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Working Paper #11-19

October 2011

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James Rutt
University of Cambridge

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October 1, 2011

Abstract

The Internet has drastically altered the nature of competition in the news industry. This article develops a model of price and quality competition between firms in the online news industry. In equilibrium, firms randomise in their pricing strategies and this generates the cross-sectional mixture of advertiser and subscription funded models we observe. The model also plausibly explains why pricing strategies differ across content areas. Finally, an important part of my explanation is that aggregators, such as Google and Digg.com, allow consumers to search amongst articles and direct consumers towards high quality articles. The model's results have implications for the ongoing public debate about the effects of aggregators on the news industry; although aggregators may harm firms, consumers may benefit.
Keywords: Internet, Newspapers, Aggregators, Paywalls.
JEL Classification: L11, L13, L82

1 Introduction

Twenty years ago, geographic barriers in the offline news industry meant that an individual in the U.K. had a choice between a relatively small number of

*Faculty of Economics, University of Cambridge. Email: jmr81@cam.ac.uk. I thank Sanjeev Goyal, my supervisor, for his detailed comments; Aytek Erdil, Rupert Gatti and Pushmeet Kohli for their advice; and seminar participants at Microsoft Research, Cambridge and the University of Cambridge for helpful comments. I am also grateful to the ESRC and the NET Institute (`www.NETinst.org`) for financial support.

domestic news providers. The Internet has eroded these geographic barriers, and today, the same individual can easily access any English language news website in the world. As a result, it is estimated that 73% of the *Daily Mail*'s online readers are from outside of the U.K. (OECD (2010)). Meanwhile, the *Guardian* has more online readers in the U.S. than the *Los Angeles Times* (Lanchester (2010)).

The Internet has also changed the way in which news is consumed. Offline, consumers tend to purchase a single newspaper. The newspaper is a bundled product collecting together articles covering a number of topics. A consumer interested in a single article has to purchase the entire newspaper, regardless of whether they are interested in the other articles. Bundling the product provides firms with more scope for horizontal differentiation and such models have traditionally been used to examine competition in the media industry (e.g. Anderson and Coate (2005) and Gabszewicz et al. (2001)).

Online, it is easier for consumers to personalise their coverage and to switch between providers (Lanchester (2010)). This has meant that the traditional newspaper has been unbundled. Online, articles are consumed as individual products and consumers might use one site for sports coverage, another for business news and yet another for entertainment news. Generally, firms are less able to horizontally differentiate individual articles. Instead, vertical differentiation becomes more important and this is the focus of this article.

An important facilitator of these changes has been the rise of online news aggregators such as Google News and Digg.com. These sites allow consumers to identify high quality articles and stories of interest. Such services are becoming an increasingly important source of consumers for firms. For example, in 2006 it was estimated that 20 percent of visitors to news websites came via Google and a further 7 percent came via Yahoo (Newspaper Association of America (2007)). By 2009 between one third and one half of visitors to five of America's major newspapers arrived via Yahoo, Microsoft or Google (Weir (2010)).[1]

These developments have posed firms a number of challenges. In particular, there is much debate over how firms should price access to their articles online:

"For every outfit that is trying to build a premium subscription

[1]The newspapers were *The Washington Post*, *The New York Times*, *Los Angeles Times*, *USA Today* and *The Wall Street Journal*.

> service, another is becoming more convinced of the virtues of giving away free content." (The Economist (2010))

One group of firms (e.g. the *Daily Mail*, the *Guardian*, and *CNN*) are aggressively expanding their websites and providing all of their articles for free. These firms appear to believe that an advertiser funded model is feasible so long as sufficient scale is achieved. Conversely, another group of firms are erecting paywalls and charging for access to their articles (e.g. *The Times*, *The Wall Street Journal*, the *Financial Times* and *The New York Times*). These paywalls take a variety of forms. *The Times* and *The Sunday Times* take an extreme position. These firms charge for access to all of their articles and even block search engines from listing their articles amongst search results. A more common model is to have some form of metered paywall, as pioneered by the *Financial Times* and *The Wall Street Journal*. These firms allow visitors to view certain articles (e.g. general news articles but not editorials) or a certain number of articles for free, within a given time period, before charging for any further access.

The first part of this article develops a model of price and quality competition in the market for an individual news article. To do this I utilise a methodology commonly used to analyse price dispersion in homogeneous good markets (see Varian (1980) and Baye and Morgan (2001), amongst others). In the model there are two types of consumer: loyal consumers and searchers. Loyal consumers only consider the articles produced by one firm and are willing to pay to access that firm's articles. Searchers have no *ex ante* preferences over firms and are assumed to be fully informed about the quality of the articles provided by different firms because they use an aggregator to search amongst the available providers. However, it is assumed that searchers are not willing to pay to access an article. As a result searchers select the firm providing the highest quality article which is free to access.

These assumptions about consumer behaviour are consistent with the following evidence. Firstly, in 2010, 64 percent of visitors to the top twenty-five US news websites averaged only 1 visit per month to a particular site (Pew Research Center (2011)). So, many consumers are not loyal to any specific firm. Secondly, Athey et al. (2011) find that the concentration of a user's consumption amongst different websites is strongly and negatively correlated to their frequency of using Google or Bing news. Thus, consumers who switch between firms use aggregators to search amongst firms. Thirdly, a Pew Research Center survey found that 82% of consumers said they would use

another firm if their favourite firm began charging for access to their articles (Pew Research Center (2010)). Hence, many consumers do not consider using firms who charge for access to their articles. Fourthly, some firms, such as *The Times*, have erected paywalls which prevent aggregators from displaying the articles of those firms.

Thus, in my model, searchers are those consumers who are unwilling to pay for the article and who use an aggregator to search and switch amongst the providers. Meanwhile, loyal consumers can be thought of as regular news readers who always use the same newspaper website.

Given the behaviour of consumers, firms simultaneously decide on their price and quality investments. Firms can charge advertisers to display advertisements alongside their articles. As a result, firms receive revenue for every consumer who reads their article regardless of their pricing strategy.

Firms face a trade-off in their pricing strategy between earning sales revenue from loyal consumers and losing potential advertising revenue from searchers. I show that this trade-off leads to a symmetric mixed strategy equilibrium. In such an equilibrium, firms randomise between providing the article for free and charging for access to the article. There is a unique level of quality provided by firms who charge for access to the article. However, there is a distribution of quality levels for articles which are free to access.

The model's equilibrium is consistent with several characteristics of the online news industry. Firstly, in equilibrium firms randomise in their pricing decisions and quality investments. This endogenously generates the cross-sectional mixture of pricing strategies we observe and also generates quality dispersion across, *ex ante* identical, firms. Additionally, in a dynamic setting, the symmetric equilibrium's strategy can be interpreted in terms of a metered paywall, in which firms sometimes charge for access to their articles, whilst providing free access at other times. Over time, as firms randomise between providing their articles for free and charging for access to their articles, this generates the temporal variation in pricing strategies we observe by some firms who use such metered paywalls.

Secondly, it is never an equilibrium for *every* firm to provide their article for free with certainty. This result arises because, when all firms provide their article for free, the behaviour of the searchers creates a Bertrand effect which erodes away profits. This is consistent with recent changes in the pricing strategies used by firms. Until recently, the predominant online business model has been for every firm to provide free access to their articles. This period has coincided with firms investing heavily in their websites and the

quantity and variety of the content they provide. However, there has been a recent movement away from this strategy. Firms have struggled to be profitable and several firms, most notably Rupert Murdoch's News Corporation, have claimed that a universal free content model is unsustainable.

Thirdly, it is clear that strategies differ across content areas. For example, the vast majority of entertainment news is available for free online whereas consumers are often charged for access to financial news. In particular, it is usually claimed that the paywalls of the *Financial Times* and *The Wall Street Journal* have been successful because these firms have few direct competitors and many loyal consumers who value the articles these firms provide highly (Lanchester (2010)). I show that my model's predictions are consistent with these claims.

The second part of this article focuses on the model's welfare implications. In particular, I focus on how changes in certain parameters affect the expected quality of free articles and consumer welfare. These results provide insights into how aggregators affect the quality of articles, online pricing strategies, firm profits and consumer welfare.

The effects of aggregators on the news industry has received much attention in the popular press (e.g. The Economist (2009)) and in policy circles (e.g. OECD (2010) and Kirchhoff (2010)). This debate has generally focussed on the detrimental effects aggregators are believed to have on firm profitability and the quality provision of firms who charge for access to their articles.

My model agrees with the popular claim that aggregators reduce the profitability of firms and the quality levels provided by firms who charge for access to their articles. However, the model also highlights the potential benefits aggregators can bring consumers. For example, as more consumers use the aggregator, firms increase the propensity with which they provide their article for free and the expected quality of a free article also increases. These results imply that a loyal consumer's expected utility increases as more consumers use the aggregator. Additionally, I show that it is possible for the expected quality level of a free article to exceed the first best level chosen by a social planner maximising the sum of firm profits and consumer utility. These possibilities have received little attention in the existing literature.

I proceed, in Section 2, by discussing the relationship between this article and the existing literature. Section 3 sets up the model and Section 4 presents the model's symmetric equilibrium. Section 5 discusses the comparative statics for this equilibrium and analyses how the parameters of the model affect

quality investments for free articles and consumer welfare. Section 6 discusses the model, offering some interpretations of the results and outlining some extensions to the basic framework. Section 7 concludes. Finally, an appendix presents some of the longer proofs.

2 Related Literature

The existing literature analysing the impact of the Internet on the news industry focuses on a variety of issues including: the implications of online news for offline newspapers (Gentzkow (2007)) and the implications of the Internet for firms who rely on advertising for their funding (Athey et al. (2011), Athey and Gans (2010) and Bergemann and Bonatti (2010)). This article contributes to this literature by focussing on the determinants of a firm's online pricing strategy and quality investments and the impact of aggregators on the news industry.

Much of the discussion concerning the online news industry focuses on how the Internet and especially online aggregators affect the quality of the news provided. However, the media industry has traditionally been analysed using models of horizontal differentiation (e.g. Anderson and Coate (2005) and Gabszewicz et al. (2001)). Such models are not well suited to addressing the questions concerning product quality which arise in the online news industry. Therefore, I develop a model of price and quality competition in the online news industry using the methodology widely used to model price dispersion in the market for a homogeneous good (e.g. Varian (1980) and Baye and Morgan (2001)). This article's contribution is to apply this methodology in a new setting, whose structure is designed to reflect the features of the online news industry. This permits an analysis of how specific features of the industry, such as aggregators, affect the strategies and profits of firms and the implications for consumer welfare. However, in keeping with the price dispersion literature, firms face the following trade-off which drives the results.

A firm can choose to act as a local monopolist and serve a small set of loyal consumers. Alternatively, a firm can attempt to attract a larger group of consumers, but only if the firm exposes itself to competition from other firms. Thus, firms must trade-off lost revenue from their loyal consumers with the potential revenue they could gain if they compete with other firms and attract the larger group of consumers. This trade-off leads to a mixed

strategy equilibrium, which generates heterogeneity in pricing decisions and quality investments across, *ex ante* identical, firms.

A notable feature of many media industries is the presence of heterogeneity in pricing strategies across firms. This heterogeneity in pricing strategies is particularly stark in the online news industry. We regularly observe some firms charging for access to articles, as other firms rely on advertising revenue and provide essentially the same article for free.

Several papers have drawn on the two-sided markets literature to compare the strategies of firms when they are forced to rely solely on advertising revenues and when they are free to charge subscription prices (e.g. Anderson and Coate (2005) and Crampes et al. (2009)). However, the majority of this literature has not tried to explain why we observe cross-sectional variation in pricing strategies across competing firms. An exception is the work of Ambrus and Reisinger (2006). However, Ambrus and Reisinger use a model of horizontal differentiation and focus on the broadcasting industry and the implications of multi-homing consumers for advertising revenues. In contrast, I focus on the online news industry and my model generates cross-sectional heterogeneity in pricing strategies within a model of vertical differentiation.

The economics literature has mainly focussed on price aggregators (e.g. Baye and Morgan (2001), Smith and Brynjolfsson (2001) and Ellison and Ellison (2009)). To my knowledge, only Dellarocas et al. (2010) and Katona and Sarvary (2008) have considered the effects of aggregators on the news industry or content providers. Katona and Sarvary's analysis suggests that aggregators encourage firms to specialise in specific content areas. Meanwhile, Dellarocas et al. focus on how aggregators can free-ride on the content provided by firms and how this effects the hyperlinking and content investment decisions of firms.

This article addresses a different set of issues by considering how aggregators affect the pricing decisions of firms and the quality of articles they provide. In particular, my model emphasises the contrasting effects that aggregators have on the quality of an article depending on the pricing strategy the firm follows. The existing literature focuses exclusively on the effects of aggregators on firms. In contrast, my approach allows a consideration of how aggregators affect consumers. As a result, I am able to provide a more general welfare analysis than has been attempted in previous research. I show that, although aggregators may reduce the profitability of firms, consumers may benefit.

3 Model

A continuum of consumers of unit mass consume a vertically differentiated news article. The utility of a consumer from an article of quality x purchased at a price p is given by $U(x,p) = \delta u(x) - p$. $\delta > 0$ reflects the intensity of preferences and will be interpreted as the willingness to pay of consumers. I assume that $u(0) = 0$, $u'(\cdot) \geq 0$, $u''(\cdot) \leq 0$, $\lim_{x\to 0} u'(x) > 0$ and $\lim_{x\to\infty} u'(x) = 0$.

Consumers are one of two types; a proportion μ are searchers and $1-\mu$ are loyal consumers. Loyal consumers are only aware of one firm. Equivalently, these consumers have a single most preferred firm and do not consider the articles of other firms to be substitutable for the article of their most preferred firm. Additionally, loyal consumers are willing to pay to access this firm's article, subject to a participation constraint. Finally, these consumers are uniformly distributed across the n firms, so each firm has $\frac{1-\mu}{n}$ loyal consumers.

Searchers are fully informed about the quality levels provided by different firms. However, searchers are assumed not to be willing to pay to access the article. As searchers have no *ex ante* preferences over firms, they access the highest quality article provided for free. For now, I assume that $\mu \in (0,1)$ is exogenously given. I will discuss this assumption and the assumption that loyal consumers are uniformly distributed across firms in Section 6.

As was discussed in Section 1, these assumptions are consistent with several features of the online news industry. Firstly, loyal consumers can be thought of as regular news readers. It seems likely that regular readers are conscious of any horizontal differentiation between firms and it may be an important consideration in their choice of firm. This is consistent with Gentzkow and Shapiro (2010)'s findings that some consumers prefer to read news which confirms their pre-existing views and biases.

Secondly, many consumers are casual consumers, who only use any given firm infrequently and who switch between firms regularly. These casual readers are a significant source of traffic, and thus potential revenue, to firms. In this model these casual readers are the searchers. At the level of an individual article vertical differentiation becomes more important when attracting consumers. As a result, the searchers focus on quality in their choice of firm.

Thirdly, evidence suggests that consumers who switch between firms use aggregators to identify articles of interest. Therefore, we might imagine that searchers are aware of the variability in quality across firms because they use an aggregator to search amongst the available providers. In this interpreta-

tion μ captures the importance of the aggregator. As μ increases a greater proportion of consumers are searchers and use the aggregator to search for articles.

Fourthly, most consumers are unwilling to pay to access an article and will switch to another firm. Additionally, the paywalls of some firms, such as *The Times*, prevent aggregators from displaying their articles in search results. As a result, searchers do not to consider firms who charge for access to their articles.

Given the behaviour of consumers, the n firms simultaneously decide what subscription price (p_i for firm i) to set and the quality investment (x_i for firm i) to make, at a cost $c(\gamma x_i)$. I assume that $c(0) = 0$, $c'(\cdot) \geq 0$, $c''(\cdot) \geq 0$, $\lim_{x\to 0} c'(x) = 0$ and $\lim_{x\to\infty} c'(x) = \infty$. γ is used to analyse an increase in costs. The quality of an article, x might be determined by the quantity of coverage, the amount of critical analysis and so forth.

Finally, firms can display advertisements alongside their articles. Thus, a firm earns advertising revenue, β, from every consumer who reads their article. This advertising revenue is assumed to be constant and independent of the firms pricing strategy. Suppose that advertising is informative, creating product awareness and allowing the products of advertisers to be matched with consumers. Each advertiser has a constant valuation ν of an impression to a consumer. ν is distributed according to $G(\nu)$ on $[0, \bar{\nu}]$ across the advertisers. An advertiser with value ν purchases an impression at firm i if $\nu - \phi_i \geq 0$, where ϕ_i is the per impression advertising price of firm i. If advertisers can only purchase adverts at the firms, and not the aggregator, then each firm has monopoly power over access to every consumer reading its article. The firm's advertising demand function is $a_i(\phi_i) = 1 - G(\phi_i)$. Thus, all firms will charge the same per impression advertising price (ϕ^*) which maximises $\phi_i(1 - G(\phi_i))$. A sufficient condition for ϕ^* to be unique is that $1 - G(\nu)$ is log-concave (Bagnoli and Bergstrom (2005)). Thus, each firm earns the same per consumer advertising revenue, $\beta = \phi^*(1 - G(\phi^*))$.[2]

[2]Alternatively, advertisers might be able to advertise at both the firms and the aggregator. This provides advertisers with two opportunities to reach searchers, but only one opportunity to reach loyal consumers. However, if consumers can be perfectly tracked across sites, then firms can price discriminate based on consumer type. This results in two advertising prices, one for searchers and one for loyal consumers, but does not alter any of the analysis.

4 Analysis

I focus on the existence and properties of the unique symmetric Nash equilibrium of this model. In this equilibrium every firm provides their article for free with probability α^*. Those firms who charge for access to their article select a unique quality level, x_M^*, and those firms providing free access to their article select a quality level from a distribution $F(\cdot)$. The possibility and some implications of asymmetric equilibria are discussed further in Section 6.[3]

To solve for the symmetric equilibrium consider the decision of a single firm assuming that all other firms follow the symmetric strategy described by α^*, x_M^* and $F(\cdot)$. Suppose that the firm decides to charge for access to their article. In this case the firm only attracts their loyal consumers and maximises:

$$\begin{aligned}\max_{p_i>0, x_i\geq 0} \pi_M(x_i, p_i) = \frac{\beta(1-\mu)}{n} + \frac{(1-\mu)}{n}p_i - c(\gamma x_i)\\ s.t. \quad U(x_i, p_i) = \delta u(x_i) - p_i \geq 0\end{aligned}$$

$\frac{\beta(1-\mu)}{n}$ is the exogenous advertising revenue from these customers, $\frac{(1-\mu)}{n}p_i$ is the sales revenue earned when charging p_i for access to the article and $c(\gamma x_i)$ is the cost of providing the quality level x. It is clear that the participation constraint must bind so that $p_i = \delta u(x_i)$. Thus:

Lemma 1. *The profit maxisimising quality level is x_M^* such that:*

$$\frac{(1-\mu)\delta}{n}u'(x_M^*) = \gamma c'(\gamma x_M^*) \tag{1}$$

The associated profit maximising price and profits are:

$$p_M = \delta u(x_M^*) \tag{2}$$

$$\pi_M(x_M^*) = \frac{\beta(1-\mu)}{n} + \frac{(1-\mu)\delta}{n}u(x_M^*) - c(\gamma x_M^*) \tag{3}$$

Existence and uniqueness of $x_M^* > 0$ is ensured because the left hand side of (1) is monotonically decreasing with x from above 0 and the right hand

[3]The symmetric equilibrium is the unique equilibrium for $n = 2$.

side is monotonically increasing with x from 0. Additionally, the second order condition holds from concavity of $u(\cdot)$ and convexity of $c(\cdot)$.

Now consider the expected profit of a firm which provides free access to its article and makes a quality investment of x, given that the other firms are following the symmetric strategy. This firm earns $\frac{\beta(1-\mu)}{n}$ in exogenous revenue from their loyal consumers. The cost of the quality investment x is $c(\gamma x)$. The expected revenue from searchers when x is chosen is $\sum_{j=0}^{n-1}\binom{n-1}{j}\alpha^j(1-\alpha)^{n-1-j}F(x)^j\beta\mu$. $\beta\mu$ is the exogenous revenue the firm earns if the searchers select their article. This occurs when the firm has the highest quality article of all firms who do not charge for access to their article. The probability that j firms, other than i, decide not to charge is $\binom{n-1}{j}\alpha^j(1-\alpha)^{n-1-j}$. As quality investments are independently drawn from a common distribution $F(\cdot)$, the probability that x is higher than that of the other j firms is $F(x)^j$. Summing over all possible j gives the expected probability that firm i is used by the searchers given x, α^* and $F(\cdot)$. So:

$$\begin{aligned} E[\pi_i(x)] &= \left[\sum_{j=0}^{n-1}\binom{n-1}{j}\alpha^j(1-\alpha)^{n-1-j}F(x)^j\beta\mu\right] + \frac{\beta(1-\mu)}{n} - c(\gamma x) \\ &= \beta\mu[1-\alpha(1-F(x))]^{n-1} + \frac{\beta(1-\mu)}{n} - c(\gamma x) \qquad (4) \end{aligned}$$

There are two possible types of equilibrium. In the first, firms play a mixed strategy in their pricing decision, $\alpha^* \in (0,1)$. In the second, all firms play a pure strategy and either charge or don't charge for access to their article, $\alpha^* = \{0,1\}$. I begin by focussing on the former.

When firms randomise in their pricing decision they must be indifferent between charging and not charging. Additionally, as is standard in this class of model, firm's providing free access to their article select a quality investment from a continuous distribution, $F(\cdot)$. The intuition is well understood. Suppose all other firms choose the same quality level x when they provide free access to their article. Then a firm could provide $x+\epsilon$ and guarantee that the searchers select their article when the firm provides it for free. This causes a discrete jump in the firm's expected revenue relative to the choice of x but only a marginal increase in cost. Thus, expected profits increase and the deviation is profitable. As a result, firms must be randomising in their quality choices. Now suppose that there was a gap in the support of $F(\cdot)$ between x_1 and x_2, with $x_1 < x_2$. Then a quality level $x_2 - \epsilon > x_1$

would increase profits because the cost of providing this quality level would be strictly lower than for x_2 but $F(x_2 - \epsilon) = F(x_2)$, so the expected revenue would be the same. Thus, the distribution must be continuous. Varian (1980) provides a formal proof of these arguments.

For $F(\cdot)$ to be part of an equilibrium it must be that a firm providing free access to their article cannot increase their profit by deviating and selecting a quality level from outside of this distribution. Thus, the following conditions must hold:

$$E[\pi(x)] = E[\pi(x')] \quad \forall x, x' \in \mathbf{supp}(F(\cdot)) \tag{5}$$

$$E[\pi(x)] = \pi_M(x_M^*) \quad \forall x \in \mathbf{supp}(F(\cdot)) \tag{6}$$

$$E[\pi(x)] > E[\pi(x')] \quad \forall x \in \mathbf{supp}(F(\cdot)) \quad \text{and} \quad x' \notin \mathbf{supp}(F(\cdot)) \tag{7}$$

Let $\underline{x} = \inf(\mathbf{supp}(F(\cdot)))$ and $\bar{x} = \sup(\mathbf{supp}(F(\cdot)))$. Assuming an equilibrium exists (3), (4), condition (6) and $F(\underline{x}) = 0$ can be used to solve for α^*.

$$\alpha^* = 1 - \left(\frac{1}{\beta\mu} \left(\frac{(1-\mu)\delta}{n} u(x_M^*) + c(\gamma \underline{x}) - c(\gamma x_M^*) \right) \right)^{\frac{1}{n-1}} \tag{8}$$

Then (4), condition (6) and (8) yield a potential distribution, $F(x)$.

$$1 - F(x) = \frac{1}{\alpha^*} \left(1 - \left(\frac{1}{\beta\mu} \left(\frac{(1-\mu)\delta}{n} u(x_M^*) + c(\gamma x) - c(\gamma x_M^*) \right) \right)^{\frac{1}{n-1}} \right) \tag{9}$$

It can easily be verified that $F(\underline{x}) = 0$ and that $F(x)$ is increasing with x. Additionally, profits are equal $\forall x \in \mathbf{supp}(F(\cdot))$ by construction. It must then be the case that no firm can benefit by selecting a quality level from outside this distribution (condition (7)). It is clear that a firm choosing $x > \bar{x}$ will earn lower expected profits.[4] This final requirement also implies that $\underline{x} = 0$. Suppose $\underline{x} > 0$ then a firm providing free access to their article could strictly increase its profits by selecting $x < \underline{x}$. The probability that the searchers select the firm's article is the same and so the expected revenue, remains unchanged. However, the cost is strictly lower, so profits must

[4] As the probability of being the highest quality provider remains the same but the cost of providing quality $x > \bar{x}$ is greater. Thus, $E[\pi(\bar{x})] > E[\pi(x)]\ \forall x > \bar{x}$.

strictly increase. The only possible $\underline{x}$ for which this argument does not apply is $\underline{x} = 0$.

Using (9) and $F(\bar{x}) = 1$, it is possible to derive the upper bound of the quality distribution:

$$\bar{x} = \frac{1}{\gamma} c^{-1} \left(\beta\mu + c(\gamma x_M^*) - \frac{(1-\mu)\delta}{n} u(x_M^*) \right) \tag{10}$$

Using $\underline{x} = 0$ and $c(0) = 0$:

$$\alpha^* = 1 - \left(\frac{1}{\beta\mu} \left(\frac{(1-\mu)\delta}{n} u(x_M^*) - c(\gamma x_M^*) \right) \right)^{\frac{1}{n-1}} \tag{11}$$

Finally, we require that $\alpha^* \in (0, 1)$ and $\bar{x} > 0$. Manipulating (10) and (11) it can be shown that $\alpha^* > 0$ and $\bar{x} > 0$ both require that:

$$\frac{(1-\mu)\delta}{n} u(x_M^*) - c(\gamma x_M^*) < \beta\mu \tag{12}$$

Intuitively, this requires that when there is no probability of another firm providing free access to their article, then a firm finds it profitable to provide free access to their article and make a quality investment of 0. $\alpha^* < 1$ requires that:

$$c(\gamma x_M^*) < \frac{(1-\mu)\delta}{n} u(x_M^*) \tag{13}$$

So it must be the case that charging for access to their article and providing the profit maximising level of quality creates positive net profits for the firm. The conditions imposed on $c(\cdot)$ and $u(\cdot)$ ensure that this is the case.

Now consider the possibility of an equilibrium in which firms pursue a pure pricing strategy. Firstly, there cannot be an equilibrium in which every firm provides free access to their article with certainty, $\alpha^* = 1$. To see this, suppose that every firm were to provide free access to their article with certainty. As searchers only select the highest quality article, there is a classic Bertrand effect as quality levels are bid up to the point at which expected profits are zero. However, a firm can always make a strictly positive profit by charging for access to its article. Thus, it cannot be an equilibrium for every firm to provide access to their article for free with certainty.

This result is consistent with recent developments in the news industry. Whilst most content has been provided for free, firms have invested heavily in the scale and the scope of their websites. At the same time firms have struggled to be profitable and this has led a number of firms to begin charging for access to their articles. In this model searchers are informed about the quality levels provided by firms because they use an aggregator. Thus, the model suggests that aggregators have driven this effect, creating excessive competition between firms when they use a universal free access model.

On the other hand, an equilibrium in which no firm provides access to their article for free ($\alpha^* = 0$) is possible. In this case it must be that, when no other firm provides free access to their article, a single firm does not want to switch to providing their article for free with a zero quality level.[5] This requires that:

$$\begin{aligned} \pi(x_M^*) &\geq \frac{\beta(1-\mu)}{n} + \beta\mu \\ \Rightarrow \frac{(1-\mu)\delta}{n} u(x_M^*) - c(\gamma x_M^*) &\geq \beta\mu \end{aligned} \tag{14}$$

This is the opposite condition to that required for $\alpha^* > 0$ and $\bar{x} > 0$. Intuitively, when the searchers are not a sufficiently attractive source of revenue every firm charges for access to their article and makes a quality investment defined by (1).

4.1 Equilibrium

The following proposition summarises the symmetric equilibrium.

Proposition 1. *In a symmetric Nash equilibrium:*

i If $\frac{(1-\mu)\delta}{n} u(x_M^*) - c(\gamma x_M^*) < \beta\mu$ *then each firm provides free access to their article with probability*

$$\alpha^* = 1 - \left(\frac{1}{\beta\mu} \left(\frac{(1-\mu)\delta}{n} u(x_M^*) - c(\gamma x_M^*) \right) \right)^{\frac{1}{n-1}}$$

[5]The optimal quality choice is zero because when the firm is the only one providing their article for free they always attracts the searchers and the revenue earned from this traffic is independent of the quality level. However, investing in quality is costly, thus it is optimal to set $x = 0$.

If $\frac{(1-\mu)\delta}{n}u(x_M^*) - c(\gamma x_M^*) \geq \beta\mu$ *then every firm charges for access to their article and* $\alpha^* = 0$.

ii When a firm charges for access to their article, they set a price $p_M = \delta u(x_M^*)$*, and selects a quality level* x_M^* *where* x_M^* *is implicitly defined by* $\frac{(1-\mu)\delta}{n}u'(x_M^*) = \gamma c'(\gamma x_M^*)$.

iii When a firm does not charge for its article, they selects a quality level from the distribution:

$$1 - F(x) = \frac{1}{\alpha^*}\left(1 - \left(\frac{1}{\beta\mu}\left(\frac{(1-\mu)\delta}{n}u(x_M^*) + c(\gamma x) - c(\gamma x_M^*)\right)\right)^{\frac{1}{n-1}}\right)$$

on [0,$\bar{x}$*] where*

$$\bar{x} = \frac{1}{\gamma}c^{-1}\left(\beta\mu + c(\gamma x_M) - \frac{(1-\mu)\delta}{n}u(x_M^*)\right)$$

iv Each firm earns expected profit $E(\pi(x)) = \frac{\beta(1-\mu)}{n} + \frac{(1-\mu)\delta}{n}u(x_M^*) - c(\gamma x_M^*)$

Thus, in equilibrium, firms either never provide the article for free or randomise between free access to the article and charging for the article. Firms charging for their article will provide the same quality level, whereas there will be a range of quality levels for the free articles. Sometimes a firm providing free access to their article might invest heavily in an article, providing detailed analysis, commentary and background information. In other cases they might only provide a small amount of coverage, for example only reporting basic information about an article.

Randomisation by firms in their pricing strategies generates the cross-sectional mixture in pricing strategies we observe in the online news industry, with some firms charging for similar articles to those being provided for free by others. Although the model is static, it is not uncommon to interpret this class of model as a repeated game in which the behaviour of the agents is fairly predictable, so that the dynamic aspects of the game are less important (Rosenthal (1980)). Taking this approach, suppose that articles are constantly arriving. Firms must make decisions as to whether to charge for access to each article and the quality of coverage to provide. In this case α^* is the proportion of all articles that a firm provides for free. The equilibrium

can then be interpreted in terms of a metered paywall where firms provide access to some of their articles for free but charge for access to others.

However, the model faces the problem commonly encountered when interpreting this class of model and relating the equilibrium strategy to observed behaviour.[6] In practice, some firms use metered paywalls and pricing strategies which allow consumers access to some articles but not to others. One might claim that these strategies have some similarities to the equilibrium strategies described above. However, most firms follow a strategy of always providing their articles for free or always charging for their articles. In this model, the behaviour of searchers means that there is no equilibrium in which more than one firm always provides access to their article for free. Thus, although the symmetric equilibrium can generate the observed cross-sectional mixture of pricing strategies, it does not accurately describe the pricing strategies we observe in practice.

5 Comparative Statics and Welfare

The initial comparative static results for the symmetric Nash equilibrium are:[7]

Proposition 2.

i The quality level provided by firms who charge for access to their article, x_M^*, is decreasing with the proportion of searchers, μ, is independent of advertising revenues, β, and is increasing with consumer valuation of content, δ.

ii The probability with which firms provide their article for free, α^*, is increasing with β and with μ but decreasing with δ.

iii The expected profit of a firm, $E[\pi(x)]$, is decreasing with μ but is increasing with β and δ.

Proof. See appendix. □

[6] Baye et al. (2004), discuss these issues in the pricing literature.

[7] For completeness the comparative static results for $\bar{x}$ and the parameters n and γ are collected in the appendix.

Thus, when a greater proportion of consumers are searchers (μ increases), the value of advertising (β) increases or the willingness to pay of consumers (δ) decreases we would expect an increase in the propensity of firms to provide their article for free. Intuitively, as the potential value of attracting the searchers increases, firms increase the propensity with which they provide free access to their article, α^*. Additionally, as β and μ increase and δ decreases the condition for $\alpha^* > 0$ is more likely to be satisfied.[8] The proportion of searchers, μ, can be interpreted as measuring the importance of aggregators as a source of consumers. Thus, as the importance of the aggregator increases we would expect an increase in the proportion of articles provided for free.

As would be expected the quality investment of a firm charging for access to its article, x_M^*, is decreasing with μ, is independent of β but is increasing with δ. Intuitively, x_M^* is increasing with factors which increase the value of a firm's loyal consumers. Finally, the expected profit of a firm is decreasing with μ but increasing with β and with δ. If a parameter change decreases the potential profits from charging loyal consumers, then firms increase the propensity with which they provide their article for free. This fuels the *competition effect* which reduces the expected profit when providing the article for free. These results are consistent with the argument that aggregators have reduced the profitability of firms and decreased the quality level of articles firms provide when they charge for access in the online news industry (e.g. Kirchhoff (2010) and OECD (2010)).

5.1 Quality Levels of Free Articles

How do the quality levels chosen by firms charging for access to their article compare to the quality levels of free articles? How do changes in key variables, in particular the share of consumers who are searchers (μ), affect the equilibrium level of quality provision and consumer welfare? Answering these questions will provide insights into the welfare effects of aggregators in the online news industry.

I begin by comparing free article quality investments with the quality investments of firms who charge. The factors driving the choice of quality investment are rather different in each case. Firms who charge for their articles have an incentive to increase their quality investment in order to

[8] As $\beta\mu$ is increasing with μ and β and independent of δ and $\frac{(1-\mu)\delta}{n}u(x_M^*) - c(\gamma x_M^*)$ is decreasing with μ and increasing with δ and independent of β.

extract more surplus from their loyal consumers. However, these consumers are captive, so the firm faces no competitive pressure. On the other hand, firms providing their article for free have an incentive to invest in quality to ensure that they are the highest quality provider and attract the searchers.

For certain parameter values there is no probability that firms providing the article for free will offer a higher quality level than those provided by firms who charge (i.e. when $x_M^* \geq \bar{x}$). From (10) $\bar{x} > x_M^* \iff \beta\mu > \frac{(1-\mu)\delta}{n} u(x_M^*)$. This is a stricter condition than that required for $\alpha^* > 0$. As would be expected, x_M^* is more likely to lie in the distribution when the value of attracting the searchers is large and less likely when the value of a firm's loyal consumers is large. This result also implies that there will be a range of parameters in which firms charging for access to their article provide a higher quality level than the expected quality level provided by those not charging.

The expected quality investment of a free article is:

$$\begin{aligned} \hat{x} &= \int_0^{\bar{x}} x f(x) dx \\ &= \bar{x} - \int_0^{\bar{x}} F(x) dx \end{aligned} \tag{15}$$

It appears that no closed form solution exists for (15) which allows comparisons to be made between $\hat{x}$ and x_M^*. An exception is the duopoly case of the model with linear utility ($\delta u(x_i) = \delta x_i$) and quadratic costs ($c(\gamma x_i) = \frac{\gamma x_i^2}{2}$). This example illustrates that it is possible for the expected quality level of a free article to be above, as well as below, the quality level firms charge for. In this case:

$$\begin{aligned} x_M^* &= \frac{(1-\mu)\delta}{2\gamma} \\ \hat{x} &= \frac{(8\beta\mu\gamma - (1-\mu)^2\delta^2)^{\frac{1}{2}}}{3\gamma} \\ \alpha^* > 0 &\Rightarrow \beta\mu > \frac{(1-\mu)^2\delta^2}{8\gamma} \\ \hat{x} > x_M^* &\Rightarrow \beta\mu > \frac{(1-\mu)^2\delta^2}{8\gamma}\frac{13}{4} \end{aligned}$$

So it is possible that $x_M^* < \hat{x}$ and this is more likely when consumers have a low valuation of quality (small δ), when quality investments are cheap (small γ) and when the revenue earned by attracting the searchers is large (μ and β are large).

More generally, it is possible to describe how the free quality distribution changes with the key parameters of the model.

Proposition 3.

i *If $\mu' > \mu$ then the distribution $F(x;\mu')$ first order stochastically dominates the distribution $F(x;\mu)$. Thus $\hat{x}(\mu') > \hat{x}(\mu)$.*

ii *If $\beta' > \beta$ then the distribution $F(x;\beta')$ first order stochastically dominates the distribution $F(x;\beta)$. Thus $\hat{x}(\beta') > \hat{x}(\beta)$.*

iii *If $\delta' > \delta$ then the distribution $F(x;\delta)$ first order stochastically dominates the distribution $F(x;\delta')$. Thus $\hat{x}(\delta) > \hat{x}(\delta')$.*

Proof. See appendix. □

Intuitively, these effects result from the *competition effect*, as each parameter affects the probability with which an article is provided for free (α^*). For example, as μ increases a higher proportion of consumers are searchers. This increases the incentives firms have to provide their article for free (α^* increases) and this increases competition for the searchers. This leads firms to increase their quality investment when they provide their article for free and this increases the expected quality investment for a free article. These results are in sharp contrast to the effects of δ and μ on the quality provided by firms when they charge for access to their article (x_M^*).

Proposition 3 implies that aggregators have important effects on the quality of articles provided online. If quantity and depth of coverage are important determinants of quality, then the result is consistent with the rapid expansion of websites and free content offerings by a number of news providers in recent years as aggregators (μ) and online advertising revenues (β) have grown in importance.

5.2 Welfare Implications

Proposition 3 also has implications for consumer welfare. Consider the expected utility of a loyal consumer. With probability $(1 - \alpha^*)$ this consumer

must pay for the article, in which case their full surplus is extracted. However, with probability α^* they do not have to pay in which case their expected utility is $\delta E[u(x)]$, where $E[u(x)] = \int_0^{\bar{x}} u(x)f(x)dx$. Thus, a loyal consumer's expected utility is $E[U_{\text{loyal}}] = \alpha^* \delta E[u(x)]$.

It is the case that:

Proposition 4. *The expected utility of a loyal consumer is increasing with the fraction of consumers using the aggregator, μ, and the per consumer advertising revenue, β.*[9]

Proof. This result follows immediately from Propositions 2 and 3. □

Propositions 3 and 4 have important implications for the current policy debate over whether high quality and pluralistic news provision can be left to market forces (e.g. OECD (2010), Kirchhoff (2010)). This debate emphasises the role that a healthy and independent press plays in the democratic process. In particular, there is a worry that firms will no longer be able to provide a critical analysis of government policy and the activities of businesses. It has been argued that lower quality news will be provided and that high quality news might increasingly be restricted to the few individuals who can afford to pay for it.

Much of the popular debate and existing research (e.g. The Economist (2009) and Dellarocas et al. (2010)) has focussed on the negative effects free news provision and aggregators are believed to have had on firm profitability and quality provision. In contrast, this model emphasises that consumers may benefit from using aggregators, even if the quality of the articles some firms provide falls. Here, as is commonly argued, an increase in the importance of the aggregator, μ, reduces both the profits of firms and the quality level provided by firms who charge for access to their articles. However, as described above, an increase in the use of aggregators by consumers increases competition between firms and increases the expected quality level of an article provided for free. This leads to an increase in a consumer's expected utility. The searchers create an externality, by encouraging some firms to

[9]It is not possible to provide a similar result for the expected utility of a searcher. Although, analogous results hold for the expected utility of a searcher conditional on j firms providing an article for free, the complication is that the probability that j firms provide their article for free also changes. This latter effect may be such that the expected utility of a searcher actually decreases with μ and with β.

provide free access to their articles, which benefits loyal consumers. This possibility has received little attention in the current literature.

Additionally, the value of online advertising revenues have been increasing over time and are expected to continue do so, partly as a result of better targeting and matching of consumers with advertisers (The Economist (2011)). If this is the case, then Propositions 2, 3 and 4 imply that we should expect to see increases in expected profits, in the expected quality level of a free article and in consumer utility. This could help alleviate some of the concerns currently being expressed by policymakers and firms.

Finally, it is possible to show that, if the proportion of consumers who use the aggregator is sufficiently large, then the expected quality level of a free article could even exceed the first best level chosen by a social planner to maximise the sum of firm profits and consumer welfare. Suppose that the social planner is free to decide which firms consumers use. Then, in the first-best, the social planner sends all consumers to a single firm, which has a 0 price and only that firm produces a positive quality level. To see this, suppose that this were not the case and that two or more firms produced a positive quality level. Without loss of generality suppose that firm i has the (weakly) highest quality level. Then, social welfare can be (weakly) increased by transferring all consumers to firm i. As quality investments are costly, social welfare can be increased further by reducing all quality investments at firms other than i to 0. Prices are only a transfer between consumers and firms, and searchers only participate if at least one price is 0. As a result the first best price is 0.

Thus, all consumer's participate and the social planner sets x_i to maximise:

$$SW = \beta + \delta u(x_i) - c(\gamma x_i)$$

and x_{FB} is such that $\delta u'(x_{FB}) = \gamma c'(\gamma x_{FB})$. It is immediately clear that the quality level provided by a firm charging for access to their article is always below the first best. However, this may not necessarily be the case for the expected quality level of a free article. To see this consider the linear utility, quadratic cost example discussed earlier. In this case:

$$
\begin{aligned}
x_{FB} &= \frac{\delta}{\gamma} \\
\hat{x} &= \frac{(8\beta\mu\gamma - (1-\mu)^2\delta^2)^{\frac{1}{2}}}{3\gamma} \\
\alpha^* > 0 &\Rightarrow \beta\mu > \frac{(1-\mu)^2\delta^2}{8\gamma} \\
\hat{x} > x_{FB} &\Rightarrow \beta\mu > \frac{(1-\mu)^2\delta^2}{8\gamma} + \frac{9\delta^2}{8\gamma}
\end{aligned}
$$

Once again the intuition is that if the searchers are a sufficiently attractive source of revenue, then there is a *competition effect* which drives the quality level of a free article up. This *competition effect* can be so strong that the expected quality level of a free article can be sub-optimally high relative to the first best.

6 Discussion and Extensions

The previous results can be used to provide guidance as to why quality levels and pricing strategies differ across content areas in the online news industry. Suppose that firms are split into distinct content areas, for example political, entertainment and sports news, and that each content area makes decisions over pricing and quality investments. α^*, x_M^* and $F(\cdot)$ are now specific to the content area in question. Consider the observation that the *Financial Times* and *The Wall Street Journal* were amongst the first to use paywalls because their customers place a high value on the financial news they provide (Lanchester (2010)). It is also generally believed that the quality of the articles these firms provide is relatively high. In contrast, it might be that the valuation of entertainment news by customers is fairly low. In my model this is equivalent to assuming that $\delta_{\text{finance}} > \delta_{\text{enter}}$, implying that, *ceteris paribus*, financial news firms are more likely to charge for access to their articles. Additionally, although the quality level financial news firms charge for will be higher, the expected quality level of free entertainment news will be higher.

The model also highlights additional factors which might explain these differences. For example, only a few firms provide specialist financial coverage

whereas many provide some form of entertainment coverage, so $n_{\text{finance}} < n_{\text{enter}}$. Thus, it is more likely that there will be an equilibrium in which every firm charges for access to financial news articles. Alternatively, it might be that a lower proportion of consumers use aggregators to search for financial news, so $\mu_{\text{finance}} < \mu_{\text{enter}}$. This seems reasonable if we believe that consumers interested in financial news are more likely to be regular news readers and thus, loyal to a given firm. The same analysis can be used to explain why firms are more likely to charge for access to editorial content (which is highly valued by consumers) than for general news stories (which might have a lower valuation).

I have focussed on the symmetric equilibrium of this model. However, it is well understood that a continuum of asymmetric equilibria exist in this class of model (Baye et al. (1992)). I will not attempt to provide a general treatment of asymmetric equilibria here. However, I will make a number of comments about such equilibria. Firstly, these asymmetric equilibria will continue to exhibit cross-sectional heterogeneity in the pricing strategies and quality investments of firms. The analysis is analogous to that of Baye et al. (1992). Firms will continue to randomise between charging for access to their articles and providing free access to them. At most one firm will always provide free access, whilst multiple firms might always charge for access to their articles.

Secondly, public broadcasters, who always provide their articles for free, are a common feature of media markets in many countries. As described above, the model does not explicitly incorporate a public broadcaster. However, it can be extended to do so using a simple example of an asymmetric equilibrium. Suppose that there are n firms. $n-1$ of these firms are privately owned and can choose whether to provide their article for free or to charge for access. The n^{th} firm is a public broadcaster who always provides their articles for free. In all other respects this firm is identical to the other firms. In particular, the public broadcaster is a profit maximiser, with mass $\frac{1-\mu}{n}$ of loyal consumers and earns per consumer revenue of β.[10] If this is the case, there is little change in the equilibrium outcome and the public broadcaster uses its quality distribution to mimic the actions of the private firms. The private firms still follow the symmetric strategy described by x_M^*, α^* and $F(\cdot)$ in Proposition 1. The quality distribution of the public broadcaster is given by $F_n(x) = 1 - \alpha^*(1 - F(x))$ and has a mass point at 0 of

[10]This can be thought of as either advertising revenue or public funding.

$F_n(0) = 1 - \alpha^*$. The inclusion of a public broadcaster, in this way, changes none of the comparative statics or analysis presented above.

Finally, until now I have taken several aspects of consumer behaviour as exogenous. Firstly, I assumed that the loyal consumers were evenly distributed across the n firms, rather than explicitly selecting who to consume from. Secondly, I assumed that an exogenous fraction of consumers were loyal consumers and there was no choice of whether to be a loyal consumer or a searcher. I address each issue in turn.

A symmetric distribution of loyal consumers across the n firms could arise from strategic behaviour in the following setup, due to Baye et al. (1992). Continue to assume that an exogenous fraction $1 - \mu$ of consumers are loyal consumers, who are willing to pay to access an article. Suppose that loyal consumers and firms move simultaneously, with firms making their pricing and quality decisions and loyal consumers deciding who to consume from. After quality levels and pricing strategies have been made, searchers use the aggregator to search amongst the providers. However, the aggregator only presents the results for firms providing free access to their article and searchers are unaware of the firms who charge for access to their article.[11]

A subgame perfect equilibrium of this game is for loyal consumers to uniformly distribute themselves across the n firms, for the firms to follow the symmetric strategy of Proposition 1, and for searchers to select the highest quality free article.

Begin by considering the behaviour of searchers in any subgame. As searchers are informed about quality levels, then their optimal behaviour in any subgame is to select the highest quality free article. In the previous subgame, loyal consumers choose their firm and firms choose prices and quality investments taking the subsequent behaviour of searchers as given. Given a uniform distribution of the other loyal consumers across firms and the symmetric equilibrium being played by all other firms, no firm wants to deviate from the symmetric strategy. Additionally, given the uniform distribution of other consumers and the symmetric strategy of the firms, the expected utility of a loyal consumer is the same across all firms. Thus, loyal consumers are indifferent between all of the firms and do not want to deviate. Thus, there is a Nash equilibrium from this subgame and we have a subgame perfect equilibrium of the whole game.

Now consider the strategic decision of an individual whether to be a loyal

[11] So the paywall is like that of *The Times*.

consumer or to be a searcher. Following Varian (1980), suppose that consumer i faces a fixed cost c_i of using the aggregator and becoming informed. This cost might represent the time cost of going via the aggregator rather than directly to the website of a firm. Once again, the aggregator is only able to present the articles of those firms who provide free access. Suppose that a proportion $1-\mu$ of consumers have a search cost $\bar{c}$ and proportion μ have a search cost $\underline{c}$. Then, a loyal consumer does not want to switch and become a searcher and a searcher does not want to deviate and become a loyal consumer if $\bar{c} > E[U_{\text{search}}] - E[U_{\text{loyal}}] > \underline{c}$.

These extensions begin to endogenise consumer behaviour within the current model. However, a natural starting point for future work would be to develop a model which fully endogenises the behaviour of consumers and firms. Such a model would involve firms competing for both loyal consumers and searchers on both quality and price and would allow individuals to decide whether to be a searcher or a loyal consumer.

7 Conclusion

This article has developed a model of price and quality competition in the online news industry, using a methodology commonly used to model price dispersion in the market for a homogeneous good. In the symmetric mixed strategy equilibrium firms randomise in their pricing decisions and quality investments. This endogenously generates heterogeneity in quality across, *ex ante* identical, firms and is also consistent with the cross-sectional heterogeneity in pricing strategies that we observe. When applied in a dynamic setting, this equilibrium strategy has similarities to the metered paywalls currently used by some firms, which allow consumers to access some articles for free but charge for access to others. I have used the model to analyse how quality investments respond to a variety of factors, such as consumer willingness to pay and advertising revenues, and how these responses differ when firms use different pricing strategies.

The model's predictions are consistent with a number of characteristics of the online news industry. Firstly, it is never an equilibrium for every firm to provide their article for free with certainty because this leads to excessive competition which erodes away profits. This is consistent with the recent movement away from universal free content provision. Secondly, the model provides plausible explanations as to why strategies might differ across

content areas. I focussed on the case of financial news because two major players in this area, the *Financial Times* and *The Wall Street Journal*, have had success charging for their articles. My model is consistent with the widely held belief that this is because readers of these papers value the articles they provide highly. However, my model also highlights a number of other factors which may explain this outcome. In particular, the fact that there are a relatively small number of specialist providers and it may be that readers are more loyal to a given publication in this content area than elsewhere.

Finally, a distinctive feature of the online news industry is that aggregators allow consumers to search and switch between providers and are an important source of consumers for firms. I have shown that, as a greater proportion of consumers use the aggregator, firms are more likely to provide free access to their articles. Furthermore, I have been able to provide some insights into the relationship between the importance of the aggregator and consumer welfare. I have shown that both the expected quality level provided for free and the expected utility of some consumers are increasing in the proportion of consumers using the aggregator. These results are in contrast to much of the recent policy debate which has focussed on the negative effects aggregators and free content provision are believed to have had on firm profits and the quality of articles.

8 Appendix

The remaining comparative static results omitted from Proposition 2 are:

Proposition 5.

i x_M^* *is decreasing with* n *and with* γ*.*

ii α^* *is increasing with* γ*.*

iii $\bar{x}$*, is increasing with* β*, with* n *and with* μ *but decreasing with* δ*. However, the effect of* γ *on* $\bar{x}$ *is ambiguous.*

iv $E[\pi(x)]$ *is decreasing with* n *and with* γ*.*

Proof of Propositions 2 and 5. A contradiction implies that x_M^* is decreasing with n. Suppose this were not the case and that x_M^* was weakly increasing with n. As n increases concavity of $u(\cdot)$ implies that the left hand side of (1)

falls but the right hand side increases due to convexity of $c(\cdot)$. Therefore, the first order condition could not hold for the hypothesised new x_M^* and as a result it must be the case that x_M^* decreases in n. Analogous arguments imply that x_M^* is decreasing with γ and μ, is increasing with δ and is independent of β.

The comparative statics for $\bar{x}$, α^* and $E[\pi(x)]$ use the following lemma.

Lemma 2. *$\frac{(1-\mu)\delta}{n}u(x_M^*) - c(\gamma x_M^*)$ is decreasing with μ, with γ and with n, is independent of β and increasing with δ.*

Proof. Suppose that $\mu' > \mu$. If the firm always sets $p_i = \delta u(x_i)$ then $x_M^*(\mu')$ is still a feasible choice when the firm faces μ. If $\mu' > \mu$ then it is the case that:

$$\begin{aligned}
&\tfrac{(1-\mu')\delta}{n}u(x_M^*(\mu')) - c(\gamma x_M^*(\mu')) \\
&< \tfrac{(1-\mu)\delta}{n}u(x_M^*(\mu')) - c(\gamma x_M^*(\mu')) \\
&\leq \tfrac{(1-\mu)\delta}{n}u(x_M^*(\mu)) - c(\gamma x_M^*(\mu))
\end{aligned}$$

where the final inequality follows because $x_M^*(\mu)$ is the profit maximising choice when faced by μ. The proofs for n, δ, γ and β are analogous. □

The comparative static results for $E[\pi(x)]$ follow immediately from Lemma 2. The results for $\bar{x}$ and α^* follow from comparing the expressions (10) and (11) respectively for $\delta' > \delta$, and so forth, and applying Lemma 2.

□

Proof of Proposition 3. Stochastic dominance requires that $F(x;\mu') \leq F(x;\mu) \quad \forall x$ with strict inequality for some x whenever $\mu' > \mu$.

Using (9) and (8):

$$\begin{aligned}
F(x;\mu) \;=\; & 1 - \left(\frac{1}{1 - \left(\frac{(1-\mu)\delta u(x_M^*(\mu))}{n\beta\mu} - \frac{c(\gamma x_M^*(\mu))}{\beta\mu} \right)^{\frac{1}{n-1}}} \right) \times \\
& \left(1 - \left(\frac{(1-\mu)\delta u(x_M^*(\mu))}{\beta\mu n} + \frac{c(\gamma x) - c(\gamma x_M^*(\mu))}{\beta\mu} \right)^{\frac{1}{n-1}} \right)
\end{aligned}$$

If $\kappa = \frac{1}{\beta n}$ then this becomes:

$$
\begin{aligned}
F(x;\mu) &= 1 - \left(\frac{1}{1 - \left(\kappa \frac{(1-\mu)\delta u(x_M^*(\mu)) - nc(\gamma x_M^*(\mu))}{\mu} \right)^{\frac{1}{n-1}}} \right) \times \\
&\quad \left(1 - \left(\kappa \frac{(1-\mu)\delta u(x_M^*(\mu)) + n(c(\gamma x) - c(\gamma x_M^*(\mu)))}{\mu} \right)^{\frac{1}{n-1}} \right) \\
&= 1 - \frac{\mu^{\frac{1}{n-1}} - \{\kappa[(1-\mu)\delta u(x_M^*(\mu)) + n(c(\gamma x) - c[\gamma x_M^*(\mu)])]\}^{\frac{1}{n-1}}}{\mu^{\frac{1}{n-1}} - \{\kappa[(1-\mu)\delta u(x_M^*(\mu)) - nc(\gamma x_M^*(\mu))]\}^{\frac{1}{n-1}}}
\end{aligned}
$$

Then the requirement that $F(x;\mu') \leq F(x;\mu)$ becomes the requirement that:

$$
\begin{aligned}
&\frac{\mu'^{\frac{1}{n-1}} - \{\kappa[(1-\mu')\delta u(x_M^*(\mu')) + n(c(\gamma x) - c[\gamma x_M^*(\mu')])]\}^{\frac{1}{n-1}}}{\mu'^{\frac{1}{n-1}} - \{\kappa[(1-\mu')\delta u(x_M^*(\mu')) - nc(\gamma x_M^*(\mu'))]\}^{\frac{1}{n-1}}} \\
&\geq \frac{\mu^{\frac{1}{n-1}} - \{\kappa[(1-\mu)\delta u(x_M^*(\mu)) + n(c(\gamma x) - c[\gamma x_M^*(\mu)])]\}^{\frac{1}{n-1}}}{\mu^{\frac{1}{n-1}} - \{\kappa[(1-\mu)\delta u(x_M^*(\mu)) - nc(\gamma x_M^*(\mu))]\}^{\frac{1}{n-1}}} \\
&\Rightarrow \frac{\mu'^{\frac{1}{n-1}} - \{\kappa((1-\mu')\delta u(x_M^*(\mu')) + n[c(\gamma x) - c(\gamma x_M^*(\mu'))])\}^{\frac{1}{n-1}}}{\mu^{\frac{1}{n-1}} - \{\kappa((1-\mu)\delta u(x_M^*(\mu)) + n[c(\gamma x) - c(\gamma x_M^*(\mu))])\}^{\frac{1}{n-1}}} \\
&\qquad \geq \frac{\mu^{\frac{1}{n-1}} - \{\kappa[(1-\mu)\delta u(x_M^*(\mu)) - nc(\delta x_M^*(\mu))]\}^{\frac{1}{n-1}}}{\mu'^{\frac{1}{n-1}} - \{\kappa[(1-\mu')\delta u(x_M^*(\mu')) - nc(\gamma x_M^*(\mu'))]\}^{\frac{1}{n-1}}} \qquad (16)
\end{aligned}
$$

The right hand side of this final expression is independent of x and label the left hand side as:

$$
g(x) = \frac{\mu'^{\frac{1}{n-1}} - \{\kappa((1-\mu')\delta u(x_M^*(\mu')) + n[c(\gamma x) - c(\gamma x_M^*(\mu'))])\}^{\frac{1}{n-1}}}{\mu^{\frac{1}{n-1}} - \{\kappa((1-\mu)\delta u(x_M^*(\mu)) + n[c(\gamma x) - c(\gamma x_M^*(\mu))])\}^{\frac{1}{n-1}}}
$$

then $g(0) = \frac{\mu'^{\frac{1}{n-1}} - \{\kappa[(1-\mu')\delta u(x_M^*(\mu')) - nc(\gamma x_M^*(\mu'))]\}^{\frac{1}{n-1}}}{\mu^{\frac{1}{n-1}} - \{\kappa[(1-\mu)\delta u(x_M^*(\mu)) - nc(\gamma x_M^*(\mu))]\}^{\frac{1}{n-1}}}$. Thus a sufficient condition for (16) to hold is that $\frac{\partial g(x)}{\partial x} \geq 0$ so that $g(0)$ is the minimum of $g(x)$.

It can be shown that $\frac{\partial g(x)}{\partial x} \geq 0$ requires that:

$$\begin{aligned} &\left(\frac{(1-\mu)\delta u(x_M^*(\mu)) + n[c(\gamma x) - c(\gamma x_M^*(\mu))]}{(1-\mu')\delta u(x_M^*(\mu')) + n[c(\gamma x) - c(\gamma x_M^*(\mu'))]}\right)^{\frac{1}{n-1}-1} \\ &\geq \frac{\mu^{\frac{1}{n-1}} - \{\kappa((1-\mu)\delta u(x_M^*(\mu)) + n[c(\gamma x) - c(\gamma x_M^*(\mu))])\}^{\frac{1}{n-1}}}{\mu'^{\frac{1}{n-1}} - \{\kappa((1-\mu')\delta u(x_M^*(\mu')) + n[c(\gamma x) - c(\gamma x_M^*(\mu'))])\}^{\frac{1}{n-1}}} \end{aligned} \quad (17)$$

The left hand side of (17) is greater than 1 if:

$$\frac{(1-\mu)\delta}{n} u(x_M^*(\mu)) - c(\gamma x_M^*(\mu)) \geq \frac{(1-\mu')\delta}{n} u(x_M^*(\mu')) - c(\gamma x_M^*(\mu')) \quad (18)$$

The right hand side of (17) is less than 1 if:

$$\begin{aligned} \mu^{\frac{1}{n-1}} - \mu'^{\frac{1}{n-1}} \quad \leq \quad & \kappa^{\frac{1}{n-1}} \Big[\{(1-\mu)\delta u(x_M^*(\mu)) + n(c(\gamma x) - c[\gamma x_M^*(\mu)])\}^{\frac{1}{n-1}} \\ - \quad & \{(1-\mu')\delta u(x_M^*(\mu')) + n(c(\gamma x) - c[\gamma x_M^*(\mu')])\}^{\frac{1}{n-1}}\Big] \end{aligned} \quad (19)$$

The left hand side of (19) is less than 0 because $\mu' > \mu$ thus a sufficient condition for (19) to hold is that the right hand side is greater than 0. This also requires that (18) holds. This condition holds from Lemma 2.

The proofs for β and δ are analogous.

□

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