) for $\gamma < \widehat{\gamma}^{NR} = 1.96$, and otherwise it will deviate in the retail stage (Stage 2). However, in either case the prices of a deviating firm violate the margin squeeze condition, such that the MSR would become binding here. Consequently, under MSR, a deviating firm has two options: Either it deviates in the retail stage by lowering its retail price to the collusive access price, or it deviates in the wholesale stage by setting the constrained monopoly access price (as in Section 4). Again, it can be shown that under MSR a firm will deviate in the wholesale stage if $\gamma < \widehat{\gamma}^{MSR} = 2.34$, and deviate in the retail stage otherwise. Note that $\widehat{\gamma}^{MSR} > \widehat{\gamma}^{NR}$, i.e., under MSR an integrated firm is more likely to deviate in the wholesale market.

Based on these insights, the critical discount factors can be computed depending on γ (see Appendix C), and the results are summarized in Figure 8. For $\gamma < \widehat{\gamma}^{NR} = 1.96$ the critical discount factor is (slightly) higher under MSR, i.e., collusion incentives are lower compared to NR. This effect is so small that it is not discernible in Figure 8. In reverse, for $\gamma > \widehat{\gamma}^{NR}$ the critical discount factor is (substantially) lower under MSR, such that collusion incentives are (substantially) higher compared to NR. In other words, if the margin squeeze condition reduces the deviation profit of an integrated firm by stipulating a lower limit for the firm's retail price, this is likely to foster incentives for tacit collusion. In fact, MSR is ineffective in reducing the collusive profit of the vertically integrated firms, because the

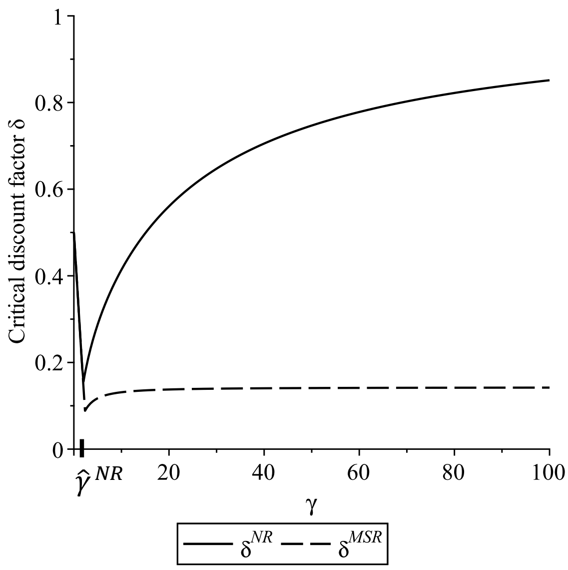


Figure 8: Critical discount factors under NR and MSR. For $\gamma > \widehat{\gamma}^{NR} = 1.96$ the critical discount factor is (substantially) lower under MSR, such that collusion incentives are (substantially) higher compared to NR.

price structure that maximizes industry profit does not violate the margin squeeze condition for any degree of substitutability. Therefore, also in the context of tacit collusion, MSR is likely to have a detrimental effect on consumers' surplus.

6 Discussion and Conclusions

This study scrutinizes margin squeeze regulation in the presence of infrastructure competition under both monopolistic and duopolistic wholesale provision. More specifically, we consider two integrated firms and one non-integrated firm that depends on the wholesale good as an input to produce its retail good. In contrast to a market with a single integrated firm, it is shown that under infrastructure competition the access provider may engage in a margin squeeze also in the case of an equally efficient retailer. Our central finding is that margin squeeze regulation is detrimental to consumers, irrespective of the substitutability of retail goods, and irrespective whether the wholesale input is provided monopolistically or competitively. Moreover, under MSR total surplus may only increase if MSR indeed prevents foreclosure of the independent retailer, and lowers total surplus in all other cases. But even if total surplus increases, this is due to higher industry profits and at the expense of consumers' surplus.

In reverse, this means that margin squeeze regulation predominantly benefits each of the firms individually. The only exception is that the access provider may be worse off under the regulation if and only if it wants to foreclose the downstream firm, i.e., if the retail goods are close substitutes. In this case, the access provider makes less profit than the integrated non-access provider, which is likely to evoke non-price discrimination (cf. Mandy and Sappington, 2007).

These findings bear important policy implications. Many antitrust investigations of margin squeezes and corresponding regulation are enacted in markets where multiple integrated firms produce an upstream input good, i.e., in industries with infrastructure competition next to service-based downstream competition. In fact, the European Commission (2013) states that infrastructure competition is a necessary condition for margin squeeze regulation to replace traditional access price regulation. The rationale behind this is that infrastructure competition would constrain retail prices and thus the access provider is compelled to lower its wholesale price to comply with the requirements of the regulation. Our findings indicate that this reasoning is flawed if firms compete in prices that are strategic complements, which is likely to apply to network industries such as telecommunications, but also to other industry contexts. In this case, competitors raise their retail prices in anticipation of the access provider's constrained pricing ability. In similar fashion, under wholesale competition, MSR may raise prices also because it facilitates the emergence of monopoly-like equilibria.

In summary, we find a positive total welfare effect of margin squeeze regulation only if the non-integrated retailer is foreclosed. However, even then the non-access providing integrated firm has a competitive advantage over the access provider. Thus, margin squeeze regulation reduces the incentives to provide access, which runs contrary to its original rationale as an open access rule. Moreover, European authorities currently do not distinguish between (non-)foreclosure scenarios in margin squeeze investigations. Even if they did, our results raise skepticism with regard to the alleged goal of margin squeeze regulation, i.e., to establish a level playing field for competition, as well as to the ultimate objective of regulatory intervention, i.e., to protect consumers.

Furthermore, in markets where few infrastructure competitors also compete to supply wholesale access to independent retailers, margin squeeze regulation is likely to facilitate tacit collusion. This is because the margin squeeze condition limits firms' potential deviation profits compared to no regulation, unless firms' retail goods are highly differentiated. In consequence, firms can gain relatively less by deviating from a collusive state, which in turn makes market outcomes above the competitive equilibrium more likely. With regard to regulatory practice, this raises additional concerns about the effectiveness of margin squeeze regulation in the context of infrastructure competition.

The analyses conducted in this study are limited to price competition in the retail market. With competition in quantities, decisions constitute strategic substitutes, which may affect the mechanics of margin squeeze regulation. Yet, in Appendix A.2, a model with differentiated quantity competition à la Singh and Vives (1984) is considered, which yields similar welfare implications with respect to margin squeeze regulation.

Moreover, our model analysis does not consider vertically integrated firms' common costs, which require a more complex specification of the margin squeeze rule. Whereas common costs are likely to shift the parameter regions, where the margin squeeze condition becomes binding, they do not qualitatively affect firms' strategic incentives in the context of infrastructure competition. In particular, we expect the same detrimental effects on consumers' surplus in those cases where margin squeeze regulation becomes binding and constrains firms' price setting.

Furthermore, our investigations abstract from cost asymmetries between integrated firms and non-integrated retailers as well as different application contexts of margin squeeze regulation in ex post antitrust enforcement, on the one hand, and ex ante sector-specific regulation, on the other hand. The latter issue of different application contexts has been discussed thoroughly from a legal perspective (Geradin and O'Donoghue, 2005; Heimler, 2010). Whereas authorities' objectives—and therefore their assessment of market outcomes—may differ in these application contexts, the presented economic effects arise irrespective of an ex post or ex ante application of the margin squeeze rule. With regard to cost asymmetries, Gaudin and Saavedra (2014) summarize the debate whether a margin squeeze test should be based on an *Equally Efficient Operator* or a *Reasonably Efficient Operator* standard. As our results apply to the stricter standard of an equally efficient retailer, the consideration of a less efficient retailer would further worsen market outcomes from the view of consumers in light of yet higher retail prices. Taking into account additional complexity (e.g., due to non-linear pricing or bundling), which in practice is likely to increase the number of false-positive findings of margin squeeze conduct (Ergas et al., 2010), augments the issues that already arise in the simplified setting of this study.

Finally, with respect to future work, the ineffectiveness of margin squeeze regulation to increase consumers' surplus calls for alternative regulatory approaches in cases when there is infrastructure-based *and* service-based competition at the same time. It has been observed that it is not desirable to rely on (symmetric) access price regulation in this case (cf. Bacache et al., 2014), because the inherent trade-off between static and dynamic efficiency is likely to stifle investments in infrastructure (Briglauer et al., 2015; Krämer and Schnurr, 2014). Therefore, further research that is dedicated to the design and theoretical or empirical evaluation of new regulatory institutions in an environment of competing infrastructures is warranted.

References

Atiyas, I., T. Doganoglu, and F. Inceoglu (2015). Upstream competition and complexity of contracts. Working Paper. Available at `https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=EARIE42&paper_id=501`.

Auf'mkolk, H. (2012). From regulatory tool to competition law rule: The case of margin squeeze under eu competition law. *Journal of European Competition Law & Practice 3*(2), 149–162.

Bacache, M., M. Bourreau, and G. Gaudin (2014). Dynamic entry and investment in new infrastructures: Empirical evidence from the fixed broadband industry. *Review of Industrial Organization 44*(2), 179–209.

Bouckaert, J. and P. M. Kort (2014). Merger incentives and the failing firm defense. *The Journal of Industrial Economics 62*(3), 436–466.

Bouckaert, J. and F. Verboven (2004). Price squeezes in a regulatory environment. *Journal of Regulatory Economics 26*(3), 321–351.

Bourreau, M., J. Hombert, J. Pouyet, and N. Schutz (2011). Upstream competition between vertically integrated firms. *The Journal of Industrial Economics 59*(4), 677–713.

Briglauer, W., S. Frübing, and I. Vogelsang (2015). The impact of alternative public policies on the deployment of new communications infrastructure - A survey. *Review of Network Economics 13*(3), 227–270.

Briglauer, W., G. Götz, and A. Schwarz (2011). Margin squeeze in fixed-network telephony markets–competitive or anticompetitive? *Review of Network Economics 10*(4), Art. 3.

Ergas, H., E. K. Ralph, and E. Lanigan (2010). Price squeezes and imputation tests on next generation access networks. *Communications and Strategies 78*, 97–85.

European Commission (2013). Commission recommendation on consistent non-discrimination obligations and costing methodologies to promote competition and enhance the broadband investment environment (2013/466/EU). *Official Journal of the European Union L 251*, 13–32.

Friedman, J. W. (1971). A non-cooperative equilibrium for supergames. *The Review of Economic Studies 38*(1), 1–12.

Fudenberg, D. and J. Tirole (1984). The fat-cat effect, the puppy-dog ploy, and the lean and hungry look. *American Economic Review 74*(2), 361–66.

Gaudin, G. and D. Mantzari (2016). Margin squeeze: an above-cost predatory pricing approach. *Journal of Competition Law & Economics 12*(1), 151–179.

Gaudin, G. and C. Saavedra (2014). Ex ante margin squeeze tests in the telecommunications industry: What is a reasonably efficient operator? *Telecommunications Policy 38*(2), 157–172.

Geradin, D. and R. O'Donoghue (2005). The concurrent application of competition law and regulation: the case of margin squeeze abuses in the telecommunications sector. *Journal of Competition Law & Economics 1*(2), 355–425.

Häckner, J. (2000). A note on price and quantity competition in differentiated oligopolies. *Journal of Economic Theory 93*(2), 233–239.

Heimler, A. (2010). Is a margin squeeze an antitrust or a regulatory violation? *Journal of Competition Law & Economics 6*(4), 879–890.

Höffler, F. (2008). On the consistent use of linear demand systems if not all varieties are available. *Economics Bulletin 4*, 1–5.

Höffler, F. and K. M. Schmidt (2008). Two tales on resale. *International Journal of Industrial Organization 26*(6), 1448–1460.

Ivaldi, M., B. Jullien, P. Rey, P. Seabright, and J. Tirole (2003). The economics of tacit collusion. Report for DG Competition, European Commission.

Jaunaux, L. and M. Lebourges (2015). Economic replicability tests for next-generation access networks. *Telecommunications Policy 39*(6), 486–501.

Jullien, B., P. Rey, and C. Saavedra (2014). The economics of margin squeeze. Working Paper. Available at `http://idei.fr/doc/by/jullien/Margin_Squeeze_Policy_Paper_revised_March_2014.pdf`.

Krämer, J. and D. Schnurr (2014). A unified framework for open access regulation of telecommunications infrastructure: Review of the economic literature and policy guidelines. *Telecommunications Policy 38*(11), 1160–1179.

Mandy, D. and D. Sappington (2007). Incentives for sabotage in vertically related industries. *Journal of Regulatory Economics 31*(3), 235–260.

Nocke, V. and L. White (2007). Do vertical mergers facilitate upstream collusion? *American Economic Review 97*(4), 1321–1339.

Normann, H.-T. (2009). Vertical integration, raising rivals costs and upstream collusion. *European Economic Review 53*(4), 461–480.

Petulowa, M. and C. Saavedra (2014). Margin squeeze in a regulatory environment: an application to differentiated product markets. Working Paper. Available at `http://ssrn.com/abstract=2236258`.

Shubik, M. and R. Levitan (1980). *Market Structure and Behavior*. Cambridge, MA: Harvard University Press.

Singh, N. and X. Vives (1984). Price and quantity competition in a differentiated duopoly. *RAND Journal of Economics 15*(4), 546–554.

Appendix

A Wholesale Monopoly

A.1 Simultaneous price competition

According to price competition à la Shubik and Levitan (1980), firms' profits are given by

$$\pi_A = p_A \cdot q_A(p_A, p_B, p_D) + a \cdot q_D(p_A, p_B, p_D),$$
$$\pi_B = p_B \cdot q_B(p_A, p_B, p_D),$$
$$\pi_D = (p_D - a) \cdot q_D(p_A, p_B, p_D),$$

with retail demand of firm $k \in \{A, B, D\}$ with $n = 3$ active firms as

$$q_k^{Triopoly} = \frac{1}{3}(1 - p_k - \gamma(p_k - \frac{p_A + p_B + p_D}{3}).$$

We solve by backward induction. Under NR, if firm A makes a viable wholesale offer in Stage 1, in Stage 2 firms choose retail prices simultaneously, yielding the following prices:

$$p_A^{NR} = \frac{1}{2}\frac{5a\gamma^2 + 9a\gamma + 15\gamma + 18}{5\gamma^2 + 21\gamma + 18},$$
$$p_B^{NR} = \frac{3}{2}\frac{a\gamma^2 + a\gamma + 5\gamma + 6}{5\gamma^2 + 21\gamma + 18},$$
$$p_D^{NR} = \frac{1}{2}\frac{7a\gamma^2 + 21a\gamma + 18a + 15\gamma + 18}{5\gamma^2 + 21\gamma + 18}.$$

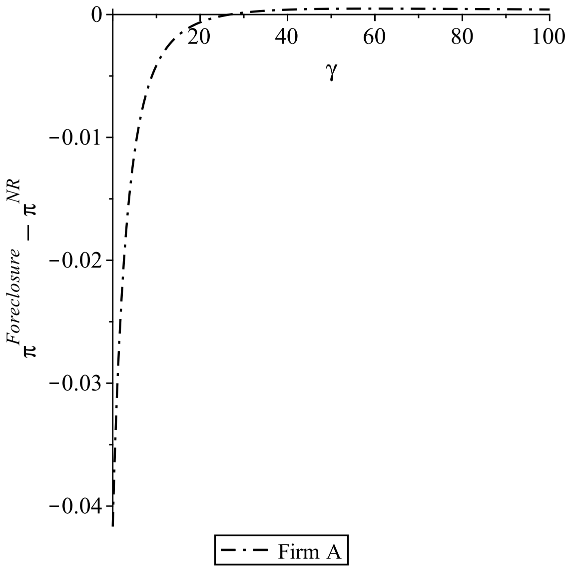


Figure A1: Comparison of firm A's profit in the case of (non-)foreclosure under NR.

Anticipating these retail prices, firm A chooses the profit-maximizing wholesale price

$$a_m^{NR} = \frac{3(25\gamma^3 + 120\gamma^2 + 198\gamma + 108)}{20\gamma^4 + 249\gamma^3 + 909\gamma^2 + 1296\gamma + 648}.$$

If instead, firm A does not make a viable wholesale offer but decides to foreclose firm D, integrated firms' profits are given by $\pi_i^{Foreclosure}(\gamma)$ as obtained for the three-stage model in Appendix B.2. Solving $\pi_A^{Foreclosure} > \pi_A^{NR}$ for the degree of substitutability yields $\gamma > 26.77 =: \overline{\gamma}$, i.e., firm A benefits from foreclosure if retail goods are close substitutes (see Figure A1). Therefore, as noted by Bourreau et al. (2011) and Atiyas et al. (2015), foreclosure is the unique equilibrium outcome for $\gamma > \overline{\gamma}$. Otherwise, firm A makes a viable wholesale offer and all three firms participate in the downstream market in equilibrium.

While in case of foreclosure firm A's price structure clearly violates the margin squeeze constraint, an additional analysis is warranted for $\gamma \leq \overline{\gamma}$. Testing for the margin squeeze condition

$$\Delta = p_A^{NR} - a^{NR} = -\frac{3}{2}\,\frac{\gamma\,(5\gamma^2 - 9\gamma - 18)}{20\gamma^4 + 249\gamma^3 + 909\gamma^2 + 1296\gamma + 648}$$

demonstrates that $\Delta < 0$ for $\gamma > 3$ so that only for strongly differentiated goods, i.e., $\gamma \in [0,3]$, the margin squeeze condition is not binding. Therefore, under MSR, in Stage 2 firm A sets $p_A^{MSR} = a^{MSR}$ for all $\gamma > 3$. The competitors' prices for $\gamma \in (3, \overline{\gamma}]$ are given by

$$p_B^{MSR} = \frac{1}{3}\frac{7a\gamma^2 + 9a\gamma + 15\gamma + 18}{5\gamma^2 + 16\gamma + 12},$$
$$p_D^{MSR} = \frac{1}{3}\frac{13a\gamma^2 + 30a\gamma + 18a + 15\gamma + 18}{5\gamma^2 + 16\gamma + 12}.$$

In Stage 1, firm A anticipates these decisions and sets the wholesale price $a_m^{MSR} = \frac{3}{4}\frac{5\gamma+6}{\gamma^2+9\gamma+9}$. To assert that firm A has no incentive in Stage 2 to raise its retail price p_A above a_A after a_m^{MSR} is set in Stage 1, we check in which cases the condition $p_A \geq a_A$ is non-binding. For $\gamma > 0$ this is only the case for $\gamma = 3$. However, this is precisely the degree of differentiation at which firm A sets $p_A = a_A$ in the case of unconstrained profit maximization under NR. Therefore, we can conclude that it is never profitable for firm A to raise its retail price p_A above a_A under MSR.

For $\gamma \in [0,3]$, firm A's price structure does not violate the margin squeeze condition, as $a_m^{MSR} \leq p_A^{MSR}$. Suppose, however, that firm A increases its access price a_A to a level such that the margin squeeze condition may in fact become binding. Then, by strategic complementarity, competitors' prices p_A and p_D increase as well and, thus, under MSR firm A may possibly be able to achieve a profit that is higher than π_m^{NR}. However, in the following, we show that any a_A, for which the margin squeeze constraint is binding, yields a profit $\widetilde{\pi}_A^{MSR}$ that never exceeds π_A^{NR} for $\gamma \in [0,3]$. Thus, for $\gamma \in [0,3]$ MSR has indeed no effect.

To see this, we characterize the two necessary conditions for a profitable increase of a_A under MSR. First, the margin squeeze constraint must be binding. This is the case iff firm A sets its unconstrained retail price p_A below its wholesale price a_A. We therefore solve the condition $a_A < p_A^{NR} = \frac{5a_A\gamma^2+9a_A\gamma+15\gamma+18}{2(5\gamma+6)(\gamma+3)}$ and obtain $a_A > \frac{3(5\gamma+6)}{5\gamma^2+33\gamma+36} =: \hat{a}_A$. Second, for an increase of a_A to be profitable for firm A, the constrained price setting in reaction to a_A by all firms must yield a profit $\widetilde{\pi}_A^{MSR}(a_A)$ that is higher than the unconstrained monopoly profit $\pi_A^{NR}(a_m^{NR})$, with

$$\widetilde{\pi}_A^{MSR}(a_A) = \pi_A^{MSR}(a_A) = \frac{-(14(\gamma^2 a_A + (9a_A - \frac{15}{2})\gamma + 9a_A - 9))a_A(\gamma + \frac{9}{7})}{(135\gamma^2 + 432\gamma + 324)}.$$

Thus, we solve $\widetilde{\pi}_A^{MSR}(a_A) > \pi_A^{NR}(a_m^{NR})$ and obtain $a_A \in (\underline{a}_A, \overline{a}_A)$ with

$$\begin{aligned}
\underline{a}_A = {} & (3(140\gamma^5 + 1923\gamma^4 + 8604\gamma^3 + 17253\gamma^2 - ((280\gamma^{10} + 2586\gamma^9 - 99\gamma^8 \\
& - 39150\gamma^7 - 70956\gamma^6 + 98172\gamma^5 + 413343\gamma^4 + 437400\gamma^3 + 157464\gamma^2)^{\frac{1}{2}} \\
& + 16200\gamma + 5832))(5\gamma + 6)/(4(140\gamma^7 + 3183\gamma^6 + 27171\gamma^5 \\
& + 111996\gamma^4 + 248913\gamma^3 + 306909\gamma^2 + 198288\gamma + 52488)), \\
\overline{a}_A = {} & (3(140\gamma^5 + 1923\gamma^4 + 8604\gamma^3 + 17253\gamma^2 + ((280\gamma^{10} + 2586\gamma^9 - 99\gamma^8 \\
& - 39150\gamma^7 - 70956\gamma^6 + 98172\gamma^5 + 413343\gamma^4 + 437400\gamma^3 + 157464\gamma^2)^{\frac{1}{2}} \\
& + 16200\gamma + 5832))(5\gamma + 6)/(4(140\gamma^7 + 3183\gamma^6 + 27171\gamma^5 \\
& + 111996\gamma^4 + 248913\gamma^3 + 306909\gamma^2 + 198288\gamma + 52488)).
\end{aligned}$$

It is then straightforward to show that $\hat{a}_A \geq \overline{a}_A \geq \underline{a}_A$ for $\gamma \in [0, 3]$. Because a profitable increase of a_A requires $a_A > \hat{a}_A$ and at the same time $a_A < \overline{a}_A$, both conditions cannot be met at the same time. Therefore, we can conclude that for $\gamma \leq 3$ firm A is not able to increase its profit above the monopoly level under MSR by raising its access price.

A.2 Simultaneous retail quantity competition

In order to examine the effect of MSR in case of retail quantity competition, we consider a two-stage game that is similar to the one detailed in Appendix A.1 with the exception that firms choose quantities in Stage 2 and compete according to the demand structure suggested by Singh and Vives (1984). Following the generalization by Häckner (2000) for more than two firms, inverse retail demand of firm $k \in \{A, B, D\}$ is given by

$$p_k = \omega - \lambda \left(q_k + \theta \sum_{j \neq k} q_j \right)$$

with $\omega, \lambda > 0$ and θ as a standardized measure of substitutability. If $\theta < 0$ goods are complements and if $\theta > 0$ they are substitutes. We consider only the case of $\theta \in [0, 1]$, where goods are independent of one another if $\theta = 0$ and goods are perfect substitutes if $\theta = 1$. For ease of illustration, let $\omega = 100$ and $\lambda = 1$.

We solve by backward induction. Under NR, in Stage 2, firms simultaneously choose

$$q_i^{NR} = -\frac{1}{2} \frac{a\theta - 100\theta + 200}{\theta^2 - \theta - 2},$$
$$q_D^{NR} = \frac{1}{2} \frac{a\theta + 2a + 100\theta - 200}{\theta^2 - \theta - 2},$$

where $i \in \{A, B\}$. In Stage 1, firm A anticipates these decisions and sets

$$a^{NR} = -\frac{100(\theta^3 - 4\theta^2 + 2\theta + 4)}{2\theta^3 + 3\theta^2 - 8\theta - 8}.$$

In order to identify whether firm A engages in a margin squeeze, we calculate firm A's retail price p_A^{NR} that arises from all firms' quantity decisions and then calculate

$$\Delta = p_A^{NR} - a^{NR} = \frac{50\theta\left(2\theta^2 - 5\theta + 2\right)}{2\theta^3 + 3\theta^2 - 8\theta - 8}$$

to test the margin squeeze condition, for which $\Delta < 0$ if $\theta \in (0, 0.5)$. Therefore, firm A engages in a margin squeeze for rather differentiated goods.

Substituting equilibrium quantities and the optimal wholesale price yields equilibrium profits π_k^{NR}, which we now compare to the case of foreclosure which ensues profits $\pi_i^{Foreclosure}(\theta)$. Provided that firm D is foreclosed, the integrated firms choose $q_i^{Foreclosure} = \frac{100}{\theta+2}$. Comparing profits between foreclosure and non-foreclosure for both integrated firms yields

$$\pi_A^{Foreclosure} - \pi_A^{NR} = \frac{2500(\theta^4 + 4\theta^3 - 4\theta^2 - 16\theta + 16)}{(\theta+2)^2 (2\theta^3 + 3\theta^2 - 8\theta - 8)},$$
$$\pi_B^{Foreclosure} - \pi_B^{NR} = \frac{2500\theta (7\theta^5 + 24\theta^4 - 36\theta^3 - 128\theta^2 + 48\theta + 128)}{(\theta+2)^2 (2\theta^3 + 3\theta^2 - 8\theta - 8)^2},$$

where $\pi_A^{Foreclosure} - \pi_A^{NR} < 0$ and $\pi_B^{Foreclosure} - \pi_B^{NR} > 0$ for all $\theta \in [0,1]$. Hence, in analogy to the three-stage price competition model described in Appendix B, firm B prefers foreclosure, whereas firm A benefits from making firm D a viable wholesale offer. In consequence, the retailer is never foreclosed.

Under MSR, in Stage 2, constrained pricing of firm A and simultaneous profit maximization by its competitors yields retail quantities

$$q_A^{MSR} = \frac{2(a + 50\theta - 100)}{2\theta^2 - \theta - 2},$$
$$q_B^{MSR} = -\frac{2a\theta^2 - 3a\theta - 100\theta^2 + 300\theta - 200}{(\theta - 2)(2\theta^2 - \theta - 2)},$$
$$q_D^{MSR} = \frac{2(a\theta + 50\theta^2 - a - 150\theta + 100)}{(\theta - 2)(2\theta^2 - \theta - 2)}.$$

In Stage 1, firm A sets $a^{MSR} = -25\theta + 50$. Ensuing prices and profits allow to compute consumers' surplus, producers' surplus, and total surplus as in the main analysis. Figure A2 depicts the effect of MSR in comparison to NR for these welfare measures. The implications are similar to the investigated three-stage price competition model: while MSR is to consumers' detriment, producers benefit from it. Because the former effect outweighs the latter, total surplus is unambiguously lower under MSR than NR.

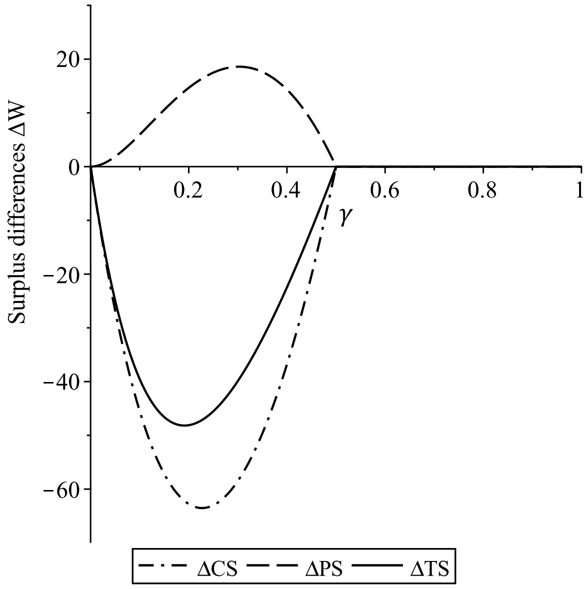


Figure A2: MSR effect on consumers' surplus, producers' surplus, and total surplus.

B Wholesale Monopoly with Stackelberg follower

B.1 Model and Results

When firm D is thought of as a Stackelberg follower that reacts to the integrated firms' prices, the timing of the model is as follows:

Stage 1: Firm A sets the wholesale price a.

Stage 2: Firm A and firm B set their respective retail prices p_A and p_B.

Stage 3: Firm D sets its retail price p_D.

Under NR, in Stage 3 firm D's first order condition is $\frac{\partial \pi_D}{\partial p_D} = 0$, which yields $p_D^{NR} = \frac{1}{2}\frac{2a\gamma+\gamma p_A+\gamma p_B+3a+3}{3+2\gamma}$ as the best response to the integrated firms' prices. In stage 2, both integrated firms $i \in \{A, B\}$ solve $\frac{\partial \pi_i(p_D^{NR})}{\partial p_i} = 0$ simultaneously, yielding $p_A^{NR}(a,\gamma)$ and $p_B^{NR}(a,\gamma)$, respectively. Anticipating these decisions, firm A solves $\frac{\partial \pi_A(p_A^{NR}, p_B^{NR}, p_D^{NR})}{\partial a} = 0$ in Stage 1 and sets the optimal wholesale charge $a^{NR}(\gamma)$ accordingly. More detailed computations are found in Appendix B.2.

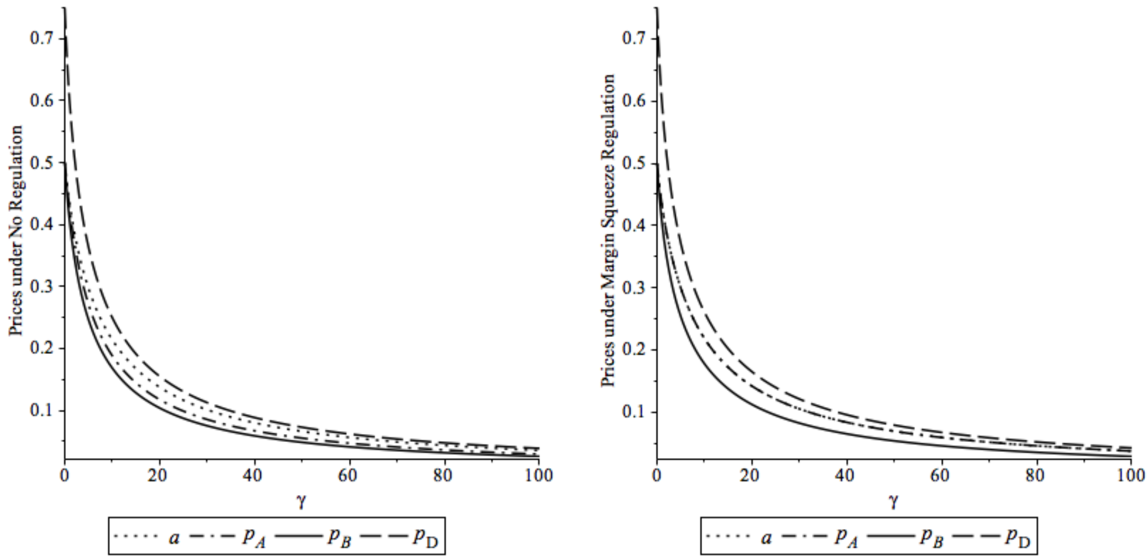
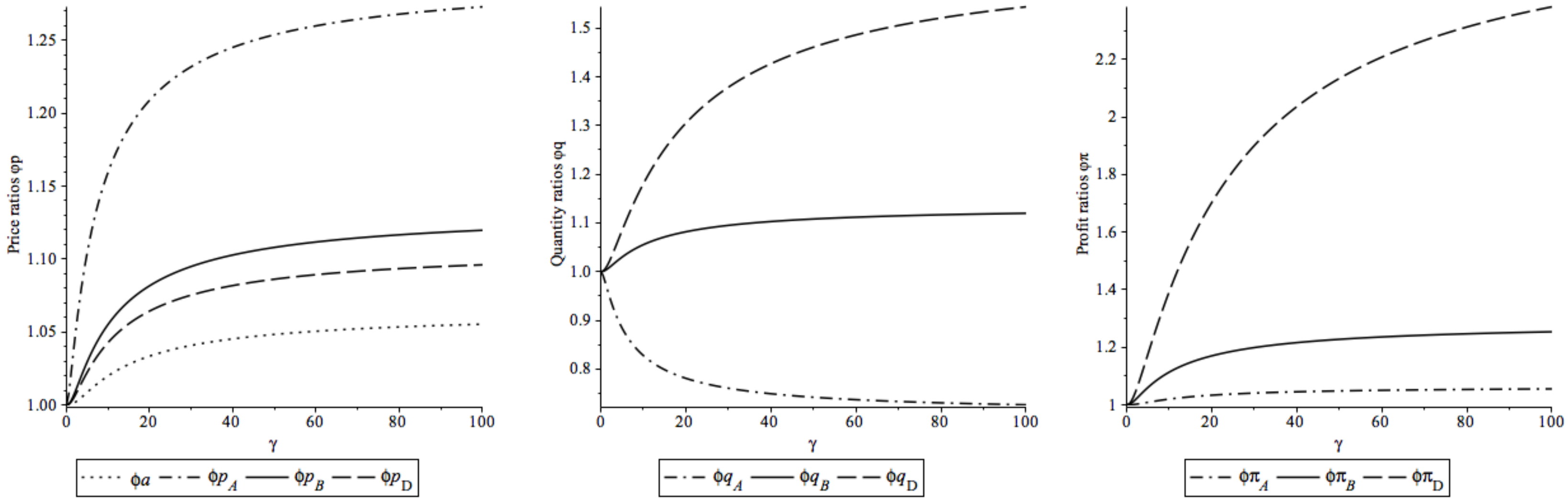


Figure A3: Equilibrium prices under NR and MSR.

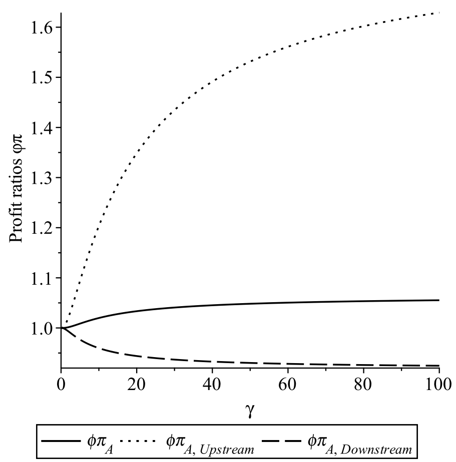
The left panel of Figure A3 depicts the equilibrium retail and wholesale prices depending on γ. Notice that firm A violates the margin squeeze condition for all $\gamma > 0$. Yet, firm D makes positive profits in equilibrium as firm A has no incentive to foreclose the retailer. In other words, firm A benefits more from the *wholesale revenue effect* than it suffers from the *business stealing effect*. In contrast, firm B prefers foreclosure of firm D, because it suffers from the business stealing effect, but receives no wholesale revenue to compensate for this. Relatedly, firm B sets lower retail prices than firm A due to the *softening effect* (Bourreau et al., 2011; Fudenberg and Tirole, 1984), which occurs because firm B has no opportunity cost in terms of foregone wholesale revenue when decreasing its retail price.

Under MSR, however, firm A's retail price setting in Stage 2 is constrained, because a margin squeeze would occur for all $\gamma > 0$ under NR. This induces firm A to raise its retail price to the level of the profit maximizing wholesale price, i.e., $p_A^{MSR} = a^{MSR}$. Otherwise, wholesale revenue, business stealing, and softening effects are qualitatively the same as under NR which preserves the relative order of equilibrium prices (see the right panel of Figure A3).

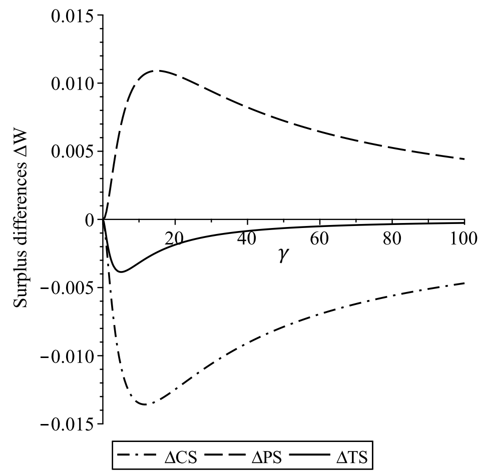
Figure A4: MSR effect on market variables in the scenario with a competitive retail fringe.



(a) Firms' prices, quantities, and profits.



(b) Firm A's total, upstream, and downstream profit.



(c) Consumers' surplus, producers' surplus, and total surplus.

Figure A4a depicts the net effect of MSR in comparison to NR with respect to its relative impact on prices, quantities, and profits. First, the reported ratios demonstrate that all prices rise under MSR, which highlights that the regulation not only fails to exert a negative impact on the wholesale price, but instead allows firms to attain higher prices in both wholesale and retail markets. Since the margin squeeze condition is binding, firm A has no incentive to lower its retail price following an increase in its wholesale price. This in turn incentivizes firm B to increase its retail price as well, because downstream prices of the integrated firms are strategic complements. In addition, firm D raises its retail price due to the increased wholesale input price. Second, despite this universal price increase, retail demands for firm B and firm D increase, and only firm A's demand decreases due to the relative magnitude of its price surge compared to NR. Third, profits increase for all firms under MSR. Whereas firm A's downstream profit deteriorates due to a decline in retail demand, the increase in wholesale revenue ultimately leads to a net benefit for the access provider as shown in Figure A4b.

The welfare analysis of MSR in relation to NR reinforces insights on the effect of MSR gained thus far (see Figure A4c). Whereas producers' surplus increases under MSR as a direct consequence of firms' ability to unanimously reap higher profits, consumers' surplus is lower than under NR. More specifically, consumers are worse off because the increased outputs of firm B and firm D are outweighed by higher retail prices of all firms. Remarkably, note that the harm to consumers due to MSR decreases with increasing substitutability of retail goods. Overall, the effects on producers' and consumers' surplus amount to an ultimately negative impact of MSR on total surplus, which is more severe for more differentiated retail goods, i.e., for lower values of γ. Altogether these results suggest that under the given market structure and timing, MSR cannot be justified by either a consumer welfare perspective nor a total welfare standard.

B.2 Equilibrium derivation

Under NR, in Stage 3, firm D's first order condition $\frac{\partial \pi_D}{\partial p_D} = 0$ yields its best response $p_D^{NR} = \frac{1}{2}\frac{2a\gamma + \gamma p_A + \gamma p_B + 3a + 3}{3 + 2\gamma}$ given integrated firms' prices. In Stage 2, integrated firms $i \in \{A, B\}$ solve $\frac{\partial \pi_i(p_D^{NR})}{\partial p_i} = 0$ simultaneously, thus yielding

$$p_A^{NR} = \frac{22a\gamma^4 + 101a\gamma^3 + 150a\gamma^2 + 95\gamma^3 + 72a\gamma + 384\gamma^2 + 504\gamma + 216}{57\gamma^4 + 428\gamma^3 + 1092\gamma^2 + 1152\gamma + 432},$$
$$p_B^{NR} = \frac{16a\gamma^4 + 64a\gamma^3 + 84a\gamma^2 + 95\gamma^3 + 36a\gamma + 384\gamma^2 + 504\gamma + 216}{57\gamma^4 + 428\gamma^3 + 1092\gamma^2 + 1152\gamma + 432}.$$

In Stage 1, firm A chooses the wholesale price a^{NR} anticipating its competitors' best responses, i.e., according to $\frac{\partial \pi_A(p_A^{NR}, p_B^{NR}, p_D^{NR})}{\partial a} = 0$, which yields

$$a^{NR} = \frac{4\left(49\gamma^4 + 336\gamma^3 + 828\gamma^2 + 864\gamma + 324\right)\left(19\gamma^2 + 54\gamma + 36\right)}{973\gamma^7 + 17071\gamma^6 + 111816\gamma^5 + 370476\gamma^4 + 686880\gamma^3 + 723168\gamma^2 + 404352\gamma + 93312}.$$

Equilibrium retail demands and equilibrium profits dependent on γ can then be obtained by simple substitution of equilibrium prices. Testing for the margin squeeze condition

$$\begin{aligned}\Delta &= p_A^{NR} - a^{NR} \\ &= -\frac{\gamma^2\left(665\gamma^4 + 3543\gamma^3 + 6984\gamma^2 + 6048\gamma + 1944\right)}{973\gamma^7 + 17071\gamma^6 + 111816\gamma^5 + 370476\gamma^4 + 686880\gamma^3 + 723168\gamma^2 + 404352\gamma + 93312}\end{aligned}$$

shows that $\Delta < 0$ for $\gamma > 0$ and thus, firm A engages in a margin squeeze if retail goods are substitutes. Despite that, firm D is still active in the retail market with a positive demand

$$q_D^{NR} = \frac{1}{6}\frac{399\gamma^7 + 9893\gamma^6 + 67488\gamma^5 + 218268\gamma^4 + 388368\gamma^3 + 391392\gamma^2 + 209952\gamma + 46656}{973\gamma^7 + 17071\gamma^6 + 111816\gamma^5 + 370476\gamma^4 + 686880\gamma^3 + 723168\gamma^2 + 404352\gamma + 93312}$$

as firm A does not find it profitable to foreclose its downstream competitor, which we show in the following.

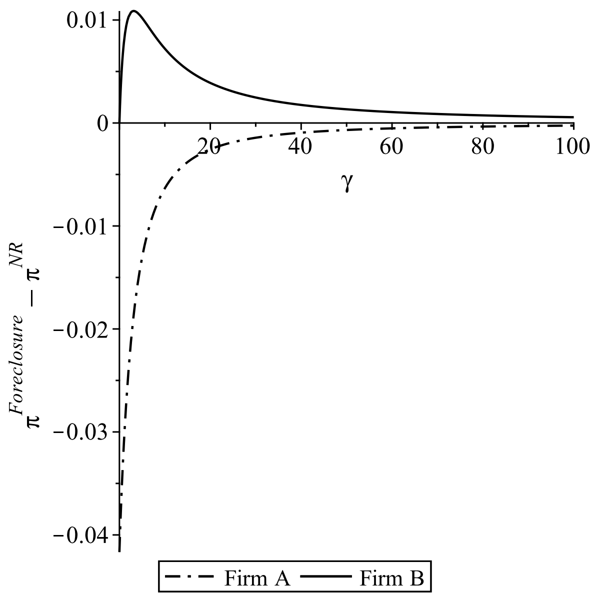


Figure A5: Comparison of profits in the case of (non-)foreclosure under NR.

Foreclosure occurs if firm A's wholesale price is so high compared to retail prices such that firm D is unable to set a retail price that would yield a positive profit. Then, firm D does not supply any retail consumers and a retail duopoly ensues with

$$q_i^{Foreclosure} = \frac{1+\gamma}{3}(1 - p_i - \frac{\gamma}{(3+2\gamma)}(2 - (p_A + p_B))$$

as integrated firm i's retail demand (Höffler, 2008). Profit-maximization of integrated firms in case of foreclosure yields equilibrium profits $\pi_i^{Foreclosure}(\gamma)$. Figure A5 depicts the difference of equilibrium profits $\pi_i^{Foreclosure} - \pi_i^{NR}$ for both integrated firms. Irrespective of the degree of differentiation, for substitute goods, i.e., $\gamma > 0$, firm B would prefer foreclosure due to higher downstream profits, but firm A does not. Instead, the firm A benefits from a viable wholesale offer to firm D and thus has no incentive to foreclose its competitor even in the absence of regulation.

Under MSR, in Stage 2, firm A is constrained in its retail price setting by the requirement that $\Delta \geq 0$. Because it prefers to engage in a margin squeeze under NR, the margin squeeze condition is binding and $p_A^{MSR} = a^{MSR}$. Firm B's corresponding retail price is $p_B^{MSR} = \frac{1}{2}\frac{7a\gamma^2+9a\gamma+15\gamma+18}{7\gamma^2+24\gamma+18}$. In Stage 1, firm A sets $a^{MSR} = \frac{3}{2}\frac{19\gamma^2+54\gamma+36}{7\gamma^3+81\gamma^2+180\gamma+108}$. Again, equilibrium retail demands and equilibrium profits can be obtained by simple computations.

C Tacit collusion under wholesale competition

In the collusive outcome, firm A and firm B maximize their joint profit by setting wholesale and retail prices like a single monopolist. Thus collusive prices are given by

$$a_i^{Collusion} = \frac{3\gamma^3 + 16\gamma^2 + 30\gamma + 18}{3(2\gamma^3 + 11\gamma^2 + 20\gamma + 12)},$$
$$p_i^{Collusion} = \frac{6\gamma^5 + 71\gamma^4 + 309\gamma^3 + 624\gamma^2 + 594\gamma + 216}{12(\gamma+2)^2(\gamma^2+6\gamma+6)(\gamma+\frac{3}{2}))},$$
$$p_D^{Collusion} = \frac{3\gamma^5 + 37\gamma^4 + 171\gamma^3 + 375\gamma^2 + 396\gamma + 162}{6(\gamma^2+6\gamma+6))(\gamma+2)^2(\gamma+\frac{3}{2})}$$

and collusive profits by

$$\pi_i^{Collusion} = \frac{9\gamma^3 + 47\gamma^2 + 81\gamma + 45}{36(\gamma+2)^2(3+2\gamma)},$$
$$\pi_D^{Collusion} = \frac{\gamma^2 + 3\gamma + 3^2}{9(\gamma+2)^4(3+2\gamma)}.$$

It follows immediately that that $a_i^{Collusion} < p_i^{Collusion}$ for all γ so that neither margin squeeze nor foreclosure would occur under collusion. Moreover, it is easy to see that the most severe punishment that is supported by a Nash equilibrium is constituted by playing the competitive equilibrium in the wholesale market, i.e., $a_A = a_B = 0$, which yields symmetric retail prices of $p_k^{Punish} = \frac{15\gamma+18}{2(5\gamma+6)(\gamma+3)}$ and symmetric profits of $\pi_k^{Punish} = \frac{(3+2\gamma)}{(4(\gamma+3)^2)}$ for all firms $k \in A, B, D$.

If an integrated firm deviates from the collusive state in the second stage, it maximizes its profit $\pi_i^{Dev,Retail,NR}$ under NR by setting $p_i^{Dev,Retail,NR}$, with

$$p_i^{Dev,Retail,NR} = \frac{15\gamma^4 + 125\gamma^3 + 369\gamma^2 + 468\gamma + 216}{12(3+2\gamma)^2(\gamma+2)^2},$$
$$\pi_i^{Dev,Retail,NR} = \frac{36\gamma^7 + 1005\gamma^6 + 8332\gamma^5 + 33543\gamma^4 + 75456\gamma^3 + 97308\gamma^2 + 67392\gamma + 19440}{1296(3+2\gamma)^2(\gamma+2)^4}.$$

If an integrated firm deviates from the collusive state in the first stage, it maximizes its profit $\pi_i^{Dev,Wholesale,NR}$ under NR by setting $a^{Dev,Wholesale,NR}$ and anticipating the ensuing retail prices $p_k^{Dev,Wholesale,NR}$. In this case it is profitable for the deviating firm to lower the wholesale price to the monopoly price, i.e., $a^{Dev,Wholesale,NR} = a_m^{NR}$ and therefore to become the sole access provider for the retailer. Consequently $\pi_i^{Dev,Wholesale,NR} = \pi_m^{NR}$.

We can then show that $\pi_i^{Dev,Wholesale,NR} > \pi_i^{Dev,Retail,NR}$ for $\gamma \in (0, \widehat{\gamma}^{NR})$, whereas $\pi_i^{Dev,Wholesale,NR} < \pi_i^{Dev,Retail,NR}$ for $\gamma > \widehat{\gamma}^{NR}$ with $\widehat{\gamma}^{NR} = 1.96$. Thus, the critical discount factor δ_i of an integrated firm under NR is given by

$$\delta_i^{NR} = \begin{cases} \frac{-(180\gamma^7+1111\gamma^6+1425\gamma^5-5373\gamma^4-21330\gamma^3-31023\gamma^2-21384\gamma-5832)(\gamma+3)^2}{27(5\gamma^2+18\gamma+18)^2(3+2*\gamma)(1+\gamma)(\gamma+2)^2} & \text{if} \gamma < \widehat{\gamma}^{NR}, \\ \frac{\gamma^2(\gamma+3)^3(4+3\gamma)(12\gamma^3+67\gamma^2+123\gamma+72)}{36\gamma^9+1221\gamma^8+12094\gamma^7+60180\gamma^6+178686\gamma^5+340335\gamma^4+425736\gamma^3+343116\gamma^2+163296\gamma+34992} & \text{if} \gamma \geq \widehat{\gamma}^{NR}. \end{cases}$$

Under NR the prices of a deviating firm violate the margin squeeze condition, because $p_A^{NR} < a_m^{NR}$ (as shown for a wholesale monopoly) if the firm deviates in the wholesale market and $p_i^{Dev,Retail,NR} < a_i^{Collusion}$ if a the firm deviates in the retail market. Under MSR an integrated firm that deviates in the retail market can maximize profit by lowering the retail price to the collusive access price, i.e., $p_i^{Dev,Retail,MSR} = a_i^{Collusion}$. Alternatively, the integrated firm can deviate in the wholesale market by setting the constrained monopoly access price $a^{Dev,Wholesale,MSR} = a_m^{MSR}$ and obtain $\pi_i^{Dev,Wholesale,MSR} = \pi_m^{MSR}$ for one supergame period. Again, for highly differentiated goods, deviation in the wholesale market is more profitable than deviation in the retail market, and vice versa. This is, $\pi_i^{Dev,Wholesale,MSR} >$

$\pi_i^{Dev,Retail,MSR}$ for $\gamma \in (0, \widehat{\gamma}^{MSR})$, whereas $\pi_i^{Dev,Wholesale,MSR} < \pi_i^{Dev,Retail,MSR}$ for $\gamma > \widehat{\gamma}^{MSR}$ with $\widehat{\gamma}^{MSR} = 2.34$.

Because the collusive and punishment profits are the same as under NR, we can then calculate the critical discount factor for each integrated firm as

$$\delta_i^{MSR} = \begin{cases} \frac{-18(\gamma^5 + \frac{23}{9}\gamma^4 - \frac{29}{6})\gamma^3 - \frac{43}{2}\gamma^2 - 24\gamma - 9)(\gamma+3)^2}{138\gamma^6 + 1365\gamma^5 + 5715\gamma^4 + 12825\gamma^3 + 16119\gamma^2 + 10692\gamma + 2916} & \text{if} \gamma < \widehat{\gamma}^{MSR}, \\ \frac{\gamma^2(3\gamma^4 + 18\gamma^3 + 41\gamma^2 + 41\gamma + 15)(\gamma+3)^2}{21\gamma^8 + 265\gamma^7 + 1455\gamma^6 + 4563\gamma^5 + 9003\gamma^4 + 11538\gamma^3 + 9450\gamma^2 + 4536\gamma + 972} & \text{if} \gamma \geq \widehat{\gamma}^{MSR}. \end{cases}$$