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Conference Paper

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24th Biennial Conference of the International Telecommunications Society (ITS): "New bottles for new wine: digital transformation demands new policies and strategies", Seoul, Korea, 23-26 June, 2024

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Howell, Bronwyn; Potgieter, Petrus H. (2024) : Unraveling the Micro-Economic Dynamics of Broadband and Content Provider Alliances, 24th Biennial Conference of the International Telecommunications Society (ITS): "New bottles for new wine: digital transformation demands new policies and strategies", Seoul, Korea, 23-26 June, 2024, International Telecommunications Society (ITS), Calgary

This Version is available at:
https://hdl.handle.net/10419/302480

Unraveling the Micro-Economic Dynamics of Broadband and Content Provider Alliances

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June 2024

Abstract

The services that run on telecommunications providers' infrastructure have evolved from *essential* to the day-to-day functioning to *hyper critical* to the minute-by-minute functioning of modern society. Telecommunications firms have however been increasingly exposed to competition and diminishing profitability. In order to face this challenge, it is essential to understand the micro-economic realities of the interaction between content providers and connectivity access providers. In this paper, we unravel options and discuss the insights revealed by micro-economic modeling of the interaction between a retailer of online content and a broadband provider. We show that heterogeneity among consumers leads to heterogeneous outcomes for the firms even where average trends are clear. One of the main results is that the absence of commercial cooperation between the content and the broadband provider delivers bad outcomes in almost all cases.

The economic theory underlying the analysis is consumer willingness-to-pay and the resulting economic surplus (often, Marshallian surplus) comprising of the consumer surplus and the producer surplus. It is assumed that the content product increases the cost of delivery of the broadband product due to increased network use. The parameters that are variable are (a) the correlation between consumer valuations of the two products and (b) the additional cost of broadband provision for users of the content product. The paper presents the results of extensive simulation models for different distributions of consumer valuations and incremental additional cost for content product users.

Our discrete modelling approach differs from the more common approach of assuming a continuum of consumers (i.e. not only infinitely many but uncountably infinitely many!) and solving for an optimal expected outcome. Our first step is to solve the problem for a finite number of customers and a single allocation valuations (drawn from a specified distribution). This allows one to see what might happen in concrete cases. We then do this many times and compute averages which approximates the expected outcome in the continuum case, of course. This approach allows us to identify more detail than an expected outcome does. We would like to remind the reader than the expected outcome from the roll of a die is $3\frac{1}{2}$ which is *never* an actual outcome.

1 Introduction

Over the past decades, the services that run on telecommunications providers' infrastructure have evolved from *essential* to the day-to-day functioning to *hyper critical* to the minute-by-minute functioning of modern society. Telecommunications firms have however been increasingly exposed to competition and diminishing profitability. In order to face this challenge, it is essential to understand the micro-economic realities of the interaction between content providers and connectivity access providers. In this paper, we unravel options and discuss the insights revealed by micro-economic modeling of the interaction between a retailer of online content and a broadband provider. We show that heterogeneity among consumers leads to heterogeneous outcomes for the firms even where average trends are clear. One of the main results is that the absence of commercial cooperation between the content and the broadband provider delivers bad outcomes in almost all cases.

Information (digital) goods exhibit a number of economic characteristics that render them problematic for classical economic analysis. Shapiro and Varian (1999) describe information goods as: "costly to produce but cheap to reproduce;"experience goods" that must be experienced to (consumed) to establish their value; embodying network effects and switching costs that render consumers vulnerable to "lock-in"; and subject to feedback effects that cement in the first mover's advantage so competition "for the market" prevails over competition "in the market". For this and for practical reasons, we consider only the situation of a single content provider and a single broadband provide, similar to Jeanjean (2022) and Nikkhah and Jordan (2023). Competition on either side of the market has been considered by Key and Steinberg (2020), Courcoubetis, Sdrolias, and Weber (2016) and others with informative results but less of a focus on consumer preferences.

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The model is based on simulation in a discrete environment, similar to the context of Potgieter and Howell (2021) or Potgieter and Howell (2024) but including (in this paper) a range of costs of delivery of the content product, different correlations between the consumer valuations and a broad discussion of the strategic options of the firms.

The economic theory underlying the analysis is consumer willingness-to-pay and the resulting economic surplus (often, Marshallian surplus) comprising of the consumer surplus and the producer surplus. The model used in this paper examines the outcomes of the following modes of cooperation between the content provider and the broadband provider as a result of the introduction of a content product to the market.

- Unilateral repricing of broadband (no cooperation with content provider)
- Negotiated repricing of content only (commercial agreement between the broadband and content provider)
- Vertical integration (which represents the theoretical jointly optimal position)

We also consider the hypothetical case where the broadband provider does not have the option of repricing the broadband product. It is assumed that the content product increases the cost of delivery of the broadband product due to increased network use. The parameters that are variable are (a) the correlation between consumer valuations of the two products and (b) the additional cost of broadband provision for users of the content product. The paper presents the results of extensive simulation models for different distributions of consumer valuations and incremental additional cost for content product users. The results demonstrate conclusively that cooperation between content and broadband providers benefit not only the firms' profitability but are also preferable from a social point of view to all other realistic options.

There are finitely many consumers which can be thought of as representing not simply individuals but in fact market segments. The firms set prices at integer values and not on a continuum. This corresponds to everyday experience where firms do not consider an infinity of possible prices for their products. Consumer choices are based on individual surplus. Each consumer buys a product (combination) if the price does not exceed their valuation (or, willingness-to-pay) for the product (combination). For each round of simulation, valuations are randomly assigned to each of the consumers by generating a normally distributed random variable and truncating the values to fit a finite range. This range is 0 to 100 for the broadband product and 0 to 30 for the content. An individual consumer's valuations for broadband and content can be correlated and this correlation is one of the parameters that generates the concrete instances. The other parameter is the additional cost imposed for content users on the broadband provider. The model assumes a baseline cost of 35.

2 Background

In principle, ours is an agent-based model computational model which eschews the clean and analytic results of equation-based theory in favour of simulations that allow for the exploration of a multitude of real-world scenarios. Although we do calculate some averages and consider aggregate outcomes, we also look at other statistical results from our simulations (such as the frequency of jointly optimal outcomes). This approach allows one to go down to the level of individual concrete scenarios (as Potgieter and Howell (2024) have done) of randomly assigned valuations and to look at the market dynamics in such a scenario. Individual scenarios are not discussed in this paper but the results have been archived and are available for analysis.

Our model, as opposed to an equation-based one allows for easy modification of distributions and agent behaviour. One could easily include random non-rational behaviour by consumers, for example. As Arthur (2021) writes:

> "However they are labelled, computational studies are valuable: they offer agent-based behavioural realism and they allow realistic detail; standard economics typically relates average aggregate quantities (outputs produced, say) to average aggregate quantities (inputs used) and, often, the details within such aggregates matter."

We present both main results that might be relatively easy to deduce using pencil and paper as well as more detailed ones that are unlikely to be easy, especially since we use the realistic assumption the firms set prices from a finite set of numbers.

3 Methodology

The model is based on simulation in a discrete environment. There are 100 consumers which can be thought of as representing not simply individuals but in fact market segments. The firms set prices at integer values and not on a continuum. This corresponds to everyday experience where firms do not consider an infinity of possible prices for their products. Optimal outcomes are computed through brute force computation and 10,000 distinct simulations were done for each combination of parameter values in this report. The computation ran for several days on a high-powered desktop and all the simulation results are stored for later analysis and auditing.

Consumer choices are based on individual surplus. Each consumer buys a product (combination) if the price does not exceed their valuation (or, willingness-to-pay) for the product (combination). For each of the 10,000 rounds of simulation, valuations are randomly assigned to each of the 100 consumers by generating a normally distributed random variable and truncating the values to fit a finite range. This range is 0 to 100 for the broadband product and 0 to 30 for the content. An individual consumer's valuations for broadband and content can be correlated and this correlation is one of the parameters that generates the 28

instances below. The other parameter is the additional cost imposed for content users on the broadband provider. The model assumes a baseline cost of 35 for providing the broadband service.

We also consider the hypothetical arrangement (*free-riding content*) where the broadband provider does not have the option of repricing the broadband product. It is assumed that the content product increases the cost of delivery of the broadband product due to increased network use. The parameters that are variable are (a) the correlation between consumer valuations of the two products and (b) the additional cost of broadband provision for users of the content product. The framework for the analysis is the standard economics of Marshallian surplus discussed above.

The analysis examines the frequency (over the set of simulations) for each pair of parameter values with which various arrangements are optimal for

- producer surplus;
- consumer surplus; and
- total surplus.

Although *vertical integration* is always optimal for producer surplus, this paper reveals the extent to which other arrangements (notable *content repriced*) are often simultaneously optimal and therefore indistinguishable from the point of view of the firms. We also look at the average outcomes for each set of simulations. This is a more normative approach that furnishes helpful information but should be read in conjunction with the frequency tables. Finally, we summarize the optimal outcomes with respect to the parameters.

Table 1: Market arrangements in this study

Arrangement name	Description	Action
No content product	There is only an undifferentiated broadband access product on the market.	Broadband provider sets a price to consumers to maximize its profit based on the assumption of a uniform cost of provision per customer.
Free-riding content	A paid content product is introduced.	Content provider sets a price to consumers to maximize its revenue. Broadband provider does not change its price.
Repriced broadband	In response to the content product, the broadband provider sets a new price.	Broadband provider has an additional cost per content subscriber and recomputes broadband price to maximize profit, assuming content price stays unchanged.
Content repriced	The broadband provider does not set a new price but negotiates with the content provider.	A new content price is set to maximize joint producer surplus, i.e. the sum of content revenue and broadband profit, given the original broadband price; the parties agree how the surplus is divided (i.e. whether the content provider pays the broadband provider or vice-versa).
Vertical integration	The two firms act as one.	The broadband and content provider jointly set prices for the two products to maximize producer surplus. This is the most flexible option for the firms.

Simplifying assumptions include that the fixed cost of the content provider is not taken into account as it has no influence on the model outcome and that there are single monopoly providers of broadband access and content. The assumption of a monolithic content provider is the most limiting one in the model but it can be viewed as a window on individual and independent negotiations with different content providers from the point of view of the broadband firm.

In the normal course of events, the *repriced broadband* arrangement is a natural first step but the analyses in this report will show that it is in fact a bad one. The extent to which the cooperative arrangements of

- content repriced; and
- vertical integration

can be reached will always depend on the relative negotiating power of the firms and is beyond the scope of this report. Our main results is that such arrangements are possible and should be expected.

Our discrete modelling approach differs from the more common approach of assuming a continuum of consumers (i.e. not only infinitely many but uncountably infinitely many!) and solving for an optimal expected outcome. Our first step is to solve the problem for a finite number of customers and a single allocation valuations (drawn from a specified distribution). This allows one to see what might happen in concrete cases. We then do this many times and compute averages which approximates the expected outcome in the continuum case, of course. This approach allows us to identify more detail than an expected outcome does. We would like to remind the reader than the expected outcome from the roll of a die is $3\frac{1}{2}$ which is *never* an actual outcome.

4 Results

In the first subsection, we discuss the simulation results in terms of average outcomes for each pair of parameter values. The average is taken over the 10,000 simulation rounds for each parameter instance. In the second subsection we consider, in addition, more detailed results for a selection of illustrative specific parameter values which provides additional insights. Producer surplus is always optimised by the *vertical integration* arrangement and therefore not discussed in the first subsection. Statistics for producer surplus are included in the second subsection in order to illustrate that (with integer prices) the firms can often have equivalent outcomes in the *content repriced* and *vertical integration* arrangements.

4.1 Total and consumer surplus optimal arrangements

We separately consider total surplus and consumer surplus and the optimal market arrangement for each pair of parameter values. For each type of surplus, we considered valuation correlations in the range -0.7 to 0.7 and ran the initial simulations for the cost parameter being either 0, 4, 8, 12, 16 or 20. We then investigated further cost parameter values in order to illustrated the transitions between different optimal arrangements. The optimal arrangements here are identified as those that have the highest average value for the respective type of surplus over the 10,000 simulations done for a specific set of parameter values. This can be read of in table 10 for example for the set of parameter values in that sub-subsection. For each pair of parameter values there is an interesting diversity of outcomes, which we discuss in the following subsection.

4.1.1 Total surplus

Tables 2 and 3 show the market arrangement that maximises the mean total surplus for each pair of parameter values. It illustrates, first of all, that both parameters affect the outcome. For high cost of content delivery, it is socially (total surplus) optimal for there to be no content product and this is in line with the common-sense expectation as in those situations the cost of delivery of the content product exceeds most consumer's willingness to pay and the content product is value destroying. For a wide range of cost and correlation parameter values, the optimal arrangement is *content repriced* which implies that there is some kind of commercial arrangement between the firms.

Table 2: Optimal arrangement (based on average) for total surplus (initial cost values)

	0.0	4.0	8.0	12.0	16.0	20.0
-0.7	Vertical integration	Content repriced	Free-riding content	Content repriced	Content repriced	Content repriced
-0.6	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	Content repriced
-0.5	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	Content repriced
-0.4	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	No content product
-0.3	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	No content product
-0.2	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	No content product
-0.1	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	No content product
0	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	No content product
0.1	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	No content product
0.2	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	No content product
0.3	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	No content product
0.4	Content repriced	Content repriced	Free-riding content	Content repriced	No content product	No content product
0.5	Content repriced	Content repriced	Free-riding content	Content repriced	No content product	No content product
0.6	Content repriced	Content repriced	Free-riding content	Content repriced	No content product	No content product
0.7	Content repriced	Content repriced	Free-riding content	Content repriced	No content product	No content product

Table 3: Optimal arrangement (based on average) for total surplus (interesting cost values)

	5.0	5.5	6.0	9.0	10.0	12.0
-0.7	Content repriced	Content repriced	Free-riding content	Content repriced	Content repriced	Content repriced
-0.6	Content repriced	Content repriced	Free-riding content	Free-riding content	Content repriced	Content repriced
-0.5	Content repriced	Content repriced	Free-riding content	Free-riding content	Content repriced	Content repriced
-0.4	Content repriced	Free-riding content	Free-riding content	Free-riding content	Content repriced	Content repriced
-0.3	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
-0.2	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
-0.1	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
0	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
0.1	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
0.2	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
0.3	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
0.4	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
0.5	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
0.6	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced
0.7	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content	Content repriced

Table 4: Optimal arrangement (based on average) for total surplus, excluding *free-riding content*

	0.0	4.0	8.0	12.0	16.0	20.0
-0.7	Vertical integration	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced
-0.6	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced
-0.5	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced
-0.4	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	No content product
-0.3	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	No content product
-0.2	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	No content product
-0.1	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	No content product
0	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	No content product
0.1	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	No content product
0.2	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	No content product
0.3	Content repriced	Content repriced	Content repriced	Content repriced	Content repriced	No content product
0.4	Content repriced	Content repriced	Content repriced	Content repriced	No content product	No content product
0.5	Content repriced	Content repriced	Content repriced	Content repriced	No content product	No content product
0.6	Content repriced	Content repriced	Content repriced	Content repriced	No content product	No content product
0.7	Content repriced	Content repriced	Content repriced	Content repriced	No content product	No content product

Table 4 shows that if the somewhat unrealistic *free-riding content* arrangement is excluded then almost every socially optimal (best average total surplus, the exception being for highly negatively correlated valuations) situation where the content product is available consists of the broadband price being kept at its original level and a commercial arrangement between the content and broadband provider arising.

4.1.2 Consumer surplus

In table 5 we see that, as expected, the *free-riding content* is optimal for consumers for moderately high cost of delivery. This is because the broadband provider is effectively subsidising their consumption of streaming content. However, for lower values of the delivery cost, a *content repriced* arrangement is also optimal for consumers.

Table 5: Optimal arrangement (based on average) for consumer surplus (initial cost values)

	0.0	4.0	8.0	12.0	16.0	20.0
-0.7	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
-0.6	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
-0.5	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
-0.4	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
-0.3	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
-0.2	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
-0.1	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
0	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
0.1	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
0.2	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
0.3	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
0.4	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
0.5	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
0.6	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content
0.7	Content repriced	Content repriced	Free-riding content	Free-riding content	Free-riding content	Free-riding content

Table 6: Optimal arrangement (based on average) for consumer surplus (interesting cost values)

	4.5	5.0	5.5
-0.7	Content repriced	Content repriced	Free-riding content
-0.6	Content repriced	Content repriced	Free-riding content
-0.5	Content repriced	Free-riding content	Free-riding content
-0.4	Content repriced	Free-riding content	Free-riding content
-0.3	Content repriced	Free-riding content	Free-riding content
-0.2	Content repriced	Free-riding content	Free-riding content
-0.1	Content repriced	Free-riding content	Free-riding content
0	Content repriced	Free-riding content	Free-riding content
0.1	Content repriced	Free-riding content	Free-riding content
0.2	Content repriced	Free-riding content	Free-riding content
0.3	Content repriced	Free-riding content	Free-riding content
0.4	Content repriced	Free-riding content	Free-riding content
0.5	Content repriced	Free-riding content	Free-riding content
0.6	Content repriced	Free-riding content	Free-riding content
0.7	Content repriced	Free-riding content	Free-riding content

The role of the correlation parameter is illustrated by the additional cost values in table 6.

4.2 Illustrative specific parameter value pairs

It is instructive to consider the average outcome values as well as the frequency of the market arrangements being optimal for some specific combinations of the parameter values. We here show also how frequently the market arrangements are *worst* for each kind of surplus. Similar summaries are available for all of the parameter combinations in the previous subsection and we have selected four for inclusion in the paper. Considering this level of details can help firms and regulators understand submarkets, for example.

Where we refer to frequencies in this subsection, it denotes an observed incidence from the 10,000 rounds of simulation conducted for a specific parameter value pair using the methodology described above. We still focus mainly on the average case in the discussion of possible strategies for the broadband and content provider. If either has more information about the exact structure of the consumer willingness-to-pay distribution, a different discussion would take place. Our model is able to analyse the situation for such specific cases, similar to the analysis in Potgieter and Howell (2024), which is one of the strengths of the simulation approach.

[Space left blank intentionally to make the illustrative examples easier to read and compare.]

4.2.1 Simulation results for content users imposing no cost and consumer valuation correlation positive (0.50)

We consider consumer valuations within the model parameters that have a correlation of 0.5 and where content users impose an additional cost of 0.0 on the broadband provider. This illustrates the case where (as content providers sometimes claim) the content product imposes no additional cost on the broadband provider and where consumer valuations are quite strongly correlated.

Table 7: Frequency of market arrangement being optimal, with duplicates (percentage)

	Producer surplus	Consumer surplus	Total surplus
No content product	0.0	0.0	0.0
Free-riding content	0.0	0.0	0.0
Repriced broadband	2.1	5.6	2.1
Content repriced	18.2	82.8	57.5
Vertical integration	100.0	32.2	62.1

Table 7 shows that consumer surplus is most frequently highest for *content repriced* and total surplus is highest most often for *vertical integration* in this configuration of content-delivery cost and consumer valuations. It is interesting to note that the consumer surplus is frequently also optimal in the *vertical integration* arrangement.

Table 8: Frequency of market arrangement being worst, with duplicates (percentage)

	Producer surplus	Consumer surplus	Total surplus
No content product	100.0	76.0	99.9
Free-riding content	0.0	0.0	0.0
Repriced broadband	0.0	22.2	0.1
Content repriced	0.0	0.0	0.0
Vertical integration	0.0	1.8	0.0

Table 8 shows that consumer surplus is most frequently lowest for *no content product* and total surplus is lowest most often for *no content product* in this configuration of cost and consumer valuations. Consumer surplus is also frequently worst for *repriced broadband*.

Table 9: Frequency of market arrangements being jointly optimal (percentage) for total surplus

	No content product	Free-riding content	Repriced broadband	Content repriced	Vertical integration
No content product	0.0	0.0	0.0	0.0	0.0
Free-riding content	0.0	0.0	0.0	0.0	0.0
Repriced broadband	0.0	0.0	2.1	1.7	1.4
Content repriced	0.0	0.0	1.7	57.5	19.9
Vertical integration	0.0	0.0	1.4	19.9	62.1

From the point of view of total surplus, the arrangements *content repriced* and *vertical integration* are equivalent 19.9% of the time and *content repriced* is (separately or jointly) optimal 57.5% of the time, as shows in table 9. The *repriced broadband* arrangement is very seldom optimal.

Table 10: Mean outcome for each market arrangement

Outcomes	Broadband price	Content price	Broadband profit	Content revenue	Producer surplus	Consumer surplus	Total surplus
No content product	60.27		914.21	0.00	914.21	554.69	1,468.90
Free-riding content	60.27	14.16	1,028.54	469.40	1,497.94	778.18	2,276.12
Repriced broadband	63.39	14.16	1,063.99	441.15	1,505.14	658.99	2,164.13
Content repriced	60.27	8.51	1,203.85	367.03	1,570.88	990.06	2,560.93
Vertical integration	65.77	4.51	1,408.27	195.40	1,603.67	918.06	2,521.73

Aside from when the content product is not available, the worst average outcome for consumers is *repriced broadband*. We also see in table 10 that consumer surplus is highest on average for *content repriced*. Total surplus is highest on average for *content repriced* where it is 12.5% higher than in the case *free-riding content*. In addition, for the case *content repriced* the consumer surplus average is also 50.2% higher than for *repriced broadband*. Our simulation data show that in 100.0% of cases, the content price is decreased by the *content repriced* arrangement. Content revenue is increased in only 28.3% of cases by *content repriced* when compared to the *repriced broadband* arrangement.

4.2.2 Simulation results for content cost of 4.0 and consumer valuations uncorrelated

We consider consumer valuations within the model parameters that have a correlation of 0.0 and where content users impose an additional cost of 4.0 on the broadband provider.

Table 11: Frequency of market arrangement being optimal, with duplicates (percentage)

	Producer surplus	Consumer surplus	Total surplus
No content product	0.0	0.0	0.0
Free-riding content	0.0	0.0	0.0
Repriced broadband	8.6	8.9	8.6
Content repriced	17.4	82.1	70.6
Vertical integration	100.0	31.3	46.0

Table 11 shows that consumer surplus is most frequently highest for *content repriced* and total surplus is highest most often for *content repriced* in this configuration of cost and consumer valuations. The *repriced broadband* arrangement is seldom optimal.

Table 12: Frequency of market arrangement being worst, with duplicates (percentage)

	Producer surplus	Consumer surplus	Total surplus
No content product	100.0	49.5	90.1
Free-riding content	0.0	0.0	0.0
Repriced broadband	0.0	43.8	9.9
Content repriced	0.0	0.0	0.0
Vertical integration	0.0	8.0	0.1

Table 12 shows that consumer surplus is most frequently lowest for *no content product* and total surplus is also lowest most often for *no content product* in this configuration of cost and consumer valuations.

Table 13: Frequency of market arrangements being jointly optimal (percentage) for total surplus

	No content product	Free-riding content	Repriced broadband	Content repriced	Vertical integration
No content product	0.0	0.0	0.0	0.0	0.0
Free-riding content	0.0	0.0	0.0	0.0	0.0
Repriced broadband	0.0	0.0	8.6	5.5	5.5
Content repriced	0.0	0.0	5.5	70.6	18.4
Vertical integration	0.0	0.0	5.5	18.4	46.0

From the point of view of total surplus, the arrangements *content repriced* and *vertical integration* are equivalent 18.4% of the time and *content repriced* is (separately or jointly) optimal 70.6% of the time as shown in table 13.

Table 14: Mean outcome for each market arrangement

Outcomes	Broadband price	Content price	Broadband profit	Content revenue	Producer surplus	Consumer surplus	Total surplus
No content product	60.30		913.10	0.00	913.10	553.34	1,466.44
Free-riding content	60.30	12.02	816.65	377.56	1,194.21	756.41	1,950.61
Repriced broadband	65.88	12.02	876.09	317.49	1,193.58	544.69	1,738.27
Content repriced	60.30	10.92	865.31	350.29	1,215.60	793.60	2,009.20
Vertical integration	63.92	8.70	950.94	294.80	1,245.74	715.55	1,961.29

Aside from when the content product is not available, the worst average outcome for consumers is again *repriced broadband*. We also see in table 14 that consumer surplus is highest on average for *content repriced*. Total surplus is highest on average for *content repriced* where it is 3.0% higher than in the case *free-riding content*. In addition, for the case *content repriced* the consumer surplus average is also 45.7% higher than for *repriced broadband*. Our simulation data show that in 24.9% of cases the content price is increased by the *content repriced* arrangement. Content revenue is increased in 63.1% of cases by *content repriced* when compared to the *repriced broadband* arrangement.

4.2.3 Simulation results for content cost of 8.0 and consumer valuation correlation negative (-0.30)

We consider consumer valuations within the model parameters that have a correlation of -0.3 and where content users impose an additional cost of 8.0 on the broadband provider.

Table 15: Frequency of market arrangement being optimal, with duplicates (percentage)

	Producer surplus	Consumer surplus	Total surplus
No content product	0.0	0.0	0.0
Free-riding content	0.0	0.0	0.0
Repriced broadband	2.0	9.0	5.3
Content repriced	38.0	74.8	76.2
Vertical integration	100.0	48.3	53.7

Table 15 shows that consumer surplus is most frequently highest for *content repriced* and total surplus is highest most often for *content repriced* in this configuration of cost and consumer valuations.

Table 16: Frequency of market arrangement being worst, with duplicates (percentage)

	Producer surplus	Consumer surplus	Total surplus
No content product	48.3	22.8	32.1
Free-riding content	31.8	0.0	0.0
Repriced broadband	22.3	69.9	66.0
Content repriced	0.0	0.0	0.0
Vertical integration	0.0	7.9	2.3

Table 16 shows that consumer surplus is most frequently lowest for *repriced broadband* and total surplus is lowest most often for *repriced broadband* in this configuration of cost and consumer valuations.

Table 17: Frequency of market arrangements being jointly optimal (percentage) for total surplus

	No content product	Free-riding content	Repriced broadband	Content repriced	Vertical integration
No content product	0.0	0.0	0.0	0.0	0.0
Free-riding content	0.0	0.0	0.0	0.0	0.0
Repriced broadband	0.0	0.0	5.3	1.2	1.1
Content repriced	0.0	0.0	1.2	76.2	33.8
Vertical integration	0.0	0.0	1.1	33.8	53.7

From the point of view of total surplus, the arrangements *content repriced* and *vertical integration* are equivalent 33.8% of the time and *content repriced* is (separately or jointly) optimal 76.2% of the time as seen in table 17.

Table 18: Mean outcome for each market arrangement

Outcomes	Broadband price	Content price	Broadband profit	Content revenue	Producer surplus	Consumer surplus	Total surplus
No content product	60.33		912.59	0.00	912.59	551.20	1,463.79
Free-riding content	60.33	10.69	596.35	327.82	924.17	733.89	1,658.06
Repriced broadband	68.87	10.69	707.17	230.52	937.68	425.76	1,363.44
Content repriced	60.33	16.53	766.10	233.21	999.31	617.67	1,616.98
Vertical integration	61.68	15.27	770.15	244.60	1,014.75	583.32	1,598.07

Aside from when the content product is not available, the worst outcome for consumers is *repriced broadband*. We also see in table 18 that consumer surplus is highest on average for *free-riding content*. Total surplus is highest on average for *free-riding content* where it is 0.0% higher than in the case *free-riding content*. In addition, for the case *free-riding content* the consumer surplus average is also 72.4% higher than for *repriced broadband*. Our simulation data show that in 91.5% of cases the content price is increased by the *content repriced* arrangement. Content revenue is increased in 46.5% of cases by *content repriced* when compared to the *repriced broadband* arrangement.

4.2.4 Simulation results for content cost of 8.0 and consumer valuation correlation positive (0.60)

We consider consumer valuations within the model parameters that have a correlation of 0.6 and where content users impose an additional cost of 8.0 on the broadband provider.

Table 19: Frequency of market arrangement being optimal, with duplicates (percentage)

	Producer surplus	Consumer surplus	Total surplus
No content product	0.0	0.0	0.0
Free-riding content	0.0	0.0	0.0
Repriced broadband	2.6	7.4	5.5
Content repriced	42.6	78.7	75.7
Vertical integration	100.0	51.6	59.0

Table 19 shows that consumer surplus is most frequently highest for *content repriced* and total surplus is highest most often for *content repriced* in this configuration of cost and consumer valuations.

Table 20: Frequency of market arrangement being worst, with duplicates (percentage)

	Producer surplus	Consumer surplus	Total surplus
No content product	59.9	20.1	32.6
Free-riding content	14.4	0.0	0.0
Repriced broadband	27.2	74.9	66.5
Content repriced	0.0	0.0	0.0
Vertical integration	0.0	5.7	1.3

Table 20 shows that consumer surplus is most frequently lowest for *repriced broadband* and total surplus is lowest most often for *repriced broadband* in this configuration of cost and consumer valuations.

Table 21: Frequency of market arrangements being jointly optimal (percentage) for total surplus

	No content product	Free-riding content	Repriced broadband	Content repriced	Vertical integration
No content product	0.0	0.0	0.0	0.0	0.0
Free-riding content	0.0	0.0	0.0	0.0	0.0
Repriced broadband	0.0	0.0	5.5	1.0	1.4
Content repriced	0.0	0.0	1.0	75.7	38.8
Vertical integration	0.0	0.0	1.4	38.8	59.0

From the point of view of total surplus, the arrangements *content repriced* and *vertical integration* are equivalent 38.8% of the time and *content repriced* is (separately or jointly) optimal 75.7% of the time as seen in table 21.

Table 22: Mean outcome for each market arrangement

Outcomes	Broadband price	Content price	Broadband profit	Content revenue	Producer surplus	Consumer surplus	Total surplus
No content product	60.32		912.81	0.00	912.81	552.23	1,465.04
Free-riding content	60.32	14.59	470.54	489.30	959.83	777.88	1,737.72
Repriced broadband	72.31	14.59	602.31	344.84	947.15	402.22	1,349.37
Content repriced	60.32	20.27	652.60	376.55	1,029.14	639.36	1,668.51
Vertical integration	61.82	19.20	649.16	393.06	1,042.22	607.64	1,649.86

Aside from when the content product is not available, the worst outcome for consumers is *repriced broadband*. We also see in table 22 that consumer surplus is highest on average for *free-riding content*. Total surplus is highest on average for *free-riding content* where it is 0.0% higher than in the case *free-riding content*. In addition, for the case *free-riding content* the consumer surplus average is also 93.4% higher than for *repriced broadband*. Our simulation data show that in 92.3% of cases the content price is increased by the *content repriced* arrangement. Content revenue is increased in 59.4% of cases by *content repriced* when compared to the *repriced broadband* arrangement.

5 Discussion

The main results for optimising surplus presented in subsection 4.1 show that for many combination of parameter values (cost to deliver content and consumer valuation correlation), the cooperative solution *content repriced* is optimal for both total surplus and consumer surplus. For high (but not low!) cost to deliver the content, consumer surplus is optimised by the *free-riding content* arrangement as can be expected as this amounts to a subsidy for the consumption of content that is expensive to deliver. Such an arrangement is not viable since the broadband provider can always choose to reprice the broadband product. Total surplus is optimised by the *free-riding* arrangement only for middling high cost of content delivery (around 8.0) which is where the gains to consumers outweigh the loss of profitability of the broadband provider. The *repriced broadband* arrangement, which would result from a prohibition of commercial arrangements between the firms, is not optimal for either type of surplus for any combination of parameter values. This analysis was based on the average outcome of our 10,000 simulation rounds for each parameter value pair.

In subsection 4.2, the four specific illustrative parameter value pairs are examined in detail. We look not only at the average outcomes but also at how often arrangements are (jointly) optimal. Restraining the firms to pricing at integer values is the cause of the relatively frequent join optimality and we believe that this is both illustrative and reflective or arrangements in practice. Our simulation results contain the same information for dozens of other parameter value pairs and we have chosen to discuss these four mainly because the illustrate some diversity in the outcomes.

In the case of 4.2.1 (no delivery cost for the content, 0.5 correlation for valuations), the content provider obviously always prefers the *free-riding content* arrangement. Since not only producer surplus but also broadband profit is increased appreciably by other arrangements, the firms should favour either

- the arrangement *content repriced* with a small side payment from the broadband provider to the content provider or
- *vertical integration* with a large side payment from the broadband provider.

The *repriced broadband* arrangement is also not far inferior in terms of producer surplus but since it is appreciably inferior in terms of consumer surplus to both *content repriced* and *vertical integration*, a well-informed regulator would be expected to favour one of the latter two arrangements. Assuming no cost of content delivery makes this a somewhat artificial special case but one that illustrates that even that hypothetical does not exclude a cooperative commercial arrangement being optimal – also for consumer surplus. A rational broadband provider would (based on the average) increase the broadband price in response to the introduction of the content product.

In 4.2.2 (4.0 delivery cost for the content, no correlation for valuations) a rational broadband provider would move to the *repriced broadband* arrangement after the introduction of the content product. The reasonable response would be for the content provider to attempt to reach the *content repriced* arrangement by offering the broadband provider some of the increased revenue it would have in that arrangement. Here, therefore, the content provider would have an incentive to pay the broadband provider for it to prefer not to reprice the broadband but rather take a share of the content revenue. Of course, the *vertical integration* option where both broadband and content are repriced is (as always) optimal for the firms and would require an agreement on how to share the surplus. In contrast to 4.2.1 where the availability of the content allows the broadband provider to increase its profit by charging more, the profitability of the broadband provider is reduced in this case – even if it increases the broadband price.

In 4.2.3 (8.0 delivery cost for the content, -0.30 correlation for valuations) both the broadband and the content firm are somewhat better off under either the *content repriced* or *vertical integration* arrangements but consumers are considerably better off. A regulator should therefore regard with benevolence anything that would increase the price of the content product and lower the price of broadband, such as (for example) the broadband provider imposing content delivery charges on the content firm. Again, as in 4.2.2, the profitability of the broadband provider is reduced by the introduction of the content product – even in the *repriced broadband* arrangement. Since the content provider might not have a strong incentive to move to a cooperative commercial arrangement, the improvement of average consumer (and total) surplus that lies in the *content repriced* or *vertical integration* arrangements could conceivably require the broadband provider to be able to block delivery of the content product.

In 4.2.4 (8.0 delivery cost for the content, 0.60 correlation for valuations) the situation is similar except that now more revenue accrues to the content provider which might also have a stronger incentive to seek one of the cooperative commercial arrangements. The slight differences in the average outcomes for the *no content product* arrangements with 4.2.3 that can be observed in tables 18 and 22 are due to the two respective sets of 10,000 simulation rounds having had independently generated samples of consumer valuations. The consumer valuations for the broadband product are, of course, identically distributed in both cases.

Considering the full set of results in section 4, it is clear that the one thing which is always bad is *repriced broadband* arrangement which is the natural outcome if content firms refuse to negotiate commercial arrangements with the broadband provider, or are forbidden to do so. Unfortunately, broadband providers are often highly regulated and might not be able to fully realise this outcome. If they do, broadband prices sometimes increase to levels usually significantly higher than for the arrangements *content repriced* and *vertical integration*. Regulators and consumers have an interest in avoiding this adverse arrangement. However, the April 2024 decision[1] by the US Federal Communications Commission (FCC) to reinstate so-called network neutrality places the US market firmly in the the *repriced broadband* arrangement discussed in this paper, which is almost always the worst outcome.

[1] https://www.cato.org/blog/internet-regulation-back-fcc-refuses-retire-net-neutrality-rules

6 Conclusion

We have demonstrated, using extensive simulation, that the micro-dynamics of broadband and content provider interactions suggest that some kind of commercial arrangement between the firms is always optimal. Policies that inhibit or prohibit such arrangements from arising are detrimental to consumer and overall welfare. For some parameter values, content providers might prefer a non-cooperative arrangement but in most instances even the content provider benefits from cooperation. We have also shown that the realistic assumption that the firms choose whole-number prices, implies that there is frequently more than one arrangement that is simultaneously optimal for a specific set of parameter values. Possible directions for future research include looking at more than one broadband provider, using different distributions for the consumer valuations and investigating the incentives that content and broadband providers might have to induce or avoid cooperative arrangements, including where alliances of content providers interact with broadband providers serving distinct markets in which broadband is priced differently.

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