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Discussion paper

Price-dependent Profit-Sharing as a Channel Coordination Device

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Abstract: We show how an upstream firm by using a price-dependent profit-sharing rule can prevent destructive competition between downstream firms that produce relatively close substitutes. With this rule the upstream firm induces the retailers to behave as if demand has become less price elastic. As a result, competing downstream firms will maximize aggregate total channel profit. When downstream firms are better informed about demand conditions than the upstream firm, the same outcome cannot be achieved by vertical restraints such as resale price maintenance (RPM). Price-dependent profit-sharing may also ensure that the downstream firms undertake efficient market expanding investments. The model is consistent with observations from the market for content commodities distributed by mobile networks.

1 Introduction

The Bertrand paradox may provide a plausible explanation of why the majority of the content commodities on the internet are offered for free (marginal costs). The rival is just "one click away", and competing content providers have strong incentives to undercut each other as long as there are positive profit margins.

In recent years mobile phone operators have allowed content providers to sell content commodities like ringtones, football goal alerts and jokes to the mobile subscribers. Similar to the internet, the entry barriers for providers of content commodities are low, and the rival is just "one click away" also for mobile content commodities. However, in contrast to what we have observed on the internet, mobile content commodities are not offered for free. End-user prices are well above marginal costs.

The vertical channel structure for mobile content differs from what is observed in the internet. In contrast to the internet, the (upstream) mobile access provider may use vertical restraints to reduce or eliminate competing content providers' undercutting incentives. One potential explanation why the Bertrand paradox is not observed for such mobile content commodities, is the price-dependent profit-sharing rule used as a vertical restraint by some upstream mobile providers. With this rule each content provider decides the end-user price for the good he sells, but he has to pay a share of the end-user price to the upstream firms in order to get access to the customers on the mobile networks. The crucial feature of the rule is that it is progressive, in the sense that the share maintained by the content provider is increasing in the end-user price. Table 1 shows the profit-sharing rule used by the dominant Norwegian mobile operator Telenor. If a content provider sells his good for NOK 3, say, he receives 62 % of the revenue, while he only receives 45 % of the revenue if he reduces the price to NOK 1.

End-user price (NOK)	1.0	1.5	3	5	10	20	70
Share to the content provider	45%	54.%	62%	66%	68%	70%	80%

Table 1: A price-dependent profit-sharing rule used for content messages downloaded by mobile phones.

A progressive profit-sharing rule implies that the opportunity cost of setting a low end-user price is relatively high, and this reduces the incentives to engage in fierce price competition. More specifically, in the formal model we show how an upstream firm can use such a rule to reduce the content providers' undercutting incentives by lowering their perceived elasticity of demand. Thereby the upstream firm can prevent destructive price competition. Even more interestingly, we show that a progressive profit-sharing rule achieves higher aggregate channel profit than alternatives where the upstream firm partly or fully dictates the end-user prices (e.g. through resale price maintenance, RPM). This is true if we make the realistic assumption that the content providers are better informed about the demand for their goods than is the upstream firm (asymmetric information).

The labeling of the mobile provider as an upstream firm and the content providers as downstream firms is not clear-cut in the present channel structure. The mobile access provider offers market access for multiple content providers. We choose to label the content providers as downstream firms, since they decide retail pricing and have more accurate information about retail demand conditions than the upstream mobile provider.[1]

The question of how vertical restraints can help solve channel coordination problems has received much attention in the literature. Under different assumptions on the channel structure McGuire and Staelin (1983), Shaffer (1991), Ingene and Parry (1995), Desai (2000) and Kuksov and Pazgal (2007) among others, show that a two-part tariff may be used to prevent destructive downstream price competition. However, our proposed profit-sharing rule achieves higher aggregate channel profit

[1] However, in comparable channel structures it may be more appropriate to label content providers as upstream firms and access providers as downstream firms. One example is the book publishing industry. When considering the relationship between a publisher and Amazon.com, the latter decides retail pricing and probably also has superior information about the retail demand conditions (and will in this sense be in the same marketing position as the content providers in our settting). A similar information asymmetry may also be found in other industries where downstream firms have superior hands-on market knowledge. One example is chains consisting of a large number of geographically dispersed outlets, and where local knowledge is hard to obtain for the upstream headquarters.

compared to a two-part tariff if the downstream firms have more accurate information about demand than the upstream firm.

In an extension of the basic model, we allow the downstream firms to make market-expanding investments that cannot be directly and perfectly controlled by the upstream firm (for instance because the latter has insufficient information about the market potential). The investment levels might then be too high or too low compared to the levels which maximize channel profit (e.g. Telser, 1960). Such lack of control may give rise to horizontal and vertical externalities, and there exists a sizeable literature on how vertical restraints can help solve channel coordination problems. One strand of the literature focuses on how to find the minimum number of vertical restraints sufficient to maximize total channel profit. Mathewson and Winter (1984) show how a combination of a two-part tariff and RPM may be used to achieve the integrated channel outcome where retailers undertake market expanding sales effort with potential spillovers. Lal (1990) shows that revenue-sharing may be used as an additional instrument to a two-part tariff in a context where upstream and downstream firms undertake non-contractible sales efforts (see also Rao and Srinivasan,1995).

Another strand of the literature, pioneered by Rey and Tirole (1986), emphasizes that both the private and social desirability of a given vertical restraint depend on the underlying delegation problem. They compare RPM and exclusive territories (ET) under uncertainty about demand or cost. Our starting point, too, is the underlying delegation problem; the retailers have more accurate demand information than the manufacturer. We also follow Rey and Tirole (op cit) in that we do not search for the minimum sufficient number of vertical restraints inducing the same profit outcome as under channel integration. Rather we show how the price-dependent profit-sharing rule may be used to suppress the competing retailers' undercutting incentives, and, furthermore, that this restraint may be superior to alternatives such as RPM.

In contrast to our approach, Lal (1990) and recent papers like Cachon and Lariviere (2005), Dana and Spier (2001), and Mortimer (2008), consider a revenue sharing scheme that specifies fixed rather than price-dependent shares to the manufacturer and the retailer (e.g. 60% to the manufacturer and 40 % to the retailer). Like our paper, Cachon and Lariviere (2005), Dana and Spier (2001), and Mortimer (2008) are motivated by observed contracts. These papers focus on revenue-sharing contracts implemented in the video rental industry, and show how revenue-sharing schemes may be used to solve channel coordinating problems related to inventory choices.

In the next section we present a case study of how the price-dependent profit-sharing rule has been used in practise, and in Section 3 we set up a formal model to show how an optimal profit-sharing rule may induce competing content providers to choose end-user prices that maximize aggregate channel profit. In Section 4 we extend the model to allow each downstream firm to undertake non-contractible market expanding investments (e.g. marketing) with potential spillovers, and Section 5 concludes.

2 A price-dependent profit-sharing rule - used in practice

Despite an awkward user interface, text-messaging has been an overwhelming success in Europe and Asia.[2] The average usage per month by customers in several European countries exceeded sixty messages in 2004.[3] In several markets, person-to-person messaging has been followed by a successful deployment of content messaging, which enables the mobile users to buy different types of content such as ringtones, music, logos, alerts (e.g. goal alerts), jokes, quizzes and games, directory enquiries and so forth.

In 1997, in the infancy of the market, the two Norwegian mobile providers Telenor and NetCom introduced content messaging services like news, stock quotes

[2]By typing 7777 44 2 555 555 0 9 33 0 4 666 0 666 88 8 0 333 666 777 0 2 0 3 777 444 66 55 1111 on your Nokia mobile phone, you would be sending a text-message asking your friend "Shall we go out for a drink?".

[3]There is a striking discrepancy between Europe and the United States with respect to the take up of text messaging. "No text please, we're American" is the headline in The Economist (2003) when focusing on this feature.

and weather forecasts. The mobile access providers themselves decided which types of services that should be offered and they also took care of end-user pricing. However, this model of vertical integration did not seem to work very well; the services generated limited revenues and profit.

In 2000, the two mobile providers voluntarily shifted strategy from in-house development and production of content to one of vertical separation. With this business model independent content providers behave as downstream firms ("retailers") responsible for sales effort, marketing, and end-user pricing, while the mobile providers act as upstream firms providing access to the customers (the mobile subscribers) as an input. The mobile providers offer take-it-or-leave-it wholesale contracts, specifying a menu of end-user prices among which the content providers may choose (ranging from NOK 1 to NOK 60). Moreover, the wholesale contract specifies the revenue split between the mobile provider and the content provider, where the share to the content provider increases with the end-user price (cf. Table 1 above).

Note that there is no competition between the mobile providers in the upstream market for content messaging. In order to gain access to Telenor's customers, a provider of content message services needs an agreement with Telenor, and, similarly, the content provider needs an agreement with NetCom in order to reach NetCom's customers. We have observed a high degree of cooperation between NetCom and Telenor.[4] In April 2000 the two mobile network providers launched a mechanism that to a large extent was a common wholesale concept towards content message providers. The outcome is that every mobile phone subscriber may access the same content messaging services at the same price independent of which provider they

[4]One example is the introduction of common shortcodes. It is important for the content provider to have the same number for all the mobile operators to facilitate marketing to all users. One of the most important content messages has been TV-related text-messaging where viewers vote and send comments. For such services it is important that the providers offer common shortcodes (four-digit numbers) for all subscribers. NetCom and Telenor offered common shortcodes from 2000, while common shortcodes were not offered until 2002 in the majority of other European countries. Common shortcodes have probably been the most important factor for the take-off of TV-related text messages (Economist, 2002).

subscribe to. In the formal model below, we consequently assume that there is an upstream monopoly selling access to a large number of independent retailers.

Content messaging became a success, and in 2004 the mobile customers on average bought 15 content messages per month in Norway. The total revenue generated from content messaging (NOK 1 billion) was approximately 15% of the revenues from mobile voice traffic. Vertical separation through delegation of retail activities such as retail pricing and marketing has been considered as a key feature behind the success. The Norwegian business model with delegation of content provision to independent firms is now widely adopted in Europe and Asia (Strand, 2004).

The motivation behind the mobile providers' delegation of retail pricing and marketing was that small and independent content providers appeared to have superior hands-on market knowledge (Nielsen and Aanestad, 2006). Consequently, there is a potential gain from delegation since decisions on marketing, retail pricing and introduction of new services may be based on more accurate demand information when undertaken by independent content providers rather than by the mobile providers themselves. In the formal model below, we thus assume that the source of the delegation problem is that independent downstream firms have more accurate demand information than the upstream firm.

By providing a standard interface and allowing for free entry for content providers, the mobile environment resembles what we have observed in the internet. As Shapiro and Varian (1998) put it: "Any idiot can establish a Web presence – and lots of them have". In 2004, approximately 50 different companies were active in providing content messaging services in Norway (Nielsen and Aanestad, 2006). Due to low entry barriers and the fact that the services may easily be replicated by rivals, the vast majority of the content messaging services may be considered as commodities. However, a remarkable difference from the internet is that competition among providers of content messaging services has not driven prices down to marginal costs. In Figure 1 we have the monthly average prices for content messages in the period March 2000-July 2002.[5]

[5] In this period, we have monthly data on the total revenue from content messaging and the number of content messages bought by Telenor's customers. The average price is then calculated

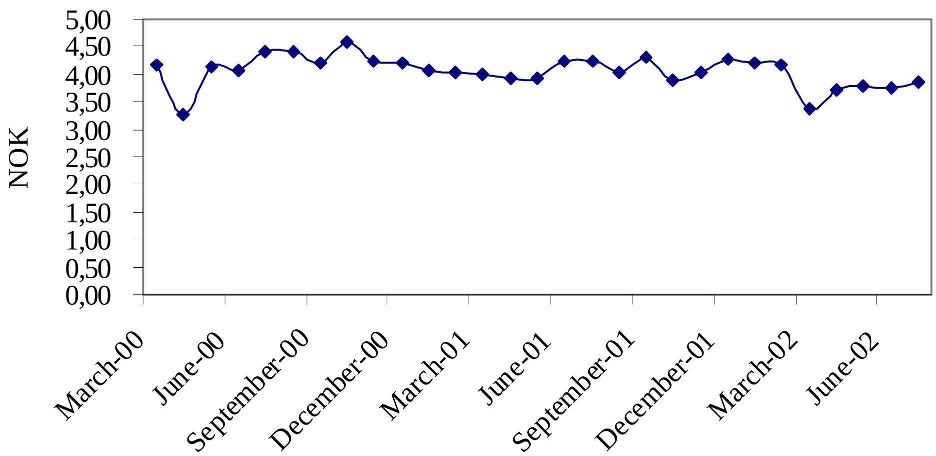

Figure 1: Average prices for mobile content services. Source: Telenor

It is interesting to note that income from content messaging in the Norwegian mobile networks in 2004 was twice as high as the revenues from internet ads.[6] Since content commodities are offered for free on the internet, advertising is the only revenue source for the majority of internet content providers. Our conjecture is that the gross willingness to pay is significantly higher for content commodities available on the internet than for mobile content commodities like ringtones and jokes. As total revenues are higher for mobile content commodities than for internet content commodities, this indicates that a significantly higher share of the potential channel profit is extracted from mobile content commodities than from internet content commodities.

Unfortunately, we only have detailed information about the Norwegian market, and cannot compare the outcome for mobile content messaging with and without the price-dependent profit sharing rule. Anecdotal evidence is, however, consistent

from total revenue/number of messages. We have no data on content messages bought by the customers of the other Norwegian mobile provider NetCom. However, since the content providers charge the same end-user price independent of which of the two mobile providers the customer subscribes to, it seems reasonable to assume that the pattern in Figure 1 holds for the total market. Moreover, Telenor had a market share of approximately 70% in this period.

[6]Calculated from statistics from the Norwegian Post and Telecommunications Authority.

with our findings. In the Swedish market, price-dependent profit sharing was not used in the infancy of the market, and the average consumer spent significantly less on content messaging than the average Norwegian user (see The Swedish Post and Telecommunication Agency, 2002). However, there are admittedly also other potential explanations for this difference between Norway and Sweden.

3 The model

We consider an upstream firm that sells access to distribution facilities to n downstream firms. The demand curve faced by downstream firm $i = 1, ..., n$ is given by $q_i = q_i(a, p)$, where a is a demand parameter and p is the vector of prices charged by the n downstream firms.[7] The demand parameter a is known by the downstream firms when they set end-user prices. The upstream firm knows that a is distributed on the interval $[\underline{a}, \overline{a}]$, but does not know its exact level.[8] We assume that the demand functions are well behaved and downward sloping in own price ($\partial q_i/\partial p_i < 0$). The consumers perceive the goods sold by the downstream firms as imperfect substitutes ($\partial q_i/\partial p_j > 0$).

Marginal costs both at the upstream and downstream levels are set equal to zero, but this does not matter for the qualitative results (see discussion at the end of this section). Hence, we can write total operating profit in the industry as

$$\Pi = \sum_{i=1}^{n} p_i q_i(a, p). \tag{1}$$

Below, we consider a two-stage game where the upstream firm at stage 1 determines the wholesale conditions, and where the downstream firms subsequently

[7] With linear demand curves a is simply the intercept with the price axis.

[8] We should emphasize that the upstream firm may also have superior demand information compared to the downstream firm regarding e.g. new product introduction. Chu (1992), Lariviere and Padmanabhan, (1997), Desai and Srinivasan (1995), and Desai (2000), among others, analyze demand screening and signaling where the manufacturer has private information about e.g. product quality. This has been given attention; not least in the grocery markets where screening and signaling have been considered as potential explanations for the existence of slotting allowances.

compete in prices. Later, we shall investigate the consequences of allowing the downstream firms to make market-expanding investments.

The upstream firm uses a profit-sharing rule where downstream firm i keeps a share $\beta(p_i) > 0$ of its operating profit, while the upstream firm gets the share $[1 - \beta(p_i)]$. The literature conventionally assumes that the profit share is a constant; i.e. $\beta' = 0$ (see e.g. Lal, 1990). However, below we show that when the downstream firms produce (imperfect) substitutes, it is optimal for the upstream firm to choose $\beta' > 0$. This means that the share accruing to each downstream firm is increasing in its end-user price. We label this as a price-dependent profit-sharing rule.

For the following analysis it is convenient to make the following definition:

Definition: $\eta_i \equiv \frac{\beta'(p_i)}{\beta(p_i)} p_i$.

The function $\eta_i(\cdot)$ is the elasticity of the profit share with respect to downstream firm i's price. Note that η_i is positive if and only if $\beta'(p_i) > 0$.

Stage 2

The profit level of downstream firm i equals

$$\pi_i = \beta(p_i) p_i q_i - f_i, \tag{2}$$

where f_i is a fixed fee to the upstream firm.

At the last stage each firm solves $p_i^* = \arg\max \pi_i$. Using the definition $\eta_i \equiv \frac{\beta'(p_i)}{\beta(p_i)} p_i$, this yields the first-order conditions (FOCs)

$$\left[q_i + p_i \frac{\partial q_i}{\partial p_i} \right] + \eta_i q_i \ = 0. \tag{3}$$

If β is constant we have $\beta' = \eta_i = 0$. In this case β merely determines how operating profits are split between the upstream and the downstream firms, and it does not affect the latters' pricing decisions. This is clear from equation (3), where the second term vanishes if $\eta_i = 0$. We then get the textbook result that a profit maximizing price p_i satisfies $[q_i + p_i \frac{\partial q_i}{\partial p_i}] = 0$, implying that we end up in a standard Bertrand game.

With $\eta_i > 0$ the second term on the left-hand side of equation (3) is positive, such that the marginal profit at any given price is higher than if $\eta_i = 0$:

Proposition 1: *The downstream firms' profit-maximizing prices are higher for $\eta_i > 0$ compared to $\eta_i = 0$.*

Defining $\varepsilon_{ii} \equiv \frac{p_i}{q_i}\frac{\partial q_i}{\partial p_i}$ as the price elasticity of demand for good i, we can rewrite first-order condition (3) as

$$\varepsilon_{ii} + \eta_i = -1. \tag{4}$$

Equation (4) characterizes the profit-maximizing equilibrium price for firm i. It is well known that revenue - and thus profit for a firm facing zero marginal costs - is maximized by choosing a price for which the elasticity is equal to minus one, other things equal. However, if $\eta_i > 0$ we see from (4) that the profit sharing rule induces the downstream service provider to behave as if demand has become less price elastic:

Proposition 2: *A price-dependent profit-sharing rule with $\eta_i > 0$ reduces the perceived elasticity of demand for the downstream firms, making them behave less aggressively.*

Stage 1

The upstream firm will use η_i to induce the downstream firms to set prices that maximize total channel profit. The optimal price-dependent profit-sharing rule is characterized by its price elasticity. To find the optimal rule we first derive the hypothetical equilibrium with vertical integration (VI) and complete information about the demand parameter a. Solving $p_i = \arg\max \Pi(p)$ yields the FOCs

$$\left[q_i + p_i\frac{\partial q_i}{\partial p_i}\right] + \sum_{j\neq i} p_j \frac{\partial q_j}{\partial p_i} = 0 \qquad (i = 1, ..., n). \tag{5}$$

The term in the square bracket of (5) measures the marginal profit on good i and is analogous to the term in the square bracket of (3). The second term of (5) internalizes the horizontal pecuniary externality when products are imperfect substitutes; other things equal, each downstream firm has incentives to set a relatively low end-user price in order to steal business from its competitors. Since the size of this business-stealing effect is larger the less differentiated the downstream goods, we shall now introduce ω_{ji}^{p} as a measure of the degree of substitutability between services offered by the downstream firms:

$$\omega_{ji}^{p} = -\left. \frac{\partial q_j}{\partial p_i} \middle/ \frac{\partial q_i}{\partial p_i} \right. \tag{6}$$

Hence, ω_{ji}^{p} measures by how much demand for good j increases per unit reduction in demand for good i when p_i increases. In total, the $(n-1)$ rivals of firm i will consequently increase their output by $\sum_{j \neq i} \omega_{ji}^{p}$ units per unit reduction of q_i.

The larger ω_{ji}^{p} is, the higher p_i should be set in order to maximize aggregate channel profit, other things equal. The challenge for the upstream firm in a vertically separated market structure is to set wholesale conditions that induce the downstream firms to internalize this effect at stage 2.

Inserting for ω_{ji}^{p} into (5) we can now characterize industry optimum as

$$q_i + p_i \frac{\partial q_i}{\partial p_i} - \left(\sum_{j \neq i} p_j \omega_{ji}^{p} \right) \frac{\partial q_i}{\partial p_i} = 0. \qquad (i = 1, ..., n). \tag{7}$$

By imposing symmetry this expression can be reformulated as

$$\left[1 - (n-1)\, \omega_{ji}^{p}\right] \varepsilon_{ii} = -1. \tag{8}$$

Note that $\omega_{ji}^{p} = 0$ if the goods are completely unrelated in demand. On the other hand, if the goods are nearly perfect substitutes, the reduced demand for good i due to an increase in p_i enlarges total demand for all the other goods by (almost) the same amount. Hence, since firm i has $(n-1)$ rivals, each of them will sell approximately $1/(n-1)$ units more per unit reduction of q_i. In the limiting case where the goods are perfect substitutes, we have $\omega_{ji}^{p} = 1/(n-1)$, making the square bracket in (8) equal to zero.[9] In the following we shall assume that there is at least a perceivable differentiation between the goods, implying that $\omega_{ji}^{p} \in [0, 1/(n-1)\rangle$.We

[9]If the goods are perfect substitutes, we have $\varepsilon_{ii} \to -\infty$ in a symmetric equilibrium (infinitely elastic demand for each good). Thus, equation (8) still holds, even if the term in the square bracket is equal to zero.

can then solve (8) with respect to ε_{ii} to find that the actual price elasticity of demand for each good in channel optimum equals

$$\varepsilon_{ii}^{*} = -\frac{1}{1-(n-1)\,\omega_{ji}^{p}}.$$

Inserting for ε_{ii}^{*} into (4) implies that the upstream firm should set η_i according to

$$\eta_i = \eta^{*} \equiv -1 + \frac{1}{1-(n-1)\,\omega_{ji}^{p}}. \tag{9}$$

In general, the derivatives $\partial q_j/\partial p_i$ and $\partial q_i/p_i$ depend on the price of the goods. However, for a wide class of utility functions this is not true for the ratio $\omega_{ji}^{p} = -\left(\partial q_j/\partial p_i\right)/\left(\partial q_i/\partial p_i\right)$, since we have the following result:

Proposition 3: *For any homothetic utility function, ω_{ji}^{p} is independent of output and prices in a symmetric equilibrium.*

Proof: *See Technical Appendix.*

The important message from Proposition 3 is that with symmetry and homothetic utility the upstream firm only needs information about the degree of substitutability, as measured by (6), and not about the size of the market. Homothethic utility is sufficient, but not necessary, for this result. It will also hold true for quasi-linear quadratic utility functions as they yield demand functions that are linear in prices.

In order to steal business from its competitors, each downstream firm would, other things equal, have incentives to set a lower price than the one which maximizes aggregate channel profit (since $\frac{\partial\left(p_i^{*}q_i^{*}\right)}{\partial p_i} < 0$ if the goods are substitutes). However, if the upstream firm uses the profit-sharing rule with $\eta_i = \eta^{*} > 0$, each downstream firm will fully internalize the effect its price has on the profit of the other firms.[10]

[10] The underlying assumption here is that the upstream firm has accurate information on price sensitivities in the downstream market, but not on market size. One motivation for this may be that the upstream firm through its market position is able to learn how the downstream market responds to price competition. As to market size, the upstream firm may have an idea about the total potential, whereas the downstream firm knows how much of the market potential it is able to capture.

Hence, the downstream firms will avoid destructive price competition also in cases where the goods are minimally differentiated.[11] Only in the special case where a price reduction of good i does not affect demand for good j, do we have $\omega_{ji}^{p} = \eta^{*} = 0$.[12]

We can state

Proposition 4: *The profit-sharing rule with $\eta_i = \eta^*$ induces downstream prices that maximize aggregate channel profit.*

The upstream firm might use a fixed fee (f_i) to capture profits from the downstream firms. The problem is that the determination of f_i must be based on some expectation of the size of the market. If the upstream firm charges a relatively high fixed fee, the downstream firms will not enter the market unless actual demand is sufficiently large. Then the industry will not be operative even if it should be intrinsically profitable. If the upstream firm sets a relatively low fixed fee, on the other hand, it will capture only a small share of total industry profit if actual demand is high.[13]

To circumvent this problem, the upstream firm can set $f_i = 0$ and use another instrument to redistribute profits. As an example, suppose that the upstream firm sets $\beta(p_i) = \theta p_i^{\lambda}$, where θ is a positive constant. The profit function of downstream firm i can then be written as $\pi_i = \theta p_i^{\lambda} p_i q_i$. Thus the upstream firm can set θ arbitrarily close to zero (such that it becomes close to 100 per cent of aggregate

[11] Suppose that the goods are actually perfect substitutes. The upstream firm could then offer each downstream firm the contract $\pi_i = \theta p_i q_i - f_i$, where the fixed fee is $f_i = \varepsilon$ (where ε is an arbitrarily small number). If two or more downstream firms enter the industry, the equilibrium price will be equal to zero, in which case they cannot cover the fixed fee. However, by setting θ sufficiently above zero to ensure that $\pi_i > 0$ one, and only one, downstream firm will find it profitable to enter the industry. As there are then no competing content providers, this firm will set an output price which maximizes aggregate profit. Note also that the lower θ is, the higher is the share of the profits that accrues to the upstream firm.

[12] If the downstream goods were complements, optimal channel coordination would require a profit-sharing function that is decreasing in prices ($\eta^* < 0$).

[13] If the upstream firm chooses to use a fixed fee to capture profits from the downstream firms, it will have to maximize its own profit with respect to η and f, taking into account the fact that an otherwise profitable industry is less likely to be operative the higher f is

channel profit), and still ensure that the downstream firms are operative for any positive market demand. It should be noted, though, that since θ is multiplied by $p_i^{\lambda} p_i q_i$ instead of by $p_i q_i$, the upstream firm cannot choose a value of θ that guarantees it a given percentage of the channel profit.[14]

What about other types of vertical restraints? The source of the problem is that the downstream firms know the actual size of the market, while the upstream firm only has an expectation about demand. The novelty of the price-dependent profit-sharing rule is its ability to ensure that competing downstream firms individually choose end-user prices which maximize total channel profit. The profit-sharing rule is thus more effective than alternatives that do not imply delegation of end-user pricing, such as RPM. The present proposal is also more effective than several other alternatives even if these entail delegation of retail pricing. The most obvious example is one where the upstream firms set a unit wholesale price that may deviate from the marginal costs. By increasing the unit wholesale price above the marginal costs (which are zero in the present model), the downstream firms will increase end-user prices. However, analogous to RPM, the upstream firm must determine the unit wholesale price based on expected rather than actual market size. Thus, it follows from Proposition 3 that we have the following result:[15]

Proposition 5: *Assume that only the downstream firms know the accurate level of a. The profit-sharing rule where $\eta_i = \eta^*$ is then superior to vertical restraints*

[14]Suppose that the upstream firm wants to extract 50 % of the channel profit, which means that $\theta p^{\lambda} = 0.5$. We then find that it would have to set $\theta = \theta^* \equiv (1/2)\,(p^*)^{\lambda^*}$. The problem is, however, that due to the demand uncertainty at stage 1 the upstream firm does not know p^*. Thus, it is also unable to calculate θ^*. We would like to thank one of the referees for pointing this out to us.

[15]It should be noted that an efficient implementation of exclusive clauses (exclusive dealing or exclusive territory) may resemble the current outcome. However, in many markets it is difficult to enforce exclusive contracts, and such exclusive contracts imply that the upstream firm picks the firms/services that will be allowed to enter the retail market. Such restrictions on entry will in many circumstances have significant disadvantages. In fact, in the case of content messaging discussed above, one of the key features behind the success seems to be that there are no such restrictions on entry. The strategy of letting a thousand flowers bloom has ensured a wide variety of services which has made the system attractive for the consumers and profitable for the industry.

(such as RPM) that require the upstream firm to know the size of the market in order to achieve maximum channel profit.

To clearly see the intuition behind the result in Proposition 5, we look at a specific example. Our example is based on the Shubik-Levitan (1980) utility function:

$$U(q_1.., q_i, .., q_n) = a \sum_{i=1}^{n} q_i - \frac{n}{2} \left((1-s) \sum_{i=1}^{n} q_i^2 + \frac{s}{n} \left(\sum_{i=1}^{n} q_i \right)^2 \right). \tag{10}$$

The parameter $a > 0$ in equation (10) is a measure of the market potential, q_i is the quantity from retailer i, and $n \geq 2$ the number of retailers. The parameter $s \in [0, 1)$ is a measure of how differentiated the services are; from the consumers' point of view they are closer substitutes the higher s. The merit of using this particular utility function is that the size of the market does not vary with s.[16]

Solving $\partial U / \partial q_i - p_i = 0$ for $i = 1, ..., n$, we find

$$q_i = \frac{1}{n} \left(a - \frac{p_i}{1-s} + \frac{s}{(1-s)\, n} \sum_{j=1}^{n} p_j \right). \tag{11}$$

When marginal costs are zero, it is straight forward to show that the price which maximizes total channel profits is $p = a/2$ for $i = 1, ..., n$. By using (6) and (11), we find that $\omega_{ji}^{p} = s / (n - s)$. Equation (9) then implies that $\eta^* = s\,(n-1) / [n(1-s)]$. This generates an aggregate channel profit equal to $\Pi = \frac{1}{4} a^2$, which is first-best from the industry's point of view.[17]

In the absence of uncertainty there is actually no need for the upstream firm to delegate retail pricing to the downstream firms. Abstracting from any legal considerations, the upstream firm might for instance use RPM and set $p = a/2$ (and redistribute profits through a fixed fee). Alternatively, a two-part tariff, consisting

[16] Other authors using the Shubik-Levitan framework to analyze vertical restraints include Shaffer (1991) and Motta (2004).

[17] From (11) we see that the derivatives $\partial q_i / \partial p_i$ and $\partial q_j / \partial p_i$ are independent of quantities. This is a special feature of linear demand functions, which does not hold in general. However, Proposition 3 makes it clear that the ratio ω_{ij}^{p} - which is the only market feature that matters for the upstream firm's choice of η - is independent of quantities and prices, also for the class of homothetic utility functions.

of a wholesale unit price w_i and a fixed fee f_i, could be used. To see the latter, suppose that there are two downstream firms, each having profits equal to $\pi_i = \theta(p_i - w_i)q_i - f_i$.[18] Then the upstream firm ensures that the downstream firms choose $p = a/2$ by setting

$$w = \left(\frac{s}{2-s}\right)\frac{a}{2}. \tag{12}$$

Note that $dw/ds > 0$. The reason for this is that the closer substitutes the downstream products are , the more fiercly the downstream firms will compete. In particular, there will be perfect competition between the downstream firms in the limit where $s \longrightarrow 1$, and in this case we therefore have $p = w = a/2$. If $s = 0$, on the other hand, each downstream firm is a de facto monopoly in the end-user market. The upstream firms will then induce them to choose $p = a/2$ by setting w equal to marginal costs (which we have normalized to zero).

To see the superiority of the profit-sharing rule when only the downstream firms know the actual size of the market, suppose that the upstream firm's best estimate of the size of the market is that a is uniformly distributed on $[\underline{a}, \overline{a}]$. Expected demand is thus equal to $a^e = (\overline{a} + \underline{a})/2$. With the profit-sharing rule, the expected industry profit from the upstream firm's point of view is consequently given by

$$E\Pi = \frac{1}{\overline{a} - \underline{a}} \int_{\underline{a}}^{\overline{a}} \frac{a^2}{4} da = \frac{\underline{a}\overline{a}}{4} + \frac{(\overline{a} - \underline{a})^2}{12}. \tag{13}$$

Also under RPM the upstream firm is fully capable of internalizing the price competition between the firms, such that the end-user price p^{RPM} will be independent of s. However, since the upstream firm does not know the exact size of the market, it will set $p^{RPM} = a^e/2$ (see Technical Appendix). This price will be higher than the one which maximizes aggregate channel profit if the actual size of the market is smaller than its expected value, $a < a^e$, and too low if $a > a^e$. In the Technical Appendix we show that the difference between aggregate channel profits under the profit-sharing rule and RPM is

$$E\Pi - E\Pi^{RPM} = \frac{(\overline{a} - \underline{a})^2}{48}. \tag{14}$$

[18]Note that we have two profit distribution variables available (θ_i and f_i), but the upstream firm only needs one. As argued above (below Proposition 4), θ may be superior in order to redistribute profit and to ensure that the downstream firms are operative.

There is no uncertainty if $\overline{a} = \underline{a}$, and in this case RPM and the profit-sharing rule naturally yield the same profit. However, the larger the span between $\underline{a}$ and $\overline{a}$, the higher the expected profits will be under the profit-sharing rule compared to RPM.

Under a two-part tariff we find that the unit wholesale price equals

$$w = \left(\frac{s}{2-s}\right)\frac{a^e}{2}. \tag{15}$$

Equations (12) and (15) make it clear that the unit wholesale price under certainty and uncertainty are equivalent, except that the latter is based on expected rather than actual market size. With w given by (15) we further have (with superscript TP for two-part tariff):

$$p^{TP} = \frac{a^e}{2} + \frac{2(1-s)}{4-3s}(a - a^e). \tag{16}$$

Other things equal, the first term in (16) implies that the end-user price is too high if $a < a^e$, and vice versa. Note that this corresponds to the outcome under RPM. However, a two-part tariff generally performs better than RPM. To see why, note that the second term in (16) adjusts for the difference between actual and expected demand. Indeed, for $s = 0$ we have the first-best outcome $p^{TP} = a/2$. This simply reflects the well-known fact that a two-part tariff between an upstream firm and a downstream monopoly maximizes aggregate profit if the unit wholesale price is set equal to the upstream firm's marginal costs (thus $w = 0$ for $s = 0$, c.f. equation (15)). This is true for any market size, and the downstream firms will therefore use their pricing discretion to set $p^{TP} = a/2$. For $s \to 1$, on the other hand, the downstream firms have no individual market power. They must therefore set $p^{TP} = w = a^e/2$. On this background it is not surprising that we find that a two-part tariff is weakly inferior to the profit-sharing rule but weakly superior to RPM (see Technical Appendix for a formal proof):

$$E\Pi - E\Pi^{TP} = \frac{s^2}{(4-3s)^2}\left(\frac{\overline{a}-\underline{a}}{48}\right)^2 > 0 \text{ for } s > 0 \tag{17}$$

$$\text{and } E\Pi^{TP} - E\Pi^{RPM} = \frac{(1-s)(2-s)}{6(4-3s)^2}(\overline{a}-\underline{a})^2 > 0 \text{ for } s < 1. \tag{18}$$

For $s \in (0,1)$ we thus have $E\Pi > E\Pi^{TP} > E\Pi^{RPM}$. Intuitively, the profit-sharing rule achieves a higher expected profit than both RPM and a two-part tariff, since it (a) fully internalizes the pricing externalities between the downstream firms, and (b) delegates the pricing decisions completely to the best informed players. Under RPM there is no delegation of pricing decisions, and this rule yields the lowest profit.[19]

The price-dependent profit sharing rule may be generalized to settings with positive marginal costs. To see this, assume that upstream and downstream marginal costs are given by c and d, respectively, and that the upstream firm offers downstream firm i the profit level $\pi_i = \beta(M_i)M_i q_i - f_i$, where $M_i = p_i - d - c$. Then the downstream firms' FOCs at stage 2 resemble (3). Thus, the sharing rule $\beta(M_i)$ can be used at stage 1 to achieve the optimal channel outcome in the same way as with zero marginal costs. However, with positive marginal costs, and in particular with positive downstream marginal costs, the monitoring problem arising with profit sharing will in practise become more complex (see discussion in the Concluding remarks).

It should be noted that the profit-sharing rule is not always superior to RPM and two-part tariffs. RPM may for instance perform better than the profit-sharing rule if the upstream firm is relatively well informed about the size of the market but uncertain about whether the downstream firms will tacitly collude when they set end-user prices. Other things equal, such collusive behavior might induce the downstream firms to set higher prices than those maximizing aggregate channel profit.[20] Which vertical restraint that is most efficient from the channel's point of view will thus vary from case to case.

[19] In equations (14) and (17) we have implicitly assumed that w and p^{RPM} under two-part tariff and RPM, respectively, are sufficiently low that the downstream firm chooses to be operative even if actual demand should be in the neighborhood of $\underline{a}$.

[20] An appendix with an illustrative example is available from the authors on request.

4 Market-expanding investments

We now extend the model to allow each downstream firm to undertake non-contractible market-expanding (or quality-enhancing) investments with potential spillovers. At the outset, it is not clear how one firm's investments affect sales and profits of the other firms. The investing firm's product will typically become relatively more attractive than those of the rivals. Thereby the latter could be harmed. However, there might also be technological or marketing spillovers from an investment such that one firm's investment is to the benefit of all the downstream firms. A given firm's marketing of ringtones, for instance, is likely to benefit also other firms selling ringtone services. We thus open up for both positive and negative spillovers from investments, and let the downstream profit function of firm i be given by

$$\pi_i = \beta(p_i)p_i q_i(a, p, x) - \varphi(x_i) - f_i. \tag{19}$$

The variable x in (19) denotes the vector of market-expanding investments undertaken by the n downstream firms, and $\varphi(x_i)$ is the investment cost function. The more a firm invests, the higher is the demand it faces; $\partial q_i/\partial x_i > 0$. Investments thus increase the size of the market beyond the initial exogenous market size a. We assume that $\varphi'(x_i) > 0$, and that it is sufficiently convex to satisfy all second-order conditions for a profit maximum. It should be noted that if the downstream firms undertake market-expanding investments, the participation constraint may require setting $f_i < 0$ (slotting fee).

The upstream firm determines the access conditions at stage 1, and at stage 2 the downstream firms decide non-cooperatively on end-user prices and investment levels.[21] Without loss of generality, it is now instructive to assume an isoelastoc profit-sharing rule. As above, we therefore let $\beta(p_i) = \theta_i p_i^{\lambda_i}$, where $\theta_i > 0$.

At stage 2 the first-order condition $\partial\pi_i/\partial p_i = 0$ is still given by equation (3),

[21] If we had considered contractible investments, it might be natural to assume that this activity takes place at stage 1. Non-contractible investments, on the other hand, should be modelled as taking place in the last stage, since it has no commitment value.

which for convenience is repeated here and where the elasticity η_i is replaced by λ_i:

$$\left[q_i + p_i \frac{\partial q_i}{\partial p_i}\right] + \lambda_i q_i \ = 0.$$

Since θ_i does not enter into this first-order condition, we argued in the previous section that it did not have any strategic value. Thus θ_i could be used as a pure profit distribution parameter, with no influence on channel performance. This is no longer true when the downstream firms can make market expanding investments, as we then have:

$$\frac{\partial \pi_i}{\partial x_i} = \theta_i \left(p_i^*\right)^{\lambda_i+1} \frac{\partial q_i}{\partial x_i} - \varphi'(x_i^*). \tag{20}$$

Downstream firm i's marginal profitability of investing is thus strictly increasing in θ. In general, aggregate channel profit is a hump-shaped function of θ_i; a too high value of θ_i yields overinvestment, while a too low value yields underinvestment.

As for now, we abstract from uncertainty. Using fixed fees to redistribute profits, the upstream firm will choose λ_i and θ_i to maximize aggregate channel profit, which is given by

$$\Pi = \sum_{i=1}^{n} \left[p_i q_i(a, p, x) - \varphi(x_i)\right]. \tag{21}$$

To find the optimal value of θ_i, solving $\partial\Pi/\partial x_i = 0$ yields

$$p_i \frac{\partial q_i}{\partial x_i} + \sum_{j \neq i} p_j \frac{\partial q_j}{\partial x_i} = \varphi'(x_i) \qquad (i = 1, ..., n). \tag{22}$$

An investment which e.g. increases the quality of good i might affect demand for the other goods negatively, tending to make $\partial q_j/\partial x_i < 0$. This effect is not taken into account by independent downstream firms, and could imply that there will be overinvestments in a decentralized market structure compared to what maximizes aggregate channel profit. However, if one firm's investments increase demand for its rivals as well, for instance through technological and marketing spillovers, we have $\partial q_j/\partial x_i > 0$.

Analogous to the procedure above, we define $\omega_{ji}^x = \frac{\partial q_j}{\partial x_i} \Big/ \frac{\partial q_i}{\partial x_i}$. The variable ω_{ji}^x measures the increase in demand for good j per unit change in the demand for good i resulting from a higher investment by downstream firm i. We have $\omega_{ji}^x = 1$ in the extreme case where one firm's investment increases demand for all downstream goods by the same magnitude ($\partial q_i/\partial x_i = \partial q_j/\partial x_i > 0$), but otherwise we have $\omega^x_{ji} < 1$ (and ω^x_{ji} is negative if $\partial q_j/\partial x_i < 0 \ \forall i$).

Imposing symmetry, we can now reformulate (22) as (with subscript VI for vertical integration)

$$p_{VI}\left[1 + \ (n-1)\,\omega^x_{ji}\right]\frac{\partial q_i}{\partial x_i} = \varphi'(x_i). \tag{23}$$

The first-order condition $\partial\Pi/\partial p_i = 0$ is still given by equation (8), so that $\lambda^* = \eta^*$ depends on the substitutability between the goods. Clearly, aggregate profit is maximized also in the decentralized market structure if it yields the same prices and investment levels as under vertical integration. We can therefore use equations (20) and (23) to find that the upstream firm at stage 1 should set

$$\theta_i \equiv \theta^* = \frac{1 + (n-1)\,\omega^x_{ji}}{p_{VI}^{\lambda^*}}. \tag{24}$$

The intuition for equation (24) is as follows. Suppose that investments primarily have business-stealing effects. Then the extra sales firm i gains when it invests are approximately countered by correspondingly lower sales by the other downstream firms ($\partial q_i/\partial x_i \approx -(n-1)\,\partial q_j/\partial x_i$). Thus, investments are a waste of resources from the channel's point of view, and the upstream firm should set θ^* close to zero. However, the more beneficial (or less negative) one firm's investment is for its rivals, the higher θ should be set in order to maximize aggregate channel profit. This explains why $\partial\theta^*/\partial\omega^x_{ji} > 0$.

It also follows from (24) that $\partial\theta^*/\partial p_{VI} < 0$, reflecting the fact that a higher end-user price increases the downstream firms' marginal profitability. This in turn reduces the necessity of setting a high value of θ in order to ensure that the downstream firms have sufficiently strong investment incentives.

We can state:

Proposition 6: *Assume that both the upstream and the downstream firms know the size of the market. Then the profit-sharing rule $\beta(p_i) = \theta_i p_i^{\lambda_i}$ with $\lambda_i = \lambda^*$ and $\theta_i = \theta^*$ gives downstream pricing and investment incentives conducive to maximum total channel profit.*

As in the basic model discussed in Section 3, it is unnecessary to delegate retail pricing to the downstream firms if the upstream firm is equally well informed about the size of the market. A three-part tariff, where the upstream firm chooses θ, a unit wholesale price w and a fixed fee would be a perfect substitute. Another alternative is RPM, with downstream profits equal to $\pi_i = \theta_i^{RPM} p_i^{RPM} q_i - \varphi(x_i) - f_i$. A proof of the latter is available in the Technical Appendix.

Once we introduce uncertainty, RPM and three-part tariffs may have negative impacts both on pricing and investment decisions compared to the profit-sharing rule. To see this, we shall in the remaining part of the paper return to our basic assumption that the upstream firm does not know the exact value of a. A three-part tariff will typically perform better than RPM (cf. the example at the end of Section 3). However, in order to highlight the importance of delegating pricing decisions to the informed players, we restrict our attention to comparing the profit-sharing rule and RPM. It should be noted that in the presence of both investments and uncertainty it is not possible to give a unique overall ranking of the alternative vertical restraints.

For most well-behaved demand functions, the end-user price which maximizes total channel profit is higher the larger the exogenous size of the market (a). This has two important implications. First, under the profit-sharing rule, it implies that $d\theta^*/da = (\partial\theta^*/\partial p_{VI})(\partial p_{VI}/\partial a) < 0$. This is quite intuitive; the larger the size of the market, the higher the end-user price will be, and the smaller is the optimal size of θ. Second, under RPM, it is important to note that the upstream firm's choice of p^{RPM} has a decisive effect on the downstream firms' investment levels, since the marginal profitability of investing in market expansion is increasing with p^{RPM} (under RPM we have $\partial\pi_i/\partial x_i = \theta_i^{RPM} p_i^{RPM} \partial q_i/\partial x_i - \varphi'(x_i)$).[22] If the realization $\hat{a}$ is higher than the upstream firm expected ($\hat{a} > a^e$), it will therefore typically be the case that $p^{RPM} < \hat{p}$ and $x^{RPM} < \hat{x}$, where $\hat{p}$ and $\hat{x}$ are the optimal price and investment level if the market size is equal to $\hat{a}$. Likewise, if $\hat{a} < a^e$ we typically have $p^{RPM} > \hat{p}$ and $x^{RPM} > \hat{x}$. Put differently, RPM tends to yield too low prices and investment levels

[22] With linear demand curves the RPM-price completely determines the investment levels; see Appendix.

when demand is higher than the upstream firm expected, and vice versa.

The basic problem with RPM is that the pricing decision is made by the upstream firm rather than by the firms with hands-on market information. This is in sharp contrast to what is the case under the profit-sharing rule, where the inherent delegation-principle ensures that the downstream firms choose correct prices for any given market size. The only distorting factor with this rule is that the upstream firm must choose θ in order to maximize *expected* profit (this distortion implies that the profit-sharing rule cannot achieve first-best either). As argued above, θ should be set at a lower value the larger the exogenous market size ($d\theta^*/da < 0$). When the upstream firm has to set θ based on the expectation of market demand, the rule therefore tends to yield too high investments compared to first-best if the actual value $\hat{a} > a^e$ and too low investments if $\hat{a} < a^e$. However, the crucial feature of the profit-sharing rule is that for any given realized market size, the end-user price will be correct from the channel's point of view.[23] Particularly when the exogenous market size differs significantly from its expected value, the profit-sharing rule is therefore superior to RPM. To illustrate this, we now turn to a simple example.

Demand uncertainty; RPM versus profit-sharing. An example.

To allow the firms to make market-expanding investments, we modify the utility function in equation (10) to

$$U(q_1.., q_i, .., q_n) = \sum_{i=1}^{n} a_i q_i - \frac{n}{2}\left[(1-s)\sum_{i=1}^{n} q_i^2 + \frac{s}{n}\left(\sum_{i=1}^{n} q_i\right)^2\right], \tag{25}$$

where $a_i = a + x_i$. Each downstream firm can increase the size of its market by x_i units by investing in e.g. marketing. The cost of doing so is given by $\varphi(x_i) = (\phi/2)\, x_i^2$, where ϕ is sufficiently large to ensure that all stability and second-order conditions are satisfied. To make it simple we assume that there are only two firms ($n = 2$) and that $s = 2/3$. We further assume that the upstream firm believes that $a = 2$, 3 or 4 with equal probabilities.

[23] The realized market size is the sum of the exogenous market size and the expansion caused by investments.

The aim of this paper is to demonstrate the efficiency of the profit-sharing rule in delegating pricing decisions to informed market players. Table 2 therefore shows the loss of profit relative to what could have been achieved if also the upstream firm knew the size of the market (labelled potential profit). Column 2 in the table compares actual to potential profit under RPM, while column 3 makes the same comparison under the profit-sharing rule (see Technical Appendix for calculations).

Actual exogenous market size	Actual profit relative to potential	
	RPM	Profit sharing
$a = 2$	Not operative	- 3.4 %
$a = 3$	- 2.7 %	- 0.6 %
$a = 4$	- 1.6 %	- 0.2 %
	- 15.5 %	- 0.8 %

Table 2: Profitability performance

The first thing to note from Table 2 is that RPM fails completely if $a = 2$; the upstream firm makes a larger profit by setting a relatively high value of p^{RPM} and accept that the market will not be served for such a low market demand. Then the industry will not be operative at all, and the loss of profit relative to the case with no uncertainty is 100 %. The profit-sharing rule, on the other hand, fares relatively well; the profit is only 3.4 % lower than what would have been achievable under certainty. Such differences in the ability to handle market uncertainty can clearly be decisive for whether emerging and potentially profitable industries take off.

If $a = 3$ or $a = 4$, the industry is operative both under RPM and the profit-sharing rule, but the latter still performs significantly better. Consistent with the discussion above, it can be shown that the firms underinvest compared to industry optimum under RPM when $a > a^e$, while they overinvest under the profit-sharing rule. However, the overinvestment in the latter case has a comparatively small impact on industry profitability, since the downstream firms can adjust the end-user price correspondingly. Indeed, unlike what is the case under RPM, the downstream firms make the correct investments under the profit-sharing rule for any realized market size ($a + x$ in our notation). This is why the last row in Table 2 shows that the expected profit loss under profit sharing in our example is as small as 0.8 %, compared to 15.5 % under RPM. As a comparison, it can be shown that the expected profit loss under a three-part tariff is 1.3 %, and that the industry is operative also in the low-demand state. However, this will not be the case if the demand uncertainty is sufficiently large.[24]

5 Concluding remarks

A major problem in many network industries is that firms may end up with destructive competition because they produce relatively close substitutes. This may prevent the firms from undertaking investments which could benefit the industry in aggregate. Such an outcome can be avoided by implementing a profit-sharing rule which reduces the downstream firms' perceived elasticity of demand.

The market in the case at hand, content messaging such as ringtones, may not be economically important as such. However, we believe that in general it is often the case that downstream firms have better demand information than upstream firms. In the paper we have illustrated why the price-dependent profit-sharing rule may then be superior to two-part tariffs, and two-part tariffs superior to RPM.[25]

[24] As emphasized above, we cannot undertake a unique overall ranking between RPM, profit-sharing and three-part tariffs when we have both demand uncertainty and investments. Examples can be constructed where three-part tariffs yield the higher profit, but we have not been able to find cases where RPM performs better than the other two schemes we have considered.

[25] According to Blair and Lafontaine (2005) the majority of revenue/profit sharing rules within franchising specify a constant percentage fee to the franchisor and the franchisee, respectively. Blair and Lafontaine emphasize, however, that contracts where the percentage rate itself is a function of sales levels are used. Contracts where the royalty rate declines or increases as outlet sales reach specific target levels are observed, and this type of non-linearity in franchising contracts has become more common (Blair and Lafontaine (2005, pp. 62-63).

In general, a limitation of profit sharing is the costs of monitoring the retailer's revenue (Cachon and Lariviere, 2005, Mortimer, 2008, and Dana and Spier, 2001). However, in the present case, this problem is rarely significant, since the upstream mobile provider collects the revenue from the end users. Another practical merit of profit sharing schemes in markets with low marginal costs is that profit sharing in that case approaches revenue sharing. In most situations it is easier to monitor retail revenue than retail profit.

Throughout we have assumed an upstream monopoly, and upstream competition may be a valuable extension of our model. Introducing upstream competition á la McGuire and Staelin (1983) is quite straightforward in the present context. We will then have n manufacturer-retailer pairs offering imperfect substitutes to the end-users. In this environment a price-dependent profit sharing rule will be a superior tool to soften downstream competition compared to a two-part tariff (a combination of a unit wholesale price and a fixed fee) also under full information.[26]

We would emphasize that the ranking between the profit-sharing rule, RPM and two-part tariffs does not always hold. The motivation for this paper is to show how the price-dependent profit-sharing rule can be used to prevent destructive competition between downstream firms even if the upstream firm does not know the size of the market. If the upstream firm is relatively well informed about the size of the market but uncertain about whether the downstream firms will tacitly collude, on the other hand, RPM may perform better than the profit-sharing rule.

In order to keep the analysis as simple as possible, we have only considered symmetric equilibria in the formal model. An interesting avenue for future research would be to analyze how the profit-sharing rule tackles asymmetries among the downstream firms. Our conjecture is that the price-dependent profit sharing rule performs better than e.g. a two-part tariff as long as the asymmetries are not too significant (and the downstream firms are better informed about the market size than is the upstream firm). For larger asymmetries, it would be particularly interesting to analyze adverse selection and moral hazard problems under the profit-sharing

[26] This is shown in an illustrative example with linear demand functions in the Appendix.

rule.[27]

6 Technical Appendix

6.1 Proof of Proposition 3:

Homothetic utility functions generate demand functions of the form $q_k = f_k(p)y$, where p is an n-vector of prices, y is total expenditure on the n goods, and $f_k(p)$ is homogeneous of degree -1 in prices. Consider an arbitrary state of the world A, where demand for good i and j is given by $q_i^A = f_i(p^A)y^A$ and $q_j^A = f_j(p^A)y^A$. We then have

$$\left(\omega_{ji}^P\right)^A = -\frac{\partial f_j(p^A)/\partial p_i}{\partial f_i(p^A)/\partial p_i}.$$

Consider another arbitrary state B, where $q_i^B = f_i(p^B)y^B,\ q_j^B = f_j(p^B)y^B$ and

$$\left(\omega_{ji}^P\right)^B = -\frac{\partial f_j(p^B)/\partial p_i}{\partial f_i(p^B)/\partial p_i}.$$

With homothetic utility we have $q_i^B = tf_i(tp^B)y^B$ and $q_j^B = tf_j(tp^B)y^B$ for any $t > 0$, which implies that $\left(\omega_{ji}^P\right)^B = -\left[\partial f_j(tp^B)/\partial p_i\right] / \left[\partial f_i(tp^B)/\partial p_i\right]$. A sufficient (but not necessary) condition for allowing us to choose t such that $tp^B = p^A$ is that we in any given state have $p_1 = ...p_n$. In a symmetric equilibrium we consequently find

$$\left(\omega_{ji}^P\right)^B = -\frac{\partial f_j(tp^B)/\partial p_i}{\partial f_i(tp^B)/\partial p_i} = -\frac{\partial f_j(p^A)/\partial p_i}{\partial f_i(p^A)/\partial p_i} = \left(\omega_{ji}^P\right)^A.$$

Q.E.D.

6.2 Calculation of expected profit in absence of investments

Expected profit under RPM

[27] Holmstrom (1979), Basu, Lal, Srinivasan and Staelin (1985), and Jeuland and Shugan (1983), among others, analyze moral hazard problems in manufacturer-retailer channel structures, while Demski and Sappington (1984), Lal and Staelin (1986), Desai (2000) and Desai and Srinivasan (1995), among others, analyze channel coordination problems in presence of adverse selection problems.

With a uniformly distributed on $[\underline{a}, \overline{a}]$, expected profits under RPM are equal to

$$E\Pi^{RPM} = \max_{\{p_1,\ldots,p_n\}} \left\{ \frac{1}{\overline{a}-\underline{a}} \int_{\underline{a}}^{\overline{a}} \left(\sum p_i q_i \right) da \right\}, \tag{A1}$$

where q_i is given by equation (7).

Solving (A1) we find a unique symmetric equilibrium with

$$p_i^{RPM} = \frac{a^e}{2} \text{ and } E\Pi^{RPM} = \frac{\underline{a}\overline{a}}{4} + \frac{(\overline{a}-\underline{a})^2}{16}.$$

Expected profit under a two-part tariff

Under a two-part tariff, the profit level of each downstream firm is equal to $\pi_i = \theta(p_i - w_i) q_i - f_i$. Solving $\partial \pi_i / \partial p_i = 0$ simultaneously for the n downstream firms we arrive at a symmetric equilibrium with

$$p = \frac{a}{2} + \frac{2w(n-s) - as(n-1)}{2[(2-s)n-s]} \text{ and } q = \frac{(a-w)(n-s)}{n[(2-s)n-s]}.$$

Expected channel profits from the upstream firm's point of view is now given by

$$E\Pi^{TP} = \max_{w} \left\{ \frac{1}{\overline{a}-\underline{a}} \int_{\underline{a}}^{\overline{a}} (np_i q_i)\, da \right\}. \tag{A2}$$

Solving (A2) yields

$$w = \frac{a^e}{2} \frac{s(n-1)}{n-s}, \tag{A3}$$

which implies that

$$p^{TP} = \frac{a^e}{2} + \frac{n(1-s)}{n(2-s)-s}(a - a^e) \tag{A4}$$

and

$$E\Pi^{TP} = \frac{\underline{a}\overline{a}}{4} + \left(\frac{1}{12} - \frac{s^2(n-1)^2}{48[n(2-s)-s]^2} \right) (\overline{a}-\underline{a})^2. \tag{A5}$$

In the main text we have assumed that $n = 2$. Equation (12), which shows the unit wholesale price under certainty, is found by setting $n = 2$ and $a^e = a$ into equation (A3). Equations (14), (15) and (16) are similarly found by setting $n = 2$ into (A3), (A4) and (A5).

Note that

$$\frac{dE\Pi^{TP}}{dn} = -\left(1-s\right)\frac{s^2\left(n-1\right)}{12\left[\left(2-s\right)n-s\right]^3}\left(\overline{a}-\underline{a}\right)^2 < 0.$$

The two-part tariff scheme under uncertainty thus performs better the smaller the number of downstream firms; $E\Pi^{TP}$ will thus be lower than the one shown in the main text if $n > 2$ (and will thus perform even worse compared to the profit-sharing rule). However, the qualitative result that $E\Pi > E\Pi^{TP} > E\Pi^{RPM}$ holds for any value of n.

6.3 Calculation of potential profit and the corresponding profit-sharing rule

Using the utility function given by equation (24) to solve $\partial U/\partial q_i - p_i = 0$ for $n = 2$, we find that consumer demand equals

$$q_i = \frac{1}{2\left(1-s\right)}\left(a_i - p_i + \frac{s}{2}\left(\left(p_1 - a_1\right) + \left(p_2 - a_2\right)\right)\right), \tag{A6}$$

where $a_i = a + x_i$. We thus have

$$\frac{\partial q_i}{\partial p_i} = -\frac{2-s}{4\left(1-s\right)};\ \frac{\partial q_j}{\partial p_i} = \frac{s}{4\left(1-s\right)} \ \Rightarrow \omega_{ij}^p = \frac{s}{2-s}\ . \tag{A7}$$

Equation (A6) also implies that

$$\frac{\partial q_i}{\partial x_i} = \frac{2-s}{4\left(1-s\right)};\ \frac{\partial q_j}{\partial x_i} = -\frac{s}{4\left(1-s\right)} \ \Rightarrow \omega_{ij}^x = -\frac{s}{2-s}\ . \tag{A8}$$

The cost of market-expanding investments is equal to $\varphi(x_i) = (\phi/2)\,x_i^2$. Assuming that ϕ is sufficiently large to ensure a unique and symmetric equilibrium, it follows from (A6) that $q = (a + x - p)/2$. We can thus rewrite first-order conditions (8) and (22) for a vertically integrated firm with full market information as $\left(a + x - p\right)/2 - p/2 = 0$ and $p/2 - \phi x = 0$. Solving these two equations simultaneously implies that

$$x^* = \frac{a}{4\phi - 1} \text{ and } p^* = \frac{4\phi}{4\phi - 1}\frac{a}{2}. \tag{A9}$$

Aggregate channel profit is equal to

$$\Pi^* = \frac{\phi a^2}{4\phi - 1}. \tag{A10}$$

Using equations (9), (23), (A8) and (A9) with $s = 2/3$ we have $\lambda^* = 1$ and

$$\theta^* = \frac{4\phi - 1}{4\phi a}.$$

The upstream firm thus ensures that the two competing downstream firms choose prices and investment levels that maximize aggregate profit by using the profit-sharing rule $\pi_i = \frac{4\phi-1}{4\phi a} p_i^2 q_i - \frac{\phi}{2} x_i^2 - f_i$.[28]

In order to calculate potential profit in Table 2, we have used (A10) with $\phi = 2$.

6.4 Calculation of the profit-sharing rule under uncertainty

At stage 2 the downstream firms know actual demand. Solving $\partial \pi_i / \partial p_i = 0$ and $\partial \pi_i / \partial x_i = 0$ for $n = 2$ and then imposing symmetry we find respectively

$$\theta (2 - s) p^{\lambda+1} - 4x\phi (1 - s) = 0 \text{ and } 2 (1 - s) (1 + \lambda) (a + x) - p (2\lambda (1 - s) + 4 - 3s) = 0.$$

In the following we shall assume that $s = 2/3$. By setting $\lambda = s/ [2(1 - s)] = 1$ we can solve the first-order conditions to find explicit solutions for the price and investment level:

$$p(a) = \frac{\phi - \sqrt{\phi (\phi - \theta a)}}{\theta} \text{ and } x(a) = \frac{\left[\phi - \sqrt{\phi (\phi - \theta a)}\right]^2}{\theta \phi}. \quad \text{(A11)}$$

Let $v(k)$ denote the upstream firm's probability that the exogenous demand parameter is equal to $a(k)$, $k = 1, ..., m$.[29] Evaluated at these probabilities expected profit is given by

$$E_v[\tilde{\Pi}] = 2 \sum_{k=1}^{m} v(k) \left(p(a(k))q(a(k)) - \frac{\phi}{2} x(a(k))^2 \right), \quad \text{(A12)}$$

where $q(a(k))$ can be found by inserting for $p(a(k))$ and $x(a(k))$ into equation (A6).

With $\lambda = 1$ the upstream firm will at stage one solve $\hat{\theta} = \arg\max E_v(\tilde{\Pi}) = \sum_{k=1}^{m} v(k)\Pi(k)$. With the example used in Table 2 this yields $\hat{\theta} \approx 0.24$, which can

[28] Note that this generally implies that $\pi = [1 - |\omega_{12}^x|] p^* q^* - \frac{\phi}{2} (x^*)^2 - f$ and that the upstream firm makes a profit equal to $|\omega_{12}^x p^* q^*|$ net of any fixed fees.

[29] In the example we have $v(1) = v(2) = v(3) = 1/3$ and $a(1) = 2$, $a(2) = 3$, $a(3) = 4$.

be used to calculate expected profits in equation (A12). Actual profits in state k can likewise be found by setting $\theta = \hat{\theta}$ and calculate $\Pi(k) = p(a(k))q(a(k)) - \frac{\phi}{2}x(a(k))^2$.

To calculate expected potential profit, we may imagine that we have a stage 0 where demand is uncertain, while actual demand is revealed at stage 1. The latter means that the upstream firm knows actual demand when it sets λ and θ. At stage 0, expected potential profits thereby equal $2\left(\sum_{v=1}^{m} v(k)[p^*(k)q^*(k) - \frac{\phi}{2}x^*(k)^2]\right)$, where $q^*(k)$, $p^*(k)$ and $x^*(k)$ are given from equations (A6) and (A9) and are the profit maximizing values for each market size.

6.5 Calculation of RPM under uncertainty

Under RPM the profit level of downstream firm i equals $\pi_i = \theta_i^{RPM} p_i^{RPM} q_i - (\phi/2)\, x_i^2 - f_i$. At stage 2 the price level p_i and the profit share θ_i (for notational simplicity we omit the superscript RPM from here on) have already been set by the upstream firm. Using equation (A6) we have

$$\frac{\partial \pi_i}{\partial x_i} = \theta p_i \frac{\partial q_i}{\partial x_i} - \phi x_i. \tag{A13}$$

With $n = 2$ we know from equation (A7) that $\frac{\partial q_i}{\partial x_i} = \frac{2-s}{4(1-s)}$, and solving $\partial \pi_i / \partial x_i = 0$ we find

$$x_i = \theta_i p_i \frac{2-s}{4\phi\,(1-s)}. \tag{A14}$$

The important lesson from equation (A14) is that apart from the exogenous parameters s and ϕ, the marginal profitability of investing in market expansion is completely determined through the upstream firm's choice of p_i and θ_i. The investment incentives are in particular independent of the market size a, once p_i and θ_i are determined. Thus, the upstream firm faces no uncertainty with respect to the downstream firms' investment levels, and expected channel profit from the upstream firm's point of view at stage 1 can thus be written as

$$E_v[\tilde{\Pi}] = p_i \left(\sum_{k=1}^{m} v(k) q_i(a(k)) \right) - \phi x_i^2.$$

As before, $v(k)$ is the upstream firm's perceived probability for $a = a(k)$. Solving $\{p_i, \theta_i\} = \arg\max E_v[\Pi]$, we find a symmetric solution

$$p^{RPM} = \left(\sum_{k=1}^{m} v(k) p^*(a(k)) \right) \text{ and } \theta^{RPM} = 2\frac{1-s}{2-s},$$

where $p^*(a(k))$ is the optimal price given that demand is equal to $a(k)$.[30] The upstream firm thus sets p^{RPM} such that it is equal to the expected monopoly price over all states, given by the sum of the state contingent profit maximizing prices, one for each k, weighted by the likelihood that this state will occur.

Unlike what is the case under the profit-sharing rule - where the downstream firms can react to actual market demand - we see that θ^{RPM} is independent of a. This reflects the fact that θ^{RPM} can only be used to adjust for the competitive pressure between the downstream firms.

Inserting for p^{RPM} and θ^{RPM} we further find

$$x^{RPM} = \frac{\sum_{k=1}^{m} v(k) a(k)}{4\phi - 1}.$$

Investments are thus proportional to expected market size, instead of being dependent on the actual size of the market. All adjustments to actual demand (a^{act}) being different from expected demand will therefore take place through the quantities sold:

$$q(a(k)) = \frac{a^{act}(4\phi - 1) - \left(\sum_{k=1}^{m} v(k) a(k)\right)(2\phi - 1)}{2(4\phi - 1)}. \tag{A15}$$

Expected profits are equal to

$$E_v[\Pi] = \phi \frac{\left(\sum_{k=1}^{m} v(k) a(k)\right)^2}{4\phi - 1},$$

while actual channel profits in each state are equal to $\Pi(a(k)) = 2p^{RPM} q(a(k)) - \left(x^{RPM}\right)^2$.

Some comments on the calculation of RPM in Table 2

Using the example in Table 2, we find that the upstream firm makes a higher profit by accepting that the market will not be served if $a = 2$. The upstream firm will

[30] From equation (A9) we know that this price is given by $p^* = \frac{4\phi}{4\phi - 1} \frac{a}{2}$.

therefore at the outset be aware of the fact that the industry will be inoperative if $a = 2$, and will use this information to obtain higher profits. More precisely, this means that the upstream firm solves $p^{RPM} = \arg\max \left\{ p_i \left(\frac{v(2)q(2)}{v(2)+v(3)} + \frac{v(3)q(3)}{v(2)+v(3)} - \phi x_i^2 \right) \right\}$. Expected profits are equal to $\frac{1}{3} * 0 + \frac{1}{3}\Pi(a(2)) + \frac{1}{3}\Pi(a(3))$.

6.6 Upstream competition

In the main text we have assumed that we have a monopoly upstream firm. As argued in Section 2 the actual upstream firms are not competitors in the market which motivated the paper. Now we introduce upstream competition in a way that resembles the decentralized market structure in McGuire and Staelin (1983). There are two upstream firms (manufacturers) and two downstream firms (retailers), and the two manufacturers produce differentiated but competing products. Manufacturer mi distributes its products through retailer ri, where $i = 1, 2$. We thus have two competing channels, labeled $ch1$ and $ch2$. This may be considered as the polar case to the assumption of upstream monopoly made in the basic model. So how does the profit-sharing rule perform relative to a two-part tariff as considered by McGuire and Staelin? For the sake of the argument, we assume that all players have accurate demand information. To simplify we use the Shubik-Levitan demand function specified in (10), where $n = 2$. At stage 1 manufacturer mi decides the wholesale contract towards ri, and we assume that mi offers a take-it-or-leave-it contract to ri. At stage 2 the retailers compete in prices.

As a benchmark we consider the case where the manufacturers use a two-part tariff as in McGuire and Staelin (1983). At stage 2 ri decides p_i in order to maximize $\pi_{ri} = (p_i - w_i) q_i - f_i$, and it is straightforward to show that the stage 2 equilibrium price p_i is given by

$$p_i^{TP} = \frac{2a(1-s)(4-s) + (2-s)[2(2-s)w_i + sw_j]}{(4-3s)(4-s)}$$

At stage 1 mi sets w_i and f_i such that ri's participation constraint is binding; i.e.$(p_i - w_i) q_i = f_i$. Manufacturer mi will thus maximize the channel profit for chi given by $\pi_{chi} = p_i q_i$. The equilibrium unit wholesale price w_i becomes $w_i =$

$[2a(1-s)s^2]/[(2-s)D] \geq 0$, where $D = 4(1-s)(3-s)+(2-s)^2$.[31] Stage 1 equilibrium price then becomes $p^{TP} = [4a(1-s)(2-s)]/D$.

Let us now consider the case where manufacturer mi uses the price-dependent profit sharing rule $\beta(p_i) = \theta_i p_i^{\lambda_i}$. At stage 2 ri then maximizes $\pi_i = \theta_i (p_i)^{1+\lambda_i} q_i$. The FOCs resemble (3), and we find that the stage 2 equilibrium prices are given by

$$p_i^{PS} = \frac{2a(1-s)(1+\lambda_i)(4-s+2\lambda_j)}{4(1-s)(2+\lambda_i)(2+\lambda_j)+s^2(3+\lambda_i+\lambda_j)} \tag{A16}$$

At stage 1 mi decides λ_i in order to maximize channel profit $\pi_{chi} = p_i q_i$. The parameter θ may be used to redistribute profit. By first solving $\partial\pi_{chi}/\partial\lambda_i = 0$ and then imposing symmetry ($\lambda_1 = \lambda_2 = \lambda$) we find that $\lambda^* = \left[(2-s)\sqrt{1-s} - 2(1-s)\right]/\left[2(1-s)\right]$. Inserting for λ^* into (A16) we find $p^{PS} = \frac{a}{s}\left(\sqrt{1-s} - (1-s)\right)$.[32]

The difference in prices under the profit-sharing rule and RPM is given by

$$p^{PS} - p^{TP} = a\frac{S_1 - S_2}{s(16-20s+5s^2)},$$

where the terms $S_1 \equiv \sqrt{1-s}(16-20s+5s^2)$ and $S_2 \equiv (1-s)(16-12s+s^2)$ are both positive if $s < 1$. We now claim that $S_1 \geq S_2$, such that $p^{PS} \geq p^{TP}$. To see this most easily, note that $S_1^2 - S_2^2 = s^5(1-s)$. This implies that $p^{PS} > p^{TP}$ for $s \in (0,1)$ and $p^{PS} = p^{TP}$ for $s = 0$ and $s = 1$. Thus, the profit-sharing rule yields higher prices than a two-part tariff if the downstream firms produce imperfect substitutes. Since it further is straight forward to show that p^{PS} is smaller than the cartel price ($p^M = \frac{a}{2}$), it follows that the profit-sharing rule yields higher profits than a two-part tariff if $s \in (0,1)$.

7 Literature

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[31] Shaffer (1991) achieves the same equilibrium unit wholesale price in the case where the retailers control the bargaining power.

[32] Note that $\lim_{s\to 0} p^{PS} = \frac{a}{2}$.

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