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Access-price structure and entrants' build-or-buy incentives in mobile markets

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by

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Abstract: We consider a market structure with three mobile providers, two of which are vertically integrated and have nationwide coverage. The third provider (an entrant) invests in partial coverage, and needs to rent access from one of its rivals in order to provide nationwide coverage. The paper is motivated by the Norwegian mobile market, where the competition authorities imposed a fine of EUR 78 million on Telenor (the dominant incumbent) for abusing market power by changing the access price structure in such a way that it hampered the entrant's investment incentives. Specifically, Telenor reduced the rental rate for the actual use of Telenor's network. At the same time, they introduced a *SIM card fee* payable by the entrant for each of its consumers. We show that the relationship between the change in the access price structure and the entrant's investment level is ambiguous. Competition among the vertically-integrated providers in the access market may drive them to offer a structure that benefits the entrant. Thus, the observed change in access price structure may be the outcome of intensified upstream competition rather than abuse of market power.

[1]We thank the Norwegian Competition Authority for financial support.

1 Introduction

Both competition authorities and sector-specific regulators within the EU argue that it is necessary to have at least four vertically integrated mobile providers in order to obtain satisfactory competition in the consumer market. However, the cost of providing nationwide coverage is high. 4G/5G require higher spectrum-bands than 3G. The cost of providing nationwide coverage is therefore greater for 4G/5G than for 3G, since a larger number of base stations are needed to provide access in a given location (see e.g. BEREC, 2018a). For this reason, market players have argued that competition authorities should allow for a more concentrated industry. However, competition authorities have followed a restrictive approach towards merger proposals (Barclays, 2018; BEREC, 2018b, European Commission, 2017, and Motta and Tarantino, 2017).[2]

Network sharing agreements are an alternative to mergers when it comes to achieving economies of scale at the upstream network level without increasing concentration at the downstream level. Competition authorities, as well as sector-specific regulators, have taken a sympathetic approach towards network sharing (see BEREC, 2018a). In that way a mobile provider, which finds it too expensive to invest in nationwide coverage, could still be competitive if it buys access to the network of an incumbent that covers the whole country (i.e. enters a national roaming agreement). A central research question in this paper, is how the structure of the access price affects the access buyer's build-or-buy incentives. This may be of crucial importance when the 5G infrastructure is deployed; BEREC (2018a) expects that infrastructure sharing will become more important.

The motivation behind the current paper springs from the Norwegian mobile market. In June 2018, the Norwegian Competition Authority imposed a fine of NOK 788 million (approximately EUR 78 million) on Telenor for abusing their dominant position in the Norwegian mobile market.[3] The case against Telenor goes back to 2007, when Network

[2] After a wave of mergers, several empirical analyses have investigated the relationship between the number of competing networks and consumer prices (Ofcom, 2016, among other). BEREC (2018b) and thr European Commission (2017) provide surveys. The main findings are that a reduction from five to four networks does not imply a significant increase in consumer prices, while a reduction from four to three networks implies a significant increase in consumer prices.

[3] The highest fine imposed by the Norwegian Competition Authority prior to this was NOK 140 million. In addition to Telenor, Telia is a vertically integrated provider with a nationwide coverage. There was a complete merger between Network Norway and Tele2 in 2013, and, in 2015, Tele2 and Telia merged. The

Norway and Tele2 formed an upstream joint venture, Mobile Norway, and started to build a third mobile network, but with only partial coverage. In 2010, Telenor altered the structure of the access price in their national roaming agreement. More specifically, they introduced a fee per consumer served by the access buyer - a SIM card fee - but reduced the rental rate for the actual use of their network correspondingly. The Norwegian Competition Authority (2018) argues that the motivation for this structural change of the access price was to limit the rollout of the third network.[4]

To analyze the consequences of changing the structure of the access price, we set up a Salop-Vickrey circle city model with three firms (Salop, 1979; Vickrey, 1964). Two of the firms are vertically integrated providers (Telenor and Telia), while the third firm is an entrant that invests in a network with partial coverage (Network Norway/Tele2). The latter firm needs a national roaming agreement with one of the full-coverage providers. We consider a three-stage game, where at least one of the two firms with nationwide coverage offers an access contract (national roaming) to the entrant at stage 0. The access price may consist of two parts; a SIM card fee (a fixed fee for each consumer the entrant serves) and a rental rate (the size of which depends on how much coverage the entrant needs to rent). At stage 1, the entrant makes its investment decision. In line with the discussion above, we assume strictly convex investment cost. The advantage for the entrant of increasing the coverage of its own network is that it reduces the marginal cost of serving its consumers (the rental rate in the roaming agreement) and becomes more competitive. At stage 2, the three firms compete in prices.

The entrant's marginal cost - and thus its consumer price - is higher the larger the SIM card fee. This in turn implies that the entrant's consumer base is decreasing in the size of the SIM card fee. With fewer consumers, it has lower incentives to invest in own coverage. The negative relationship between the SIM card fee and the entrant's network investments is therefore unambiguous. In contrast, the relationship between the rental rate and the entrant's investment level is hump-shaped. To see why, note first that the direct effect of a

network infrastructure of Tele2, the third network with partial coverage, was sold to Ice as a remedy in the Tele2-Telia merger in 2015. Consequently, Ice has a network with partial coverage and has currently a national roaming agreement with Telia.

[4] This case goes back to the years when 2G/3G infrastructure was deployed. Since the cost of providing nationwide coverage is even higher for 5G, we consider the issues that we discuss in this paper to become even more important in the future.

higher rental rate is to reduce the opportunity cost of investing. This induces the entrant to invest more. However, there is also an opposing effect; a higher rental rate reduces the entrant's consumer base since it becomes less competitive. This induces the entrant to invest less. We show that the latter effect dominates if the total access price is high at the outset. In the case at hand, the Norwegian Competition Authority (2018) claims that a change in the access price structure hampers the entrant's investment incentives. We show that this is not necessarily true; the hump-shape described above implies that this is an empirical question.

In equilibrium, at least one of the vertically integrated firms will offer the entrant an access contract. However, the firm that provides network access, will not compete fiercly with the entrant in the downstream market. This fact generates a competitive advantage for the other vertically integrated firm. In line with Bourreau et al. (2011) we find that this implies that the vertically integrated firms will not fight for the access contract if the access price is sufficiently high. As long as this is the case, there is no reason for the access provider to introduce a SIM card fee; it can instead charge the entrant entirely through the rental rate.

If the access price is reduced below a critical level, e.g. due to a price cap regulation or margin-squeeze requirements, the vertically integrated rival may be induced to compete for the access contract.[5] The reason is that the lower the access price, the smaller is the competitive disadvantage in the downstream market from being the access provider of national roaming to the entrant. If there is competition for the access contract between the

[5]For a dominant vertically integrated firm, like Telenor, the competition law may de facto imply an obligation to make an offer to the non-integrated rival (the case at hand illustrates this). To be more specific, a dominant vertically integrated firm has a duty to reply to a request from an access buyer; the seminal competition case on access to essential facilities within the EU is "Case C-7/97 Oscar Bronner" from 1998. Furthermore, during the roll-out of 2G/3G coverage from the mid 90's, vertically integrated incumbents were obligated by sector-specific regulation to offer national roaming to entrants without own nationwide coverage. Obligations on national roaming are widely used as a remedy in merger cases (BEREC, 2018a, 2018). In the majority of the European national markets there are now no sector-specific obligations to provide national roaming, since there are three or more network providers in most markets. Wholesale access and call origination (previously market 15) was removed from the list of markets with a presumption of need of regulation in 2007 (European Commission, 2007). There are, however, exceptions, among them Norway with only two full-scale vertically integrated providers (Telenor, the incumbent, and Telia). Telenor is still obligated to offer national roaming (see description in BEREC, 2018a).

two vertically integrated firms, an access price structure with a positive SIM card fee will emerge. The intuition for this is that for any given total access price, the rental rate can be reduced when a SIM card fee is introduced. This is attractive for the entrant, because it reduces the opportunity cost of not investing and thus increases its profit net of investment. A two-part tariff, with a positive SIM card fee may therefore be the outcome of less, not more, market power in the upstream market.[6] National roaming contracts are secret, but we have strong indicators that such two-part access contracts are commonly used. For instance, it is revealed that the vertically integrated rival Telia uses such two-part tariffs.[7]

Our focus is on mobile telecommunications. However, more generally our model may have relevance for markets where vertically integrated firms face competition from non-integrated firm that need to buy upstream access. The non-integrated firm faces a build-or-buy decision, where the build alternative may be considered as backward integration. Our results indicate that upstream competition between the vertically integrated firms may result in an access price structure that hampers the access buyers' backward integration incentives.[8]

[6]Note that in such a two-part tariff, there is no fixed fee that is independent of number of users and usage. Fixed fees independent of the number of users and usage are not used in the marketplace as far as we know. However, in several merger cases, obligations on national roaming are used as a remedy. In these cases, the roaming tariff typically includes a fixed fee for a given amount of usage (see BEREC, 2018b).

[7]In a court case, Telenor vs. Telia, in 2018 (Borgarting Lagmansrett, 2018, page 33) the Court of Appeal makes the following statement: "*As regards whether SIM card fees [a user-based access price] ... is a widespread commercial practice, the Court of Appeal remarks that the actual pricing structure with SIM card fee is not unique to Telenor's access agreements, cf. the information that Telia also operates with such an [access] pricing structure.*" As emphasized in footnote 3 above, in 2015 there was a merger between Telia and Tele2 (The Norwegian Competition Authority (2015). A remedy was that Tele2's partial network was sold to Ice. Furthermore, the competition authorities accepted a national roaming agreement between Telia and Ice as a remedy. The contract is secret, but in the SMP-analysis (in market 15), the sector-specific authorities state that a SIM card fee was a part of this agreement (Nkom, 2016, paragraph 455): "*Nkom emphasizes the negative effects associated with the agreement containing a fixed fee per SIM card. This fee implies that ICE will face a fixed cost per subscription that will persist as long as the firm relies on buying national roaming.*" Note that the citations are translated from Norwegian, since the original documents are in Norwegian.

[8]Bourreau et al. (2011) use the fixed broadband market as an example where vertically integrated firms compete in the downstream market and, at the same time, they may compete in upstream market where they provide access to non-integrated rivals. Licensing of technologies is another example mentioned by Bourreau et al. (2011). In several grocery markets, we observe that vertically integrated chains may

2 Related literature

The trade-off between an entrant's investment incentives and a low price for access to an incumbent's network (which makes the entrant more competitive in the downstream market) has been given much attention in the literature, e.g. within the discussion of the ladder of investment approach (Cave and Vogelsang, 2003; Cave, 2006; a more theoretical fundament is given by Bourreau and Dogan, 2005, 2006, among others). The focus of this literature is on fixed broadband networks rather than mobile networks, and its main theoretical prediction is that a lower access price reduces the access seeker's investment incentives (Bourreau et al, 2012; 2014, among others). Briglauer et al. (2018) extend Bourreau et al. (2012) to allow for more than one incumbent, and they also provide empirical analyses.

However, the view that there is a monotone relationship between the access price and an entrant's investment incentives has been challenged in the access pricing literature (Sappington, 2005). As in the present paper, Sappington uses a spatial competition framework (a duopoly model based on Hotelling, 1929) and shows that the make-or-buy decision by the entrant is not affected by the access price. The result is not general (Gayle and Weisman, 2007), but Sappington (2005) accentuates that a higher access price does not necessarily increase an entrant's incentives to invest in own infrastructure. Our focus is different in that it is not the level of the access price as such, but the composition of a usage-based part and a user-based part that matters for incentives.

The majority of the literature on access pricing considers a set-up with one facility-based incumbent offering access to entrant(s).[9] However, in mobile markets, we typically have more than one vertically integrated facility-based provider. When there are several vertically integrated providers with nationwide coverage present, competition among these providers might also arise at the upstream level. This was the expectation when the European Commission (2007) withdrew access in the mobile market (previously market

provide access to their (upstream) procurement and distribution networks to, typically smaller, rivals in the downstream market. In such a case, the access buyer may face a build-or-buy decision similar to what we analyze with respect to (partial) backward integration into distribution and procurement.

[9] In the strand of literature where an incumbent both invests and offers access to entrant(s), Klumpp and Su (2010) and Nietsche and Wiethaus (2011) study the link between access-price regulation and investment incentives.

15) from the list of markets where there is a presumption of need of regulation. Vogelsang (2019) provides a recent survey of the literature analyzing the development of the European sector-specific regulatory framework since 2002.[10]

Motivated by the Scandinavian mobile market, Ordover and Shaffer (2007) consider potential upstream competition between two vertically integrated facility-based firms to serve an entrant in the downstream market that needs access to one of the incumbents' networks. They show that if the entrant is a close rival to its access supplier in the downstream market, the other facility-based provider may choose not to compete for a contract with the entrant. Brito and Pereira (2010) find similar results. Bourreau et al. (2011) identify an effect crucial in the present model (see also Höffler and Schmidt, 2008). Even if two vertically integrated rivals produce an identical upstream product (nationwide mobile coverage in our context) they will not necessarily compete the access price down to the marginal cost. Instead, one of the vertically integrated firms may offer a monopoly access price. The vertically integrated rival may prefer not to compete in the upstream market, since it achieves a competitive advantage in the downstream market, as in our model. Furthermore, Bourreau et al. (2011) show that an access price cap may induce upstream competition between the two vertically integrated firms. Other papers that analyze competition between vertically integrated firms and non-integrated access buyers are Krämer and Schnurr (2018), showing how margin-squeeze regulation may be detrimental for consumers, and Atiyas et al. (2015) analyzing non-observable access contracts. In contrast to our paper, these papers abstract from the possibility that the entrant might invest in a network of its own and therefore faces a build-or-rent decision.

Spatial competition models (Hotelling, 1929; Salop, 1979; Vickrey, 1964) are widely used to analyze mobile competition (Laffont, Rey, Tirole, 1998a, 1998b; Armstrong, 1998; and a number of subsequent papers). Previously, mobile providers offered consumer tariffs with a combination of monthly fees and usage prices for voice and text. Laffont, Rey, Tirole (1998a, 1998b) and Armstrong (1998), among others, allowed for elastic demand with respect to usage and inelastic demand with respect to participation. In the recent years, the arena of competition has changed from voice/text to data. The firms have discrete menus of monthly subscription fees; the larger amount of data included, the higher

[10] Vogelsang (2003) provides a survey on the literature on access price regulation within telecommunications markets.

the subscription fee (unlimited usage of voice and text is included). Consequently, the majority of the consumers do not face a cost of data at the margin. For our purpose, it therefore seems reasonable to assume that all consumers have unit demand, which is inelastic with respect to both participation and volume. This keeps the model simple and highlights the forces at work.

There is no doubt that building up several mobile networks involves significant duplication of fixed costs. As mentioned in the Introduction, though, sector-specific and competition authorities within the EU have the view that sustainable competition in this market requires that there at least 3-4 vertically integrated providers. With fewer providers, costly market surveillance or regulation might be required to ensure that consumer prices are at a satisfactory level. More competition among vertically integrated providers without the need to buy access from rivals lowers consumer prices (Ofcom, 2016, among others, see footnote 2 above). Furthermore, an increase in the number of vertically integrated firms may increase the level of product and/or process innovation, as analyzed by Motta and Tarantino (2017; see also Bourreau et al., 2018). They analyze investment incentives under mergers and two-way network sharing (modelled as process innovation, as in the seminal paper by d'Aspremont and Jacquemin, 1988). We abstract from this, and do not allow the vertically integrated firms, or the entrant, to undertake investments that cause product or process innovation.

3 The model

We consider a mobile market with three competing firms. Firm 1 and firm 2 have networks with nationwide coverage, $k_1 = k_2 = K$, while firm 3 is an entrant that may build its own network. If it builds a network with only partial coverage ($k_3 < K$), it must get access to the network of either firm 1 or firm 2 in order to achieve national coverage. As we show below, in equilibrium firm 3 will be offered an access contract that it will accept. The effective network size of firm 3 is thus equal to K, which is divided into own network coverage, $k_{3,}$ and rented coverage, $K - k_3$.

Let A_j denote the per-consumer cost for firm 3 of accessing the network of firm $j = 1$ or $j = 2$. Consistent with the access contract discussed in the Introduction, we assume that

A_j has the shape of a two-part tariff:

$$A_j = s_j + w_j(K - k_3). \tag{1}$$

The first term on the right-hand side of (1), $s_j \geq 0$, is the so-called SIM card fee; this is a per consumer fee that is independent of the size of firm 3's physical network. Additionally, firm 3 has to pay a rental rate $w_j \geq 0$ per consumer for the coverage to which it obtains access to through the access agreement, $K - k_3$. This cost element is reflected by the second term on the right-hand side of (1).[11] Total payment from firm 3 to its access partner is thus equal to $A_j D_3$, where D_3 is firms 3's consumer base.

We use the Salop-Vickrey circle city model. The firms are located symmetrically around a circle of unit circumference at $x_1 = 0$ (firm 1), $x_2 = 1/3$ (firm 2), and $x_3 = 2/3$ (firm 3). Consumers have unit demand, and a mass one of consumers is uniformly distributed around the circle.

Let p_i be the consumer price of good i. The utility of a consumer located at x of buying from firm i is equal to

$$u_i(x) = v - t\,|x_i - x| - p_i,$$

where $v > 0$ is the consumer's reservation utility and $t > 0$ is the transportation cost. We assume that v is sufficiently high to ensure that each consumer buys from one of the firms.

Using that the location of the consumer who is indifferent between buying from firm i and firm j is given by $u_i(x) = u_j(x)$, where $i, j = 1, 2, 3$ and $i \neq j$, we find that consumer demand for firm i is

$$D_i(.) = \frac{1}{3} - \frac{2p_i - (p_j + p_k)}{2t}, i, j, k = 1, 2, 3 \text{ and } i \neq j \neq k. \tag{2}$$

The Norwegian Competition Authority (2018) claims that a change in the *structure* of the access price A_j hampered firm 3's investment incentives in own network. A necessary condition for this to be true, is that access prices are decided prior to firm 3's investment decision. We consequently assume the following timing of the game:

[11] The rental rate is typically for the usage (voice, text, and data) for each consumer of the access buyer. Consequently, it does not directly depend on the coverage. However, it is reasonable to believe that the higher the degree of own coverage is (for the access buyer), the lower will the usage of roaming capacity be.

- At stage 0, firm $j = 1, 2$ offers the contract (s_j, w_j) to firm 3. Since both firm 1 and firm 2 have nationwide coverage, firm 3 will sign an access contract with only one of them; it accepts the offer which maximizes own profit (given that its participation constraint is satisfied).
- At stage 1, firm 3 chooses its investment level $k_3(s_j, w_j)$, where $j = 1$ or $j = 2$, depending on its choice at stage 0.
- At stage 2, the three firms compete in prices.

We assume that it is costless to provide network access and that the cost on the upstream market is essentially the fixed cost of building the network.

Until otherwise stated, we presuppose that firm 1 offers firm 3 an access contract.[12] Below, we verify that firm 1 indeed has incentives to do so. We also provide results for the case where firm 1 and firm 2 compete for the opportunity to be firm 3's access partner.

Setting all operating costs equal to zero (except for firm 3's access cost), we can write the firms' operating profits as:

$$\pi_1 = p_1 D_1 + A_1 D_3; \pi_2 = p_2 D_2; \pi_3 = (p_3 - A_1) D_3. \tag{3}$$

The net profit of firm 3 is given by

$$\Pi_3 = \pi_3 - C(k_3),$$

where $C(k_3) = \frac{\sigma}{2} (k_3)^2$ is the investment that firm 3 must undertake in order to cover k_3 of the geographical market. We assume that the parameter $\sigma > 0$ is sufficiently large to ensure that the necessary second-order and stability conditions are satisfied.[13]

We solve the game by backward induction.

[12] We would get symmetric results if we started with firm 2 always offering an access contract.

[13] We have assumed seamless interconnection between the access seller and the access buyer. A well-known problem for a mobile provider with partial coverage is that it does not manage to use its own coverage in an efficient way. In the case at hand, the Norwegian Competition Authority (2018, page 37) describes that when the entrant (Mobile Norway) had a coverage of 40%, it only managed to have 25% of its customers' traffic in its own network. We abstract from this issue in the present model, since it is not qualitatively important for our results.

3.1 Downstream price competition (stage 2)

At the final stage, the firms maximize profit with respect to prices ($\partial\pi_i/\partial p_i = 0$). Given that firm 3 has reached an access agreement with firm 1, we find the following equilibrium prices:

$$p_1^* = \frac{1}{3}t + \frac{5}{10}A_1; p_2^* = \frac{1}{3}t + \frac{3}{10}A_1; p_3^* = \frac{1}{3}t + \frac{7}{10}A_1. \tag{4}$$

A necessary condition for (4) to hold is that firm 3 makes a non-negative profit margin. To ensure that this is the case, we make the following assumption (which we shall later see is always satisfied in equilibrium):

Assumption 1: $A_1 \leqslant 10t/9$.

Firm 3 charges a higher price the greater its marginal access cost, A_1. Since prices are strategic complements, the rivals' prices are also increasing in A_1 (although to a lesser extent). It should also be noted that firm 1 makes a positive profit from renting access to firm 3 if $A_1 > 0$, in which case firm 1 will be relatively soft compared to firm 2. This explains why $p_2^* < p_1^* < p_3^*$ if $A_1 > 0$, and it further implies that firm 2 captures the largest share of the downstream market and firm 3 the smallest share:

$$D_2^* = \frac{1}{3} + \frac{3}{10t}A_1 > D_1^* = \frac{1}{3} > D_3^* = \frac{1}{3} - \frac{3}{10t}A_1. \tag{5}$$

Therefore, firm 2 has a competitive advantage in the downstream market, and in Section 3.3. we show that this has important implications for firm 2's incentives to compete with firm 1 for the access contract with firm 3.

3.2 Entrant's investment decision (stage 1)

At stage 1, firm 3 decides its investment level k_3 by maximizing its net profit

$$\Pi_3^*(k_3) = (p_3^* - A_1)\, D_3^* - C(k_3). \tag{6}$$

Differentiating (6) with respect to k_3 and using the envelope theorem we find

$$\frac{d\Pi_3^*}{dk_3} = \left[-D_3^*\frac{dA_1}{dk_3} - C'(k_3)\right] + (p_3^* - A_1)\left(\frac{\partial D_3^*}{\partial p_1^*}\frac{dp_1^*}{dA_1} + \frac{\partial D_3^*}{\partial p_2^*}\frac{dp_2^*}{dA_1}\right)\frac{dA_1}{dk_3}. \tag{7}$$

To interpret equation (7), note that firm 3 reduces its per consumer access costs by $|dA_1/dk_3| = w_1$ units if it increases the size of its own network by one unit. The value of this for the firm is $-D_3^* dA_1/dk_3 = w_1 D_3$. Subtracting the marginal investment costs σk_3, we have that the direct effect of investing is equal to the term in the square bracket of (7). However, there is also a strategic effect; since firm 3's marginal costs fall if it invests in more coverage, the rivals will charge lower prices, c.f. equation (4). The size of this strategic effect, which reduces firm 3's investment incentives, is equal to its profit margin $(p_3^* - A_1)$ times the change in output due to the rivals' price reductions. This effect is captured by the last term in (7).

Using (1), (2) and (4) we can simplify (7) to

$$\frac{d\Pi_3^*}{dk_3} = [D_3^* w_1 - C'(k_3)] - \frac{2}{5t}(p_3^* - A_1)w_1. \tag{8}$$

Setting $d\Pi_3/dk_3 = 0$, inserting D_3^* from equation (5), and using that $A_1 = [s_1 + w_1(K - k_3)]$ we can write firm 3's optimal investment level as

$$k_3^* = \min\left\{ w_1 \frac{10t - 9(s_1 + w_1 K)}{50t\sigma - 9w_1^2}; K \right\}. \tag{9}$$

Both the numerator and the denominator in (9) are positive when the second-order condition $(d^2\Pi_3^*/dk_3^2 < 0)$ and the non-negativity constraints are satisfied.[14]

Before we move on to stage 0, let us consider how changes in s_1 and w_1 affect k_3^* (given that $k_3^* < K$). Let us start with the former. Since firm 3's marginal cost A_1 - and thus its consumer price - is strictly increasing in s_1, the firm's equilibrium number of consumers is strictly decreasing in s_1. With fewer consumers, firm 3's incentives to make investments that reduce marginal costs fall. From (9) we thus find[15]

[14] From (5) we find that firm 3 will have a positive profit margin if $A_1 = s_1 + w_1(K - k_3) < 10t/9$. This condition is equivalent to $10t - 9(s_1 + w_1 K) > 0$ and thus the numerator in (9) is positive. The denominator is positive whenever the SOC, $d^2\Pi_3^*/dk_3^2 = -\left(50t\sigma - 9w_1^2\right)/(50t) < 0$, is satisfied.

[15] Things are actually a bit more complicated. Differentiating (8) with respect to s_1 we find

$$\frac{d}{ds_1}\left(\frac{d\Pi_3}{dk_3}\right) = w_1 \frac{dD_3}{dA_1}\frac{dA_1}{ds_1} - \frac{2}{5t}\left(\frac{dp_3}{dA_1} - 1\right)\frac{dA_1}{ds_1} w_1. \tag{10}$$

$$= -\frac{3}{10t} w_1 + \frac{6}{50t} w_1 = -\frac{9}{25}\frac{w_1}{t} \tag{11}$$

The first term on the r.h.s. of (11) is negative; other things equal, firm 3's investment incentives fall because D_3 is decreasing in s_1. The second term on the r.h.s. of the equation is positive, reflecting the fact that the strategic effects identified in (7) become less pronounced when A_1 increases, because firm 3's

$$\frac{dk_3^*}{ds_1} = w_1 \frac{-9}{50t\sigma - 9w_1^2} < 0.$$

To see how an increase in w_1 affects the incentives to invest in network capacity, we differentiate (8) with respect to w_1. This yields

$$\frac{d}{dw_1}\left(\frac{d\Pi_3^*}{dk_3}\right) = \underbrace{\frac{dD_3^*}{dA_1}\frac{dA_1}{dw_1}w_1}_{-\frac{3(K-k_3)}{10t}w_1} + D_3^* - \left[\underbrace{\frac{2}{5t}\frac{d(p_3^*-A_1)}{dA_1}\frac{dA_1}{dw_1}w_1 + \frac{2}{5t}(p_3^*-A_1)}_{\frac{6(K-k_3)}{50t}w_1+\frac{2}{5t}(p_3^*-A_1)}\right]. \tag{12}$$

To interpret equation (8), recall that $w_1 D_3^*$ measures the direct positive effect of investing for firm 3; the product of the rental rate and the number of consumers. It follows that the greater is w_1, the more the positive value of investing in network capacity will fall if, for some reason, the number of consumers decreases. Anything that reduces D_3^* therefore tends to reduce k_3. An increase in w_1 reduces D_3^* because firm 3's marginal costs increase. In isolation, this indicates that firm 3's investment incentives are decreasing in w_1, particularly if w_1 is large initially. This effect is captured by the first term in (12), which consequently is more negative the greater w_1. However, there is also an opposing effect; an increase in w_1 reduces the cost of investing in network capacity *relative* to renting it. The importance of this effect is increasing in the number of consumers the firm serves, and is captured by the second term in (12). Finally, we must subtract the terms in the square bracket of (12); the strategic effect of an increase in A_1 is to reduce output from firm 3's rivals. Other things equal, this effect tends to reduce investment incentives, and more so the greater firm 3's profit margin, as noted above. However, this effect becomes less important – less negative – if w_1 increases, because firm 3's profit margin falls.

Since the first term in (12) is increasing in w_1 (and is equal to zero for $w_1 = 0$), we might expect that an increase in w_1 is more likely to reduce investment incentives for high values of w_1 than for low values of w_1. Formally, this is verified by noting that:

$$\frac{d}{dw_1}\left(\frac{d\pi_3}{dk_3}\right) = -\frac{18(K-k_3)}{50t}(w_1 - \hat{w}_1) \lesseqgtr 0 \text{ if } w_1 \gtreqless \hat{w}_1,$$

where $\hat{w}_1 \equiv \frac{10t-9s_1}{18(K-k_3)}$.

profit margin falls. As expected, the first term dominates.

Figure 1 shows a numerical example of how w_1 affects k_3^*; it is increasing in w_1 for $w_1 < \hat{w}_1 \approx 1.65$, and decreasing in w_1 for $w_1 > 1.65$.[16]

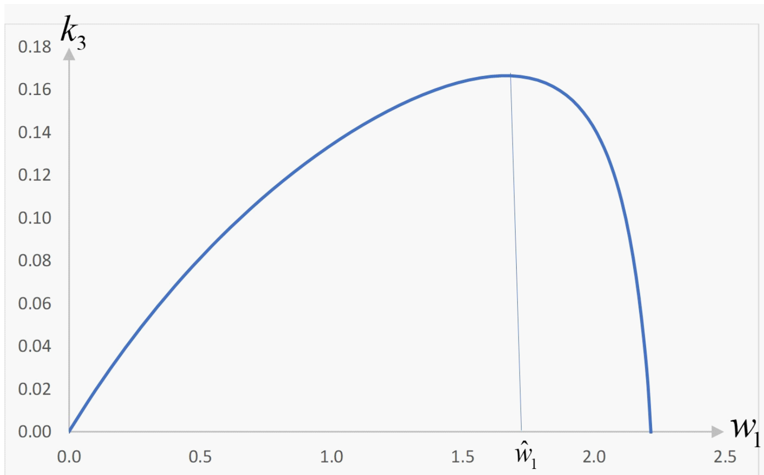

Figure 1: *Firm 3's own investment as a function of the network rental rate.*

The Norwegian Competition Authority (2018) claims that a change in the access-price structure such that the SIM card fee (s_1) increases and the rental rate (w_1) falls hampers the entrant's investment incentives. The analysis above shows that this is not necessarily true; in absence of an empirical analysis, it cannot be ascertained whether a lower rental rate has a positive or negative effect on the investment level. Consequently, we do not know how firm 3's investment incentives are affected if s_1 increases and w_1 decreases; the change implemented by Telenor (firm1) *in casu*.

3.3 The access market (stage 0)

When we analyze the first stage of the game, we open up for the possibility that firm 3 will connect with firm 2 instead of with firm 1. It is now useful to introduce a double subscript on firm profit such that a given firm is identified by the first subscript while the second subscript indicates which firm offers network access. We thus let π_{jj} denote operating profit for firm j (the vertically integrated firm that signs an access contract with firm 3), π_{ij} operating profit for the other vertically integrated firm (so that $i, j = 1, 2$; $i \neq j$) and π_{3j} profit for firm 3. Using the profit-maximizing prices and quantities from the second stage, given by equations (4) and (5), we can write the three firms' profit as

[16] Parameter values in Figure 1: $K = 1/2$, $t = 1$, $\sigma = 1$, and $s_1 = 0$.

$$\pi_{jj}^{*}=\frac{1}{9}t+A_{j}\frac{5t-3A_{j}}{10t},\ \pi_{ij}^{*}=\frac{1}{9}t+A_{j}\frac{20t+9A_{j}}{100t},\ \pi_{3j}^{*}=\frac{1}{9}t-A_{j}\frac{20t-9A_{j}}{100t}. \tag{13}$$

From (13) it is evident that firm j's profit is a hump-shaped function of A_j. The reason is that a higher value of A_j has two effects; it increases consumer prices, and therefore downstream profit, but it also makes firm i more competitive and the access buyer (firm 3) less competitive.

From (13) we find that

$$\pi_{ij}^{*}-\pi_{jj}^{*}=\frac{3A_{i}\left(13A_{i}-10t\right)}{100t}>0 \text{ if } A_{j}>A^{crit}\equiv\frac{10}{13}t\approx 0.77t. \tag{14}$$

Due to its competitive advantage in the downstream market, firm i is consequently better off than firm j if $A_j > A^{crit}$. This is the case even though firm j makes a relatively high profit from its access agreement with firm 3. It is now interesting to analyze whether we can actually have a free-market equilibrium where $A_j > A^{crit}$. To provide an answer to this question, we first derive firm j's profit-maximizing access price. Solving $d\pi_{jj}^{*}/dA_j = 0$ we find that the unconstrained optimum for firm j is to set $A_j = A^{mon} \equiv 5t/6$. Firm j will consequently set $A_j > A^{crit}$, and prices and profit levels are equal to

$$p_{j}^{mon} = \frac{9}{12}t;\ p_{i}^{mon}=\frac{7}{12}t;\ p_{3}^{mon}=\frac{11}{12}t \tag{15}$$

$$\pi_{jj}^{mon} = \frac{46}{144}t\approx 0.32t,\ \pi_{ij}^{mon}=\frac{49}{144}t\approx 0.34t,\ \pi_{3j}^{mon}=\frac{1}{144}t \tag{16}$$

The results in (16) show that firm j will not set A_j so high that firm 3 is foreclosed from the market.[17] This is perhaps not too surprising, since a high value of A_j makes firm j relatively

[17] In our model, the entrant (firm 3) always obtains nationwide coverage through a roaming agreement. Then, the entrant may benefit from reduced investment costs if the access price structure is changed (a decrease in the rental fee combined with an increase in the SIM card fee). However, to compete without a roaming agreement may be an outside option for the entrant if its own coverage is sufficiently high. We have not considered this alternative. In practice, to compete without a roaming agreement will not be an alternative before the entrant has (almost) nationwide coverage. If not, the entrant will have an inferior product, not only compared to the vertically integrated firms with nationwide coverage, but also to all virtual operators that have nationwide coverage through MVNO-agreements. We typically observe that access buyers advertise that they have nationwide coverage from one of the vertically integrated firms. For the same reason, the entrant will typically not want to degrade the quality in areas without own coverage, such that consumers use less of the access seller's network. Again, such a behavior will make the entrant's product inferior (such that the entrant cannot advertise nationwide coverage identical to the access seller).

disadvantaged in the consumer market. What if firm j could instead use tools that do not reduce its competitiveness towards firm i to prevent firm 3 from entering the market (for instance, by requiring a prohibitively high fixed cost for signing an access contract)? Would it do this? Interestingly, the answer is no. Prices and profits in an outcome where only the vertically integrated firms *1* and *2* are present would be equal to $p_i = p_j = t/2$ and $\pi_{ii} = \pi_{ij} = 0.25t$ (see Appendix A3).[18] Compared to (16), we thus see that the vertically integrated firms make a higher profit if firm 3 is operative than if it is not:

Lemma 1: *Firm j maximizes profits by setting the access cost for firm 3 equal to $A^{mon} = 5t/6 \approx 0.83t$. Each of the vertically integrated firms makes a higher profit than if firm 3 was not operative.*

The intuition behind Lemma 1 is that by signing an access contract with firm 3, firm j sends a credible signal that it will charge a relatively high price. Since prices are strategic complements, firm i will respond by increasing its price. Market competition thus becomes softer, increasing profits for both of the vertically integrated firms.

We can now conclude:

Proposition 1: *In a pure strategy Nash equilibrium with no regulation: (i) Vertically integrated firm j will sign an access contract with firm 3 and set $A_j = A^{mon}$, but it makes lower profit than its vertically integrated rival. (ii) Since the vertically integrated firms will not fight for the access contract, there is no reason for the access provider to introduce a SIM card fee; it can instead charge the entrant entirely through the rental rate.*

The results in Lemma 1 and part (i) of Proposition 1 are in line with Bourreau et al. (2011) and Höffler and Schmidt (2008). At the outset, it is uncertain which of the two vertically integrated firms will sign the access contract; all we can say is that one of them will do so. However, if competition law or regulation policies require that firm 1 provides network access for firm 3 unless firm 2 does so (as discussed above), then firm 1 will have to sign the contract. Since firm 2 does not want to compete in access market, firm 1 has

[18] We have assumed that firm 1 and firm 2 are located at 0 and 1/3 on the Salop circle. One might think that they would have incentives to relocate if firm 3 were not in the market. In Appendix A3 we also show that this is not the case.

no reason to use a SIM card fee, such that we de not expect that a SIM card fee is used in a market without competition in the access market.

We shall now follow Bourreau et al. (2011) and assume that the regulator imposes a price cap, $\bar{A}$. This price cap applies only for firm 1, which consequently cannot charge more than $A_1 \leq \bar{A}$. Firm 2 is free to choose any level it wants to for A_2. The price cap may be due to sector-specific regulation. Alternatively, it may be the case that only one of the vertically integrated firms is defined as a dominant provider according to the competition law (as in the Norwegian case). A dominant provider may de facto face a price cap due to margin squeeze requirements. If the market is otherwise unregulated, we have the following result:

Proposition 2: *Suppose that firm 1 faces a price cap $A_1 \leq \bar{A}$, and that there is no further regulation. Then in equilibrium firms 1 and 3 will be access partners. With no further regulation, firm 1 will sign the access contract, and firm 3's access cost is equal to*

(a) $A_1 = A^{mon}$ if $\bar{A} \geq A^{mon}$ (the price cap is non-binding);

(b) $A_1 = \bar{A}$ if $\bar{A} \in [A^{crit}, A^{mon}]$;

(c) $A_1 = 0$ if $\bar{A} \in (0, A^{crit})$.

Results (a) and (b) follow directly from the analysis above; firm 2 does not have any incentives to underbid firm 1 if $\bar{A} \geq A^{crit}$, since each vertically integrated firm prefers the other to sign the access contract. Result (c) follows from Bourreau et al. (2011), who have shown that the price of a homogenous upstream good will be pushed down to marginal costs if two vertically integrated firms compete to provide it. In our context this means that firm 3's access cost will be equal to zero ($A_1 = 0$) if $\bar{A} \in (0, A^{crit})$.

This paper is motivated by the Norwegian telecommunications market, where firm 1 (Telenor) is not allowed to use a SIM card fee. Firm 2 (Telia), on the other hand, faces no restrictions. Consistent with this, we assume that firm 1 is required to set $s_1 = 0$ and faces a price cap $A_1 \leq \bar{A}$, while firm 2 can freely choose both the level and structure of A_2.[19] The next proposition illustrates how strict and asymmetric regulation can have unexpected consequences for pricing strategies (the proof can be found in Appendix A1):

Proposition 3: *Suppose that firm 2 is unregulated while firm 1 faces a price cap $A_1 \leq \bar{A}$ and cannot use a SIM card fee (must set $s_1 = 0$).*

[19] As documented in the Introduction, Telia (firm 2) uses an access price that includes a SIM card fee.

(a) If $\bar{A} \geq A^{crit}$*, firm 1 and firm 3 will be access partners, with* $A_1 = \min\left\{\bar{A}, A^{mon}\right\}$.

(b) If $\bar{A} < A^{crit}$*, firm 2 and firm 3 will be access partners, with* $w_2 = 0$ and $A_2(\bar{A}) = \min\left\{\frac{10}{9}t - \frac{10}{3}\sqrt{t\Pi_{31}(\bar{A})}, A^{mon}\right\} = s_2$.

The difference between Proposition 3 (c) and Proposition 4 (b) is striking, and illustrates that asymmetric regulation of vertically firms might be problematic from a welfare point of view. If either both or none of the firms were allowed to use SIM card fees, the access price would be competed down to marginal costs if $\bar{A} < A^{crit}$. This follows from Proposition 3 (c). However, to the disadvantage of the consumers, the access cost will always be positive in the asymmetric case. This is because the asymmetric regulation gives the unregulated firm an advantage. Whatever the price cap faced by firm 1, firm 2 can always offer the same overall tariff but with a different structure that is preferred by firm 3. This implies, that for any access price offered by firm 1, firm 2 can offer a more attractive deal without lowering the overall price to firm 3. It could be argued that the regulator should therefore set $\bar{A} = 0$. However, in practise it seems unlikely that a regulator will require a commercial firm to sell the upstream good at marginal cost, even though that such an access price might be the equilibrium outcome if both firms could freely choose the structure of the access price.

The following numerical example illustrates the consequences of a cap on A_1 and the requirement that s_1 is set to zero. In the figures that follow we have set $t = \sigma = 1$ and $K = 1/2$. These parameter values ensure that $\bar{k}_3 \in (0, K)$, and we only consider cases where firm 2's profit is highest when it has an access contract with firm 3 (i.e., when $A_1 < A^{crit}$).

The solid upward-sloping curve in the left-hand panel of Figure 2 shows the access price that firm 2 will optimally set; the price is higher than the price cap that firm 1 faces for all $\bar{A} > 0$. The fact that firm 2 can use a SIM card fee allows it to offer a pricing structure that for a fixed total access price $\bar{A}$ reduces firm 3's investment costs and increases its net profits. This gives firm 2 the opportunity to raise its total access price A_2 above $\bar{A}$ and still remain the preferred partner of firm 3. Other things equal, A_2 is strictly increasing in $\bar{A}$ for $A_2 < A^{mon}$. However, it will not set the price higher than A^{mon}. Thus, if $\bar{A}$ is higher than a critical value $\hat{A}$, we have $A_2(\bar{A}) = A^{mon}$ (and firm 3 will make a strictly higher profit if it enters an access contract with firm 2 rather than with firm 1).

One might think that if firm 2 chooses to offer an access contract to firm 3, then firm 2 will make higher profit than firm 1. The right-hand side panel of Figure 3 shows that this is not the case. On the contrary, $\pi_{22} < \pi_{12}$ for sufficiently high values of $\bar{A}$. The explanation for this result is that we have $A_2(\bar{A}) \geq A^{crit}$ if $\bar{A} \geq 0.59$, in which case we know from Lemma 1 that the vertically integrated firm that does not provide access to the entrant makes the higher profit level. However, firm 2 still wants to be the access provider; if it should choose to leave the access contract to firm 1, the access price for firm 3 would fall from $A_2(\bar{A})$ to $\bar{A}$ and increase the competitive pressure. That would make firm 2 worse off.

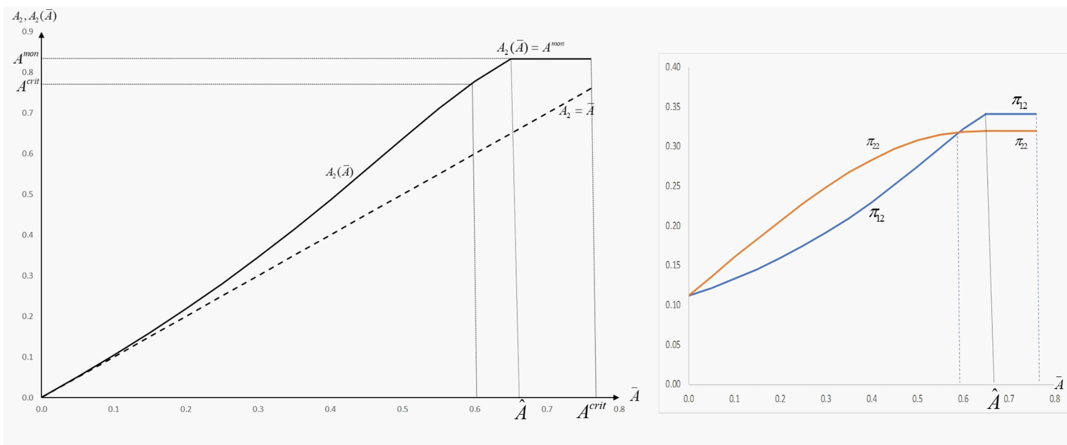

Figure 2: *Access prices and profits when firm 2 is the access provider.*

Figure 2 can be summarized by the following two corollaries:

Corollary 1: *Suppose that firm 2 is unregulated while firm 1 faces a price cap $A_1 \leq \bar{A}$ and cannot use a SIM card fee (must set $s_1 = 0$).*

a) Then there exists a threshold $\hat{A} > 0$ such that for all $\bar{A} \in (\hat{A}, A^{crit})$, $A_2 = A^{mon}$ and firm 3 makes a strictly higher profit when buying access from firm 2 rather than from firm 1 ($\pi_{32} > \Pi_{31}$).

b) Even if firm 2 chooses to be the access provider (which holds if $\bar{A} < A^{crit}$), firm 2 is less profitable than firm 1 if $A_2(\bar{A}) \geq A^{crit}$.

4 Concluding remarks

We consider a model where three mobile providers compete in the downstream market. Two of the firms are vertically integrated with nationwide coverage. The third firm is an entrant that invests in partial coverage and needs to buy access (national roaming) from one of its rivals in order to provide nationwide coverage. We show that the vertically integrated firms welcome the entrant. The reason is that the access provider commits to softening its behavior in the downstream market by allowing entry. The driving force resembles a Stackelberg pricing game (such as in the literature on strategic delegation). Both vertically integrated firms are better off compared to an outcome without entry, but the vertically integrated firm that does not provide access ("the Stackelberg follower") is better off than the access seller ("the Stackelberg leader").

If either both or none of the vertically integrated firms face restrictions on the access price structure, the total access price will be competed down to the (upstream) marginal cost, as long as a price cap is sufficiently strong to induce access competition. In contrast, if the dominant (regulated) firm is restricted with respect to which instruments it can use (here: not allowed to use a SIM card fee per consumer served by the entrant), while the other vertically integrated firm faces no restrictions, the total access price will be above the upstream marginal cost. This is detrimental for consumers. Asymmetric regulation might therefore have negative competitive consequences. This is a cautionary tale for competition authorities as well as for sector-specific regulators that both typically impose restrictions on only one of the vertically integrated firms.

Our motivation is from the Norwegian mobile market, where the competition authorities imposed a EUR 78 million fine on Telenor (the incumbent) for hampering the entrant's investment incentives by changing the structure of the total access price. More precisely, Telenor introduced a per consumer SIM card fee at the same time as it reduced the rental rate for actual usage of Telenor's network. Our model suggests that such an access price structure may be the outcome of increased competition in the access market. Interestingly, this seems to be consistent with the observations from the Norwegian mobile market, where the unregulated vertically integrated firm (Telia) uses such two-part tariffs with a positive SIM card fee (see footnote 6 in the Introduction). In the last ten years, Telia has also strengthened its market share in the upstream access market.[20]

5 Appendix

5.1 Appendix A1. Proofs of Proposition 3 and Corollary 1

Proof of Proposition 3: As for Proposition 3, result (a) follows directly from Lemma 1 and the insights on pricing from the previous propositions.

The rest of the proof deals with the case $\bar{A} < A^{crit}$. In this case, we know from Lemma 1 that each of the two vertically integrated firms would like to be the one entering into an access agreement with firm 3. Notice first that whatever access price $A_1 \leq \bar{A}$ that is offered by firm 1, firm 2 will win the contract with firm 3. This can by done by offering $A_2 = A_1$ and shifting the payment structure so that s_2 is slightly higher and w_2 slightly lower than what firm 1 offers, but without changing the overall tariff (then the operating profits of firm 3 remains unchanged but it saves on investment costs, and prefers the contract with firm 2). Since profit π_{ij} is increasing in $\bar{A}$ for $\bar{A} < A^{crit}$, firm 1 will set $A_1 = \bar{A}$ to ensure that A_2 is as high as possible and thus maximize its own profit.

If firm 1 were to provide access at price $A_1 = \bar{A}$. Using that $A_1 = w_1(K - k_3)$ when $s_1 = 0$ and inserting this into equation (9), we find

$$\begin{aligned}
\bar{w}(\bar{A}) &= 5\frac{5Kt\sigma - \sqrt{25K^2t^2\sigma^2 - 2t\sigma\bar{A}\left(10t - 9\bar{A}\right)}}{10t - 9\bar{A}}, \ \bar{s} = 0 \text{ and} \\
\bar{k}_3(\bar{A}) &= K - \frac{\bar{A}}{\bar{w}(\bar{A})}.
\end{aligned}$$

Substituting A_1 for $\bar{A}$ in equation (13), we further have

$$\bar{\pi}_{11}(\bar{A}) = \frac{1}{9}t + \bar{A}\frac{5t - 3\bar{A}}{10t}, \ \bar{\pi}_{21}(\bar{A}) = \frac{1}{9}t + \bar{A}\frac{20t + 9\bar{A}}{100t}, \ \bar{\pi}_{31}(\bar{A}) = \frac{1}{9}t - \bar{A}\frac{20t - 9\bar{A}}{100t}. \quad (17)$$

Net profit for firm 3 equals

$$\Pi_{31}(\bar{A}) = \bar{\pi}_{31}(\bar{A}) - C(\bar{k}_3(\bar{A})). \quad (18)$$

[20] Telia has strengthen its market share in the upstream access market with respect to service provider/MVNO agreements as well as national roaming. Currently Ice, the provider with a partial coverage, buy national roaming from Telia. When Tele2 merged with Telia in 2015, Tele2's partial coverage was sold to Ice as a remedy (see footnote 3).

Equations (17) and (18) show the profit levels in an outcome where firm 1 and firm 3 are access partners. If firm 2 wants to secure the contract with firm 3, this is the minimum profit level it needs to leave firm 3 (a sort of participation constraint).

To go into the details of the access price offered by firm 2, note from equation (17) that firm 2 is indifferent *per se* to the structure of A_2. However from (18) we can see that for a given access cost, it is more attractive for firm 3 to connect to firm 2 the lower w_2 (because this allows firm 3 to save on investment costs). This is mirrored by the fact that the lower w_2, the higher firm 2 can set A_2 compared to A_1 and still be attractive for firm 3. It follows that if it is profitable for firm 2 to be the access provider, it will have no incentives to set $w_2 > 0$. We can therefore conclude that $A_2 = s_2$. With such a contract it will be optimal for firm 3 to make zero investments ($k_3 = 0$), and simply rent full network coverage from firm 2. This is of course an extreme result. It is straigtforward to show that $w_2 > 0$ and $k_3 > 0$ if the marginal cost of providing network access is positive, but it does not change any of the qualitative results.

Since firm 1 offers access to firm 3 at price $\bar{A}$, firm 2 cannot win the contract with firm 3 unless $\pi_{32} = \Pi_{32} \geq \Pi_{31}(\bar{A})$. The optimal value of A_2 is thus a function of $\bar{A}$; $A_2 = A_2(\bar{A})$.

We must now distinguish between two cases:

- *Case 1* $A_2 = A^{mon}$: Firm 2 will clearly never set $A_2 > A^{mon}$. It might therefore be the case that firm 2 sets $A_2 = A^{mon}$ even if it could win the access contract with higher values of A_2. If this is true, firm 3 will get a strictly higher profit if it signs an access contract with firm 2 than with firm 1 ($\pi_{32} = \Pi_{32} > \Pi_{31}(\bar{A})$).

Inserting $A_2 = A^{mon} \equiv 5t/6$ into (13) we find

$$\pi_{12}^{mon} = \frac{49}{144}t,\ \pi_{22}^{mon} = \frac{46}{144}t,\ \pi_{32}^{mon} = \frac{1}{144}t. \tag{19}$$

This is only possible when $\Pi_{31}(\bar{A}) < \frac{1}{144}t$. If not, we are in case 2.

- *Case 2* $A_2(\bar{A}) < A^{mon}$: Operating profits for the firms are then

$$\pi_{12} = \frac{1}{9}t + A_2(\bar{A})\frac{20t + 9A_2(\bar{A})}{100t},\ \pi_{22} = \frac{1}{9}t + A_2(\bar{A})\frac{5t - 3A_2(\bar{A})}{10t}, \tag{20}$$

$$\pi_{32} = \frac{1}{9}t - A_2(\bar{A})\frac{20t - 9A_2(\bar{A})}{100t}. \tag{21}$$

The reason why $A_2(\bar{A}) < A^{mon}$ is that firm 3 will sign an access contract with firm 1 if firm 2 tries to set a higher value of $A_2(\bar{A})$. In other words, we must have $\pi_{32} = \Pi_{31}$. Solving this equation implies that

$$A_2(\bar{A}) = \frac{10}{9}t - \frac{10}{3}\sqrt{t\Pi_{31}(\bar{A})} \text{ (with } s_2 = A_2 \text{ and } w_2 = 0). \tag{22}$$

Summing up $A_2(\bar{A}) = \min\left\{\frac{10}{9}t - \frac{10}{3}\sqrt{t\Pi_{31}(\bar{A})}, A^{mon}\right\}$.

Proof of Corollary 1a: Using (17), (18), (21)[21] and that $k_3 = 0$ when firm 3 buys access from firm 2, we obtain that $\pi_{32} > \Pi_{31}$ is equivalent to

$$\frac{\sigma}{2}(\bar{k}_3(\bar{A}))^2 > \int_{\bar{A}}^{A_2} \frac{A^2(10t - 3A)}{100t} dA. \tag{23}$$

Recall from the proof of Proposition 4 that the inequality $\pi_{32} > \Pi_{31}$ only holds when $A_2 = A^{mon}$ and that firm 2 and 3 are only access partners for $A < A^{crit}$. To complete the proof of Corollary 1, we show that the functions (of $\bar{A}$) on the left and right side of the inequality in (23) cross only once and that the inequality in (23) only holds above this value of $\bar{A}$. First notice that at $\bar{A} = 0$ this does not hold while at $\bar{A} = A_2 > 0$ it holds.

Since $\bar{A} \leq A_2$, the integral is decreasing in $\bar{A}$. Differentiating $\bar{k}_3(\bar{A})$ yields

$$\frac{d\bar{k}_3(\bar{A})}{d\bar{A}} = \frac{2t\sigma(9\bar{A} - 5t)\left[-K\left(5Kt\sigma - \sqrt{25K^2t^2\sigma^2 - 2t\sigma\bar{A}\left(10t - 9\bar{A}\right)}\right) - \frac{\bar{A}}{5}(\bar{A} - 10t)\right]}{\left(5Kt\sigma - \sqrt{25K^2t^2\sigma^2 - 2t\sigma\bar{A}\left(10t - 9\bar{A}\right)}\right)^2 \sqrt{25K^2t^2\sigma^2 - 2t\sigma\bar{A}\left(10t - 9\bar{A}\right)}}. \tag{24}$$

The term in square brackets is negative for $\bar{A} < A^{crit}$ and we can conclude that $\frac{d\bar{k}_3(\bar{A})}{d\bar{A}} > 0$ if and only if $\bar{A} < 5t/9$. Since the inequality in (23) is not satisfied at $\bar{A} = 0$, but is satisfied at $\bar{A} = A_2$, we can conclude that the two functions have a unique point of intersection, $\hat{A}$, and for $A > \hat{A}$, the inequality $\pi_{32} > \Pi_{31}$ holds.

Proof of Corollary 1b: This follows directly from Proposition 4 (which proves that firm 2 prefers to be the access provider if $\bar{A} < A^{crit}$) and Lemma 1 (which shows that firm 1 makes higher profit than firm 2 if $A_2(\bar{A}) > A^{crit}$).

[21] In (21), we use A_2 instead of $A_2(\bar{A})$. Case 1 in the proof of Proposition 4 is a special case of this equation where $A_2 = A^{mon}$.

5.2 Appendix A2. Market positioning with only two firms

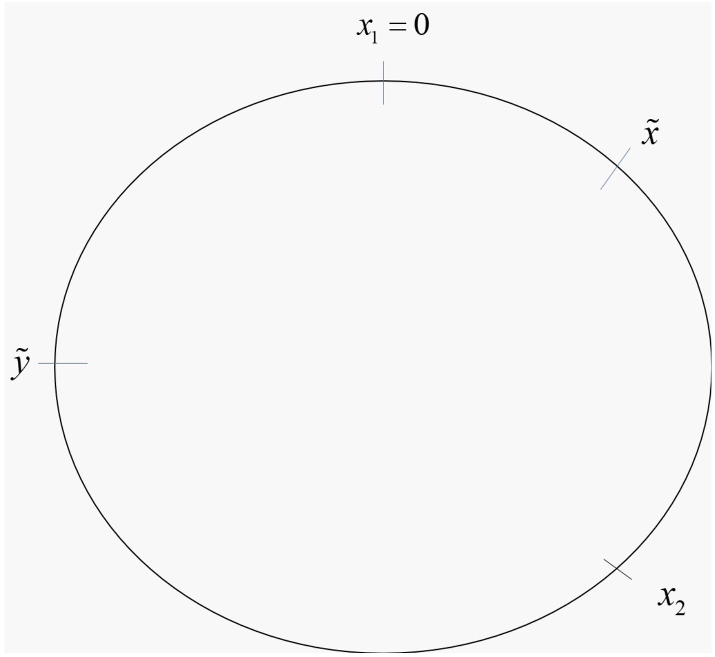

Figure A1: *Only two firms in the market.*

Suppose that firm 1 and firm 2 are the only firms in the market, and consider a two-stage game where the firms first choose location and then compete in prices. Let firm 1 be located at $x_1 = 0$ and firm 2 at some point $x_2 > x_1$. We now have two indifferent consumers; one at $\tilde{x}$ and the other at $\tilde{y}$, c.f. Figure A3. The locations of these consumers are implicitly given by $p_1 + t\tilde{x} = p_2 + t(x_2 - \tilde{x})$ and $p_1 + t\,(1 - \tilde{y}) = p_2 + t(\tilde{y} - x_2)$, respectively. From this it follows that $\tilde{x} = x_2/2 + (p_2 - p_1)/(2t)$ and $\tilde{y} = (1 + x_2)/2 + (p_1 - p_2)/(2t)$. Solving $d\pi_i/dp_i = 0$, where $\pi_1 = p_1\tilde{x} + p_1(1 - \tilde{y})$ and $\pi_2 = p_2(x_2 - \tilde{x}) + p_2(\tilde{y} - x_2)$, we find that the outcome of the second stage is $p_1 = p_2 = t/2$. Since prices are independent of locations, it follows that the firms are indifferent to where on the circle they are located, as long as they are differentiated ($x_1 \neq x_2$). To see the intuition, refer to Figure A3 and suppose that firm 2 moves a bit clockwise. Then the distance $[x_1, x_2]$ increases, and firm 2 will therefore have greater market power over the consumers who are located in the neighborhood of x_2 in the segment $[x_1, x_2]$. In isolation, this allows firm 2 to charge a higher price. However, it will now be closer to firm 1 in the segment $[x_2, x_1]$, and this calls for a lower price. With linear transportation costs these effects cancel out, implying that the firms have no incentives to relocate from any points (x_1, x_2) as long as $x_1 \neq x_2$ (if they were located at $x_1 = x_2$ we would have $\pi_1 = \pi_2 = 0$).

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We consider a market structure with three mobile providers, two of which are vertically integrated and have nationwide coverage. The third provider (an entrant) invests in partial coverage, and needs to rent access from one of its rivals in order to provide nationwide coverage. The paper is motivated by the Norwegian mobile market, where the competition authorities imposed a fine of EUR 78 million on Telenor (the dominant incumbent) for abusing market power by changing the access price structure in such a way that it hampered the entrant's investment incentives. Specifically, Telenor reduced the rental rate for the actual use of Telenor's network. At the same time, they introduced a SIM card fee payable by the entrant for each of its consumers. We show that the relationship between the change in the access price structure and the entrant's investment level is ambiguous. Competition among the vertically integrated providers in the access market may drive them to offer a structure that benefits the entrant. Thus, the observed change in access price structure may be the outcome of intensified upstream competition rather than abuse of market power.

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