Free daily newspapers: too strong incentives to print?

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Abstract. We consider a model in which a free daily newspaper distributes news to readers and sells ad-space to advertisers, having private information about its audience. Depending on the type of readers in the market, the newspaper may have a high demand or a low demand. For a given tirage, a high demand provides a greater return to the advertisers, because the average reader dedicates more time to reading the newspaper and because each copy is read by more people. A high demand has also the advantage of requiring a lower distribution cost (for a given tirage), because the average reader is willing to exert more effort to obtain a copy of the free newspaper. We find that when the demand is low, the tirage and the price of ad-space coincide with those of the perfect information scenario. In contrast, if the demand is high, the newspaper prints extra copies as a consequence of asymmetric information. The rationale for this overprinting strategy lies on the newspaper's need to send a credible signal to the advertisers that the demand is in fact high.

Keywords: Asymmetric information, Two-sided markets, Free press.

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1 Introduction

Motivation and leading research questions

The boom of freely distributed newspapers has been one of the most striking changes arising in the press industry. The first modern freely distributed newspaper was released in Sweden in 1995 (the free daily "Metro") and in less than ten years, the market of freely distributed papers has developed in an impressive way. According to the World Association of Newspapers, in 2001, the total circulation of freely distributed newspapers was already close to ten million daily copies (see Bakker, 2002). Six years later, in 2007, the total circulation of free dailies was substantially higher, with more than forty million copies of free dailies being printed every day (Bakker, 2007). More recently, the market of free dailies is starting to stabilize as it starts to reach its maturity in some regions (like Europe, for example).

Like any other newspaper, free dailies constitute a platform between readers and advertisers.[1] To the side of readers, free dailies supply news, editorial content and advertising content, free of any charge (subsidization of readers). To the side of advertisers, free dailies provide the "eyeballs" of their readers, in exchange for advertising fees. Since advertisers' marginal revenue from advertising tends to increase with the audience of the newspaper, the larger the audience of the newspaper, the higher the advertisers' willingness to pay for an ad-insertion.

However, very often, advertisers are uncertain about the characteristics (including the size) of the newspapers' audiences, either because (*i*) a single copy may be read by more than one person (multi-reading), or because (*ii*) a person with access to the newspaper does not necessarily have to read it. These uncertainty issues arise both in the context of paid press and free press. However, they tend to be more severe in the case of free press.[2]

[1] For an analysis of the role played by paid newspapers as a platform between readers and advertisers see, among others: Manduchi and Picard (2009), Anderson and Coate (2005), Dukes and Gal-Or (2003) and Gabszewicz, Laussel and Sonnac (2001, 2002).

[2] As recognized by Bakker (2007): "*Whereas the circulation of free dailies is documented quite well, less is known about readership. Common knowledge about readership of paid dailies – if there is such a thing – can hardly be applied to free dailies because these are very different from paid dailies.*"

First, in the case of freely distributed press, readers do not pay for the newspaper and, therefore, even if the newspaper has been delivered in the reader's hands, she may simply prefer to drop it in the garbage instead of reading it. In the case of paid press, since readers must pay for the newspaper, when they buy it, they should be planning to read it.[3] Moreover, the extent of multi-reading phenomena is also more uncertain in the case of freely distributed newspapers. While in the case of paid press, multi-reading phenomena occur at the level of a given household or firm, in the case of free press, this issue is much more complex since free dailies are mostly distributed through public transport or public spaces and therefore it is difficult to establish the boundaries of multi-reading phenomena.

For the reasons explained above, it is common to observe a mismatch between the number of people to whom a free newspaper is delivered and the effective number of the readers of this newspaper (who are the only ones that are exposed to the ad-insertions). In this paper, we assume that the newspaper is more informed than advertisers about the magnitude of the mismatch between audience and circulation. The rationale for this asymmetric information assumption lies on the fact that free dailies tend to be more informed than advertisers about their own distribution system: they control the type and location of the distribution points (vendors delivering the newspaper in hand or stands where readers pick up a copy of the newspaper); they have private information on leftovers at the distribution points; and they have information on how readers react to distinct distribution systems.[4]

[3]For a piece of anecdotal evidence on this argument, consider the case of the Portuguese daily OJE (http://www.oje.pt/). This newspaper is sold at a cover price of 0,01 Euro per copy. According to the management board of the newspaper, this pricing policy is an attempt to reduce advertisers' uncertainty about the newspapers' audience. Since readers that pay for a newspaper are more likely to be planning to read it, the circulation statistics become more credible as a proxy for the readership.

[4]For example, if readers have a positive attitude towards the free newspaper, they are more likely to make an effort to get the free daily at the distribution point (no leftovers). In contrast, if readers have a negative feeling towards the free newspaper, they probably won't pick up the paper from its distribution stand (significant leftovers). The number of leftovers and the type of distribution system are often private information of the newspaper. In this paper, we do not consider the possibility of advertisers acquiring information about the type of audience. Although the acquisition of such information could reduce the extent of asymmetric information, in general it is not enough to eliminate it (since newspapers are still more informed than marketing agencies collecting this type of information). This fact is acknowledged by industry players, who often stress the limitations of data on audiences published by marketing research agencies (often the collection of such data involves telephone or e-mail surveys, which are subject to problems of sample selection).

In situations of asymmetric information between advertisers and the freely distributed newspaper, the former may try to infer the type of audience in the market from the newspapers' tirage: in principle, the higher the tirage of the newspaper, the larger should be its audience. However, when the cost of bringing extra-copies to the market (production cost and distribution cost) is sufficiently small, free dailies may print extra copies in order to manipulate the advertisers' beliefs about the size of the audience, inducing them to over-estimate the audience and increase their willingness to pay for the ad-insertions. In this way, the newspaper is able to increase the advertisers' willingness to pay for ad-insertions.

In this paper, we propose a formal model to study under which circumstances asymmetric information between advertisers and free dailies may create endogenous mechanisms favouring overprinting strategies in a context of asymmetric information.

Method

To investigate whether the business model of free dailies leads or not to overprinting as a result of asymmetric information, we consider a monopolist free daily that provides: (*i*) news and advertising to readers; and (*ii*) advertising space to a group of advertisers that is less informed than the newspaper about its readership. In particular, we consider that the newspaper's audience can be one of two types: *"plentiful and seeking"* or *"lacking and avoiding"*.[5] The distinction between plentiful and lacking refers to the potential size of the audience, while the distinction between seeking and avoiding refers to the audience's feelings towards free press. For a given tirage, the advertisers' willingness to pay for ad-insertions is higher when the audience is plentiful than when it is lacking. In addition, the newspapers' marginal cost of distribution is lower when the audience is seeking than when it is avoiding.[6]

For a given triage, advertisers' willingness to pay is higher when the audience is plentiful than when it is lacking

[5] While the newspaper is able to observe the type of demand, the advertisers are not (adverse selection).

[6] We thank an anonymous referee for clarifying remarks in relation to the distinctions plentiful/lacking and seeking/avoiding.

(as advertisers' revenues of printing and distributing an additional copy is higher in the first case than in the latter). In addition, newspapers' distribution marginal costs are lower when the audience is seeking than when it is avoiding.

For a given triage, advertisers' willingness to pay is higher when the audience is plentiful than when it is lacking (as advertisers' revenues of printing and distributing an additional copy is higher in the first case than in the latter). In addition, newspapers' distribution marginal costs are lower when the audience is seeking than when it is avoiding.

Due to asymmetric information, when the audience is lacking and avoiding, the free daily may have incentives to print extra copies to make advertisers believe that the audience is plentiful and seeking. Thus, when advertisers observe a large tirage, they may wonder whether the readership is effectively large or whether the newspaper is only cheating.

In the light of this possibility, we propose a game theoretical framework to study the behavior of advertisers and the monopolist newspaper in a scenario of asymmetric information. We consider a game with the following structure. First, nature selects the type of readers in the market. Then, the newspaper observes the type of readers and chooses a publicly observable tirage. Advertisers, who are uncertain about the type of readers in the market, observe the free daily's tirage and, then, offer bids for the available slots of ad-space. Afterwards, outcomes are realized. To characterize the equilibrium contracts proposed by the free paper contingent on the type of its audience, we rely on the concept of Perfect Bayesian Equilibrium, following the method suggested by Cho and Sobel (1990).

Literature overview

The paper is related to the literature dealing with the analysis of the two-sided structure of media industries, when readers are neutral with respect to advertising (e.g. Manduchi and Picard (2009), Argentesi and Filistrucchi (2007), Gabszewicz, Laussel and Sonnac (2001)). In line with these papers, our paper addresses a degenerate two-sided market, in which a one-way externality takes place (corresponding to the effect of circulation on advertising demand). Our paper adds to this literature by introducing the possibility of asymmetric information between advertisers and a freely distributed newspaper.

Our paper is also related to the literature on signalling and economic decisions in a context of asymmetric information (Spence (1973), Cho and Kreps (1987), Cho and Sobel (1990)), from which we borrow the method to study the interaction between advertisers and the freely distributed newspaper when the latter is better informed than the former about its readers.

Main findings

The first contribution of the paper is to shed light on the adverse selection problems that may arise when a freely distributed newspaper is better informed than advertisers about its readers. If the newspaper's cost of bringing additional copies to the market is sufficiently small, it becomes impossible for advertisers to infer whether a high tirage is due to the newspaper's large readership, or if it is just a strategy used by the newspaper to making them believe that the readership is plentiful and seeking, when in reality it is lacking and avoiding.

The second contribution of the paper is to show that, when these adverse selection issues arise, the newspaper will use its tirage as a signal to advertisers about the true readership. Our model unveils that, in this case, the unique Perfect Bayesian Equilibrium in pure strategies that survives the intuitive criterion (Cho and Kreps, 1987) corresponds to the least-cost separating equilibrium, whose characteristics are the following: when the free daily's readership is lacking and avoiding, the paper does not deviate from the perfect information tirage; otherwise, the paper chooses an greater tirage than in the perfect information case, signalling to the advertisers, credibly, that the readership is plentiful and seeking.

The rest of the paper is organized as follows. Section 2 presents the basic ingredients of the model. Section 3 presents the perfect information case, as a benchmark. Section 4 characterizes the optimal contract under asymmetric information. Section 5 concludes the paper with some remarks.

2 The model

We consider a monopolist newspaper whose activity consists in producing news that are freely distributed to readers and in selling ad-space to advertisers. In what follows, the main ingredients of the model are described.

2.1 Readership

The readership of the freely distributed newspaper is represented by the function $R(\theta, T)$, where $T \geq 0$ stands for the publicly observable number of copies that the newspaper decides to print and distribute (tirage), and $\theta \in \{\theta_L, \theta_H\}$ is a parameter that describes the type of audience of the newspaper. In the case of plentiful and seeking readers, the demand is said to be high, and $\theta = \theta_H$. In contrast, when readers are lacking and avoiding, the demand is said to be low, and $\theta = \theta_L$.

While the tirage is publicly observable, the readership may not be so, because many of the persons that obtain a copy may not actually read the newspaper, and also because a single copy may be read by many persons.[7]

Assumption 1 (Readership)

The readership function, $R(\theta, T)$, satisfies the following properties:[8]

(i) $R(\theta, 0) = 0, \forall\theta$;

(ii) $R_T(\theta_H, T) > R_T(\theta_L, T) > 0, \forall T$;

(iii) $R_{TT}(\theta, T) < 0, \forall(\theta, T)$.

From Assumption 1, it follows that: (i) when the tirage of the newspaper is zero, obviously nobody reads the newspaper; (ii) as the tirage increases, the readership also

[7] As argued in the introduction, these uncertainty issues are not specific to the free press industry, arising as well in the paid press industry. Nevertheless, these issues tend to be more problematic in the case of free press than in the case of paid press (see Bakker (2007)).

[8] The functions R_T and R_{TT} are the first and second-order partial derivatives of R with respect to T.

increases, and this effect is greater when the demand is high; (*iii*) the marginal effect of tirage on readership is decreasing with the tirage of the newspaper.

2.2 Advertising

On the other side of the market (advertising), the newspaper sells ad-space to the N highest bidders out of a large number of homogeneous advertisers, who compete *à la* Bertrand. The payoff obtained by the representative advertiser is:

$$v(R) - p, \tag{1}$$

where $v(R)$ stands for the advertisers' expected return from buying an ad-insertion in the freely distributed newspaper and p stands for the price of an ad-insertion. The reservation payoff of the advertisers is normalized to zero. The assumption of homogeneous advertisers together with Bertrand competition guarantees that the newspaper is able to extract all the surplus from advertisers. Therefore:

$$p = v\left(R\right).$$

We assume that the advertisers' expected return from buying ad-space, v, is a continuous, increasing and concave function of the readership, R.

Assumption 2 (Advertising return)

The advertisers' expected return, as a function of the number of readers, satisfies the following properties:

(i) $v(0) = 0$*;*

(ii) $v'(R) > 0, \forall R$*;*

(iii) $v''(R) \leq 0, \forall R$*.*

From Assumption 2, it follows that: (i) when the tirage of the newspaper is zero, the advertisers' expected return from advertising is also zero, since nobody reads the newspaper; (*ii*) the advertisers' expected return increases with the tirage of the newspaper; and (*iii*) this effect is decreasing with the tirage of the newspaper.

Since the advertising return only depends on the number of readers, which, in turn, depends on the type of audience and on the tirage, we can write the advertising return directly as a function of the type of audience and of the tirage. It is easy to verify that such composite function, $V(\theta, T)$, preserves the properties of the readership function, $R(\theta, T)$.

Proposition 1 (Advertising return)

The advertisers' expected return, as a function of the type of audience and of the tirage, satisfies the following properties:

(i) $V(\theta, 0) = 0, \forall\theta$*;*

(ii) $V_T(\theta_H, T) > V_T(\theta_L, T) > 0, \forall T$*;*

(iii) $V_{TT}(\theta, T) < 0, \forall(\theta, T)$*.*

To obtain Proposition 1, notice that: (*i*) a null tirage implies a null readership and, therefore, a null advertising return; (*ii*) since the readership increases as the tirage increases, the advertising return also does, and this effect is also greater when the demand is high; (*iii*) as the tirage increases, its marginal effect on readership becomes smaller, therefore, its marginal effect on advertising return also does (because the advertising return is a concave function of readership).

In sum, for any given tirage, printing an additional copy has a more positive effect on the advertisers' revenues when readers are plentiful ($\theta = \theta_H$) than when they are lacking ($\theta = \theta_L$). Accordingly, advertisers' willingness to pay for advertising is higher when $\theta = \theta_H$ than when $\theta = \theta_L$.

2.3 Newspaper

The profits of the monopolist newspaper are equal to the revenues from selling ad-space to advertisers net of the newspaper's production and distribution costs:

$$\pi(\theta, T, p) = pN - c(\theta, T), \tag{2}$$

where p stands for the advertising rate (per insertion), N represents the number of advertising slots and $c(\theta, T)$ is the cost of printing and distributing T copies when the type of audience is θ.

We assume that there are no fixed costs, and that the marginal cost of printing and distributing is positive and non-decreasing with the tirage. We also assume that, for a given tirage, the cost of distributing an additional copy is lower when the readers are seeking ($\theta = \theta_H$) than when they are avoiding ($\theta = \theta_L$), because readers are willing to dedicate more time and effort to obtain a copy of the newspaper when $\theta = \theta_H$ than when $\theta = \theta_L$. Our assumptions regarding production costs are summarized below.

Assumption 3 (Production cost)

The printing and distribution cost function, $c(\theta, T)$, satisfies the following properties:

(i) $c(\theta, 0) = 0$;

(ii) $c_T(\theta_L, T) > c_T(\theta_H, T) > 0$;

(ii) $c_{TT}(\theta, T) \geq 0$.

In this context, the problem of the freely distributed newspaper consists in choosing the tirage, $(T_i;\ i = L, H)$, that maximizes its profits, conditional on (i) the type of audience, $(\theta_i;\ i = L, H)$, and on (ii) the advertisers' expected behavior, $p_i = V(\theta_i, T_i)$.

We model this economic setup as a signalling game with the following time structure:

1. Nature selects the type of readers in the market, selecting $\theta = \theta_L$ with probability q_L and $\theta = \theta_H$ with probability $q_H = 1 - q_L$.

2. The newspaper privately observes the type of readers, θ_i, and chooses a tirage, T_i.

3. A large number of advertisers offer bids for the N slots of ad-space. As a result of this Bertrand competition, N advertisers buy ad-space for the same price, p_i.

4. The newspaper prints and distributes T_i copies, the readership is $R(\theta_i, T_i)$, the payoff of the newspaper is $Np_i - c(\theta_i, T_i)$ and the payoff of the representative advertiser is $V(\theta_i, T_i) - p_i$.

To guarantee that the solution is interior, i.e., that the tirage is strictly positive and finite, we make an additional assumption.

Assumption 4 (Interior solution)

The advertising return function and the cost function satisfy the following properties:

(i) $NV_T(\theta_L, 0) > c_T(\theta_L, 0)$;

(ii) $\lim_{T \to \infty} [NV_T(\theta_H, T) - c_T(\theta_H, T)] < 0$.

Before investigating the effect of asymmetric information on the tirage of the newspaper and on the price of ad-space, we describe (in the following section) the outcome in the case of perfect information.

3 Benchmark: perfect information

In the case of perfect information, the type of readers in the market is common knowledge of the newspaper and the advertisers.

This section investigates the characteristics of the tirage chosen by the newspaper and of the prices paid by the advertisers for the ad-space, which depend on the type of readers that is observed. To this end, we rely on backward-induction techniques to solve the perfect information version of the game previously described.

Given a tirage, T_i, and the type of readers, θ_i (which, in the context of symmetric information, is common knowledge), the payoff of the representative advertiser is:

$$V(\theta_i, T_i) - p_i.$$

As a result of Bertrand competition for the ad-space, the newspaper is able to capture all the surplus from advertisers, who are willing to offer a price that is equal to the benefit that they obtain from advertising:

$$p_i^{SI} = V(\theta_i, T_i).$$

In the first stage, the newspaper chooses the level of tirage that maximizes its profit, $\pi(\theta_i, T_i, p_i)$, anticipating the price of the ad-space, p_i^{SI} (as a function of tirage):

$$\max_{T_i} \{NV(\theta_i, T_i) - c(\theta_i, T_i)\}.$$

The solution to this problem is given by the first order condition:

$$NV_T(\theta_i, T_i) = c_T(\theta_i, T_i),$$

because the second order condition, $NV_{TT}(\theta_i, T_i) - c_{TT}(\theta_i, T_i) < 0$, is always verified.[9]

Therefore, when $i = L$, the symmetric information solution is given by:

$$\begin{aligned} T_L^{SI} &: \quad NV_T\left(\theta_L, T_L^{SI}\right) = c_T\left(\theta_L, T_L^{SI}\right); \\ p_L^{SI} &= V\left(\theta_L, T_L^{SI}\right). \end{aligned} \tag{3}$$

Analogously, when $i = H$, the symmetric information solution is:

$$\begin{aligned} T_H^{SI} &: \quad NV_T\left(\theta_H, T_H^{SI}\right) = c_T\left(\theta_H, T_H^{SI}\right); \\ p_H^{SI} &= V\left(\theta_H, T_H^{SI}\right). \end{aligned} \tag{4}$$

[9]Recall that $V_{TT} < 0$ (by Proposition 1) and $c_{TT} \geq 0$ (by Assumption 3).

We conclude that, in the perfect information benchmark, advertisers obtain their reservation payoffs, as the monopolist newspaper extracts all their surplus. Furthermore, regardless of the type of readers in the market, the newspaper's tirage assures a perfect balance between the marginal benefit of printing an additional copy, $NV_T\left(\theta_i, T_i^{SI}\right)$, and the corresponding marginal cost, $c_T\left(\theta_i, T_i^{SI}\right)$.

Figure 1 identifies the equilibrium contracts in the case of perfect information. The solid lines identify the optimal contract when the type of readers in the market is H, while the dashed lines identify the optimal contract when it is L. The perfect information contracts are located at tangency points (equality between the marginal cost and the marginal benefit of an additional copy to advertisers).

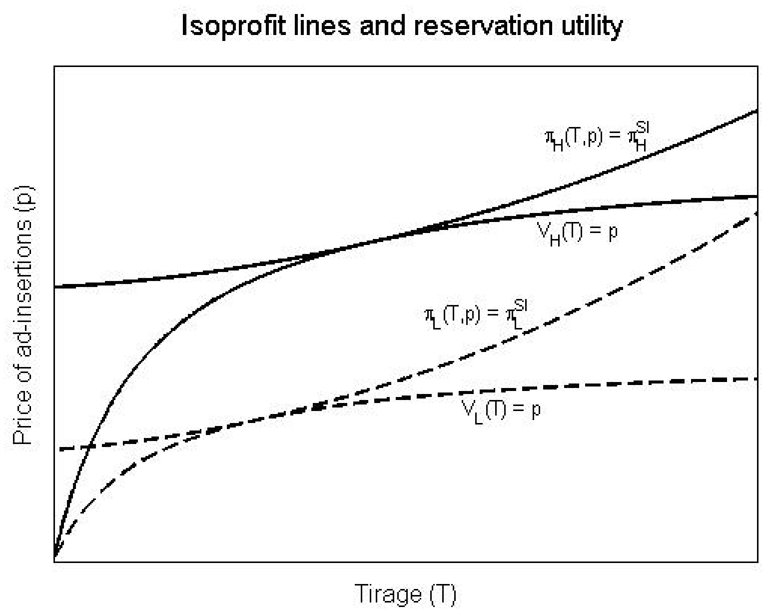

Figure 1: Tirage and ad-prices in the case of perfect information.

Figure 1 also illustrates the fact that, when the demand is high, the newspaper prints more copies and charges higher advertising rates than when it is low. Since $V_T\left(\theta_H, T\right) > V_T\left(\theta_L, T\right)$ and $c_T\left(\theta_H, T\right) < c_T\left(\theta_L, T\right)$, it follows that $T_H^{SI} > T_L^{SI}$. This, in turn, implies that $V(\theta_H, T_H^{SI}) > V(\theta_L, T_L^{SI})$ and $p_H^{SI} > p_L^{SI}$.

We now turn to the case of asymmetric information, in which the type of readers in the market is private information of the newspaper.

4 Asymmetric information

This section introduces asymmetric information about readers' characteristics. At the moment of contracting, the newspaper is better informed than the advertisers. While the newspaper observes the true type of the audience, the advertisers only know the prior probability distribution over the set of possible types.

4.1 Deviation from the perfect information contracts

With asymmetric information, the tirage and prices may differ from those obtained in the previous section, $\left(T_L^{SI}, p_L^{SI}\right)$ and $\left(T_H^{SI}, p_H^{SI}\right)$, because when the demand is low, the newspaper may prefer the contract $\left(T_H^{SI}, p_H^{SI}\right)$ relatively to $\left(T_L^{SI}, p_L^{SI}\right)$. If this is the case, the newspaper has incentives to deviate from the perfect information tirage, T_L^{SI}, and choose the higher tirage, T_H^{SI}, if that makes advertisers believe that the demand is high.

A necessary condition for such a deviation to occur is that the advertisers prefer readers of type H, relatively to readers of type L. In the conditions of Proposition 1, this is always true (we have $V_T(\theta_H, T) > V_T(\theta_L, T)$). But consider for a moment that Assumption 1 is violated and that we have $V_T(\theta_H, T) = V_T(\theta_L, T)$.[10] In this case, the only difference between the two types of audiences is that type L requires a greater distribution cost than type H. Since the type of audience is irrelevant to advertisers, the newspaper has no interest in trying to manipulate their beliefs. Therefore, the newspaper always chooses the perfect information tirage, even in a scenario of asymmetric information.

The following Proposition (proved in the Appendix) provides the necessary and suf-

[10] The case in which $V_T(\theta_H, T) < V_T(\theta_L, T)$ together with $c_T(\theta_H, T) < c_T(\theta_L, T)$ is a bit contradictory in the sense that the audience of type H is less willing to read the newspaper, but more willing to spend an effort to obtain a copy. If for some reason such scenario took place, the plausible deviation of the newspaper would consist in choosing T_L^{SI} when $\theta = \theta_H$, for the advertisers to believe that the type of audience is favorable for them.

ficient condition under which asymmetric information about the type of readers in the market leads to deviations from the symmetric information outcomes, $\left(T_L^{SI}, p_L^{SI}\right)$ and $\left(T_H^{SI}, p_H^{SI}\right)$.

Proposition 2 (Deviation)

When the type of the readers in the market is private information of the newspaper and advertisers believe that $\theta = \theta_i$ *when confronted with the tirage* T_i^{SI}*, then:*

(i) if $\theta = \theta_H$*, the newspaper prefers the pair* $\left(T_H^{SI}, p_H^{SI}\right)$ *relatively to* $\left(T_L^{SI}, p_L^{SI}\right)$*;*

(ii) if $\theta = \theta_L$*, the newspaper gains by deviating from* $\left(T_L^{SI}, p_L^{SI}\right)$ *to* $\left(T_H^{SI}, p_H^{SI}\right)$ *if and only if:*

$$c\left(\theta_L, T_H^{SI}\right) - c\left(\theta_L, T_L^{SI}\right) < N\left[V\left(\theta_H, T_H^{SI}\right) - V\left(\theta_L, T_L^{SI}\right)\right]. \quad (5)$$

If condition (5) is violated, the newspaper does not deviate neither for $\theta = \theta_H$ nor for $\theta = \theta_L$. Therefore, the asymmetric information outcome coincides with the prefect information benchmark. In particular, when $\theta = \theta_L$, the newspaper does not deviate to $\left(T_H^{SI}, p_H^{SI}\right)$ because of the high cost of printing and distributing additional copies. It is too costly to make advertisers believe that $\theta = \theta_H$.

In the rest of the paper, we solve the model for the case in which condition (5) holds. Under this assumption, regardless of the type of readers, the newspaper always prefers the pair $\left(T_H^{SI}, p_H^{SI}\right)$ relatively to $\left(T_L^{SI}, p_L^{SI}\right)$. Anticipating a deviating behavior, advertisers do not believe that $\theta = \theta_H$ when observing a tirage equal to T_H^{SI}. In other words, T_H^{SI} is not a credible signal of a high demand. Accordingly, when observing T_H^{SI}, advertisers retain their priors, and the maximum advertising rate they are willing to pay is equal to the expected benefit that they derive from advertising: $q_L V\left(\theta_L, T_H^{SI}\right) + q_H V\left(\theta_H, T_H^{SI}\right)$.

In the following section, we find the unique equilibrium of the signalling game described in section 2, and then we describe the economic implications of the newspaper's equilibrium decisions under asymmetric information.

4.2 Solution under asymmetric information

In the context of our signalling game, when the newspaper has private information about the characteristics of the readers, advertisers may try to infer the type of audience from the newspaper's tirage. Accordingly, the probabilities that the advertisers use to compute their expected return are not necessarily their priors but their interim beliefs about the type of readers, conditional on the tirage chosen by the newspaper.

The advertisers' interim beliefs are described by the belief function $\mu(\theta, T)$, which assigns a probability to each possible type (θ_L and θ_H), conditionally on the observed value of the tirage (T). Of course that, for the probabilities to be well defined, we must have $0 \leq \mu(\theta, T) \leq 1$ and $\mu(\theta_L, T) + (\theta_H, T) = 1$.

To characterize the newspaper's optimal tirage and the advertising prices under asymmetric information, we will determine the unique Perfect Bayesian Equilibrium of the signalling game that satisfies the "intuitive criterion" of Cho and Kreps (1987).[11]

Below, $p(T)$ denotes a pure strategy of the representative advertiser, which consists in choosing the bid to make for the ad-space, p, as a function of the observed tirage, T.

Definition 1 (Equilibrium)

A vector of strategies, $\{(T_L^*, T_H^*), p^*(T)\}$, and an interim beliefs function, $\mu(\theta, T)$, constitute a pure-strategy equilibrium when:

(i) the strategies (T_L^*, T_H^*) and $p^*(T)$ are optimal, given the interim beliefs function, $\mu(\theta, T)$;

(ii) the interim beliefs in equilibrium, $\mu(\theta_i, T_i^*)$, $i \in \{L, H\}$, are consistent with Bayes' rule;

(iii) the interim beliefs out of equilibrium satisfy the Cho-Kreps intuitive criterion.

It is possible to conceive two kinds of equilibria: *separating* and *pooling*. In a separating

[11] Since our signalling is monotonic in the sense of Cho and Sobel (1990), the "intuitive criterion" (Cho and Kreps, 1987) is equivalent to the related refinements designated as "universal divinity"(Banks and Sobel, 1987) and "never a weak best response" (Kohlberg and Mertens, 1986; Cho and Kreps, 1987). All these refinements consist in excluding unreasonable interim beliefs out of the equilibrium path.

equilibrium, the tirage chosen by the newspaper depends on the type of readers in the market, i.e., $T_L^* \neq T_H^*$. Therefore, by observing the contract proposed by the newspaper, advertisers are able to infer the type of the readers in the market. In this case, interim beliefs must correspond to revelation: $\mu(\theta_L, T_L^*) = 1$ and $\mu(\theta_H, T_H^*) = 1$.

In a pooling equilibrium, the tirage chosen by the newspaper is independent of the type of the readers in the market, i.e., $T_L^* = T_H^* = \overline{T}$. In this case, the tirage does not convey any additional information. Hence, the interim beliefs must coincide with the prior beliefs: $\mu(\theta_i, \overline{T}) = q_i$.

As shown and explained by Cho and Kreps (1987), Cho and Sobel (1990), and others, when Assumptions 1-4 hold, there is no pooling equilibrium of this game. The unique equilibrium, (T_L^*, p_L^*) and (T_H^*, p_H^*), is the *least-cost separating equilibrium*, which can be obtained sequentially as follows:[12]

$$\begin{aligned}
T_L^* &= \underset{T_L}{\operatorname{argmax}} \left[NV\left(\theta_L, T_L\right) - c\left(\theta_L, T_L\right) \right]; \\
p_L^* &= V\left(\theta_L, T_L^*\right); \\
T_H^* &= \underset{T_H}{\operatorname{argmax}} \left[NV\left(\theta_H, T_H\right) - c\left(\theta_H, T_H\right) \right] && (6) \\
&\quad \text{s.t.} \quad NV\left(\theta_H, T_H\right) - c\left(\theta_L, T_H\right) \leq Np_L^* - c\left(\theta_L, T_L^*\right); && (7) \\
p_H^* &= V\left(\theta_H, T_H^*\right). && (8)
\end{aligned}$$

Proposition 3 (Equilibrium)

Under Assumptions 1-4, the unique equilibrium is the least-cost separating equilibrium.

Proof: The proof follows directly from the results obtained by Cho and Sobel (1990).

It is straightforward to verify that their Assumptions A0, A1, A1', A2, A4, A5 and A6 hold. The fact that the best response of the advertiser, p, is increasing in the probability attributed to the type of readers being H, μ_H, plays the role of Assumption A3.

[12] Observe that the choice of T_H^* is subject to a restriction (7) that guarantees that, if $\theta = \theta_L$, the newspaper does not have any incentive to print T_H^* copies. An equivalent way to express this condition would be (with some abuse of notation): $\pi\left(\theta_L, T_H^*, \mu\left(\theta_H, T_H^*\right) = 1\right) \leq \pi\left(\theta_L, T_L^*, \mu\left(\theta_L, T_L^*\right) = 1\right)$.

In our definition of equilibrium, we have considered pure strategies. It is also clear, from the results of Cho and Sobel (1990), that if we allowed for mixed strategies, the unique equilibrium would remain the same. ■

4.3 Characterization of the equilibrium outcome

We have shown that the unique equilibrium is the least-cost separating equilibrium, illustrated in figure 2, and characterized below (the proof is in the Appendix).

Proposition 4 (Characterization)

The least-cost separating allocation is such that:

(i) When $\theta = \theta_L$, the least-cost separating outcome (T_L^*, p_L^*) coincides with the perfect information outcome. The advertising rate is $p_L^* = V(\theta_L, T_L^*)$ and the tirage, T_L^*, is such that $NV_T(\theta_L, T_L^*) = c_T(\theta_L, T_L^*)$;

(ii) When $\theta = \theta_H$, the newspaper has a higher profit than when $\theta = \theta_L$, but not as high as in the case of symmetric information, $\pi_H^* = \pi_L^* + c(\theta_L, T_H^*) - c(\theta_H, T_H^*) < \pi_H^{SI}$, while the advertisers remain with their reservation utility, $p_H^* = V(\theta_H, T_H^*)$. There is an excess of tirage relatively to the symmetric information case, $T_H^* > T_H^{SI}$.

When the demand is low, $\theta = \theta_L$, the optimal contract with asymmetric information, (T_L^*, p_L^*), coincides with the perfect information outcome (corresponding to the tangency between the newspaper's marginal revenue function and its marginal cost function). Accordingly, when $\theta = \theta_L$, the newspaper does not bear any signalling cost.[13] The newspaper captures all the surplus, as the advertising rate is $p_L^* = V(\theta_L, T_L^*)$. The tirage, T_L^*, corresponds to the profit maximizing level, implicitly given by: $NV_T(\theta_L, T_L^*) = c_T(\theta_L, T_L^*)$.

In contrast, when condition (5) holds but the demand is high, $\theta = \theta_H$, the newspaper deviates from the symmetric information tirage, T_H^{SI}. The newspaper must print more copies than T_H^{SI} to credibly signal to the advertisers that the demand is high. The existence

[13]The same result appears in other signalling models, following the seminal work of Spence (1973).

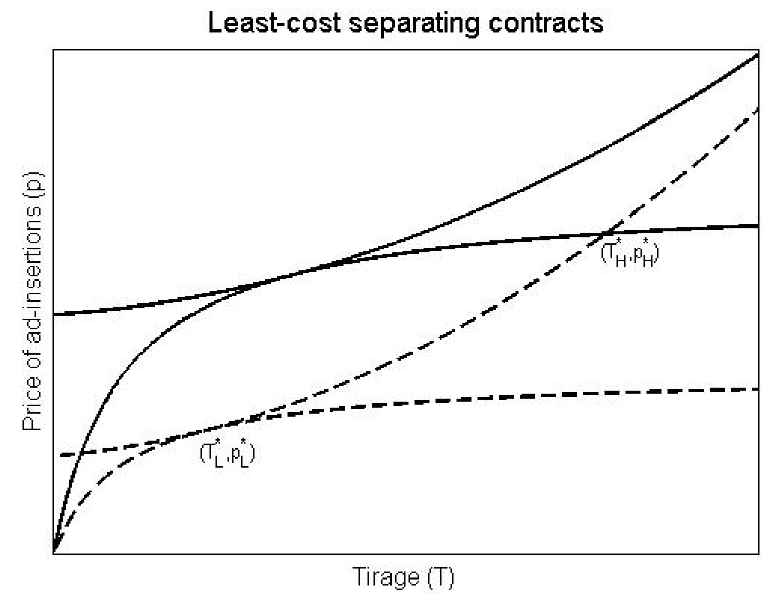

Figure 2: Tirage and ad-prices under asymmetric information.

of "*too strong incentives to print*" when $\theta = \theta_H$ is illustrated in figure 2: The tirage, T^*_H, is clearly larger than the tirage that maximizes the newspaper's profit under perfect information (which corresponds to the tangency between the solid lines). In figure 2, we also observe that, for the chosen tirage, T^*_H, the marginal revenue of printing and distributing an additional copy of the newspaper is lower than its marginal cost. However, in a context of asymmetric information, the newspaper does not reduce its tirage because, by doing so, the newspaper would not credibly signal to the advertisers that the demand is high. Therefore, when $\theta = \theta_H$, the profit of the newspaper is lower than in the case of perfect information (there is a signalling cost),[14] while the advertisers remain with their reservation utility, $p^*_H = V(\theta_H, T^*_H)$.

[14] This is also the typical result in the models of signalling.

4.4 Welfare implications

In this section, we briefly investigate the welfare implications of the existence of incentives to overprint.

4.4.1 Socially optimal tirage

We define a social welfare function, $W(\theta, T)$, as the sum of consumers' welfare, the newspaper's profits and the advertisers' profits. In our model, advertising does not yield any profits to advertisers, since Bertrand competition among advertisers dissipates their surplus in favor of the newspaper, whose profits are equal to $NV(\theta_i, T_i) - c(\theta_i, T_i)$. In the light of this, the social welfare is given by:

$$W(\theta, T) = \underbrace{U(\theta, T)}_{\text{Consumers}} + \underbrace{NV(\theta, T) - c(\theta, T)}_{\pi(\theta, T)}. \tag{9}$$

The consumers' welfare is a function of the type of readers and of the tirage, being denoted by $U(\theta, T)$. In line with Assumption 1, we assume that it satisfies the following properties: $U(\theta, 0) = 0$, $U_T(\theta, T) > 0$, $U_{TT}(\theta, T) < 0$ and $U(\theta_H, T) > U(\theta_L, T)$.[15]

For each type of readers, the socially optimal tirage, T_i^W $(i = L, H)$, is given by the first order condition, $\frac{\partial W(\theta_i, T)}{\partial T} = 0$, which yields:[16]

$$U_T\left(\theta_i, T_i^W\right) = c_T\left(\theta_i, T_i^W\right) - NV_T\left(\theta_i, T_i^W\right). \tag{10}$$

[15] The welfare effects of advertising are complex and there is an extensive literature dealing with this issue (Butters, 1977; Grossman and Shapiro, 1984; and many others). In our model, since the intensity of advertising is exogenous (N slots), the welfare associated with advertising is kept fixed (for a given readership). Therefore, it does not matter whether readers are averse, neutral, or attracted to advertising. In any case, the welfare effect of advertising is included in $U(\theta, T)$.

[16] Notice that the second order condition of the maximization problem is always met since we are assuming that $U_{TT}(\theta, T) < 0$, $V_{TT}(\theta, T) < 0$ and $c_{TT}(\theta, T) > 0$.

4.4.2 Welfare properties of the perfect information outcomes

The symmetric information outcomes, $\left(T_H^{SI}, p_H^{SI}\right)$ and $\left(T_L^{SI}, p_L^{SI}\right)$, are not socially optimal. In fact, from (3) and (4) it follows that $c_T\left(\theta_i, T_i^{SI}\right) = NV_T\left(\theta_i, T_i^{SI}\right)$. Therefore, the symmetric information tirage would only be socially optimal if $U_T\left(\theta_i, T_i^{SI}\right) = 0$, which violates the assumption made above, $U_T\left(\theta, T\right) > 0$. Under our assumption, the socially optimal tirage is larger than its perfect information level, T_i^{SI}. This welfare loss results directly from the business model of the free newspaper. Since readers do not pay for the newspaper, their marginal utility is not reflected in the price of the good, and, therefore, has no impact on the newspaper's tirage choice. We may say that the utility of reading the newspaper is not internalized in the free newspaper market.

Note that these results could be easily extended to a situation in which the social welfare function also included an environmental cost of printing. If such environmental cost is internalized by the markets, it is already supported by the newspaper in the form of a higher production cost. In this case, the analysis above still applies.

To study the case in which the environmental cost involves a negative externality, suppose that the magnitude of this externality is described by the function $h\left(\theta, T\right)$, with $h_T\left(\theta, T\right) > 0$ and $h_{TT}\left(\theta, T\right) > 0$. In that case, social welfare would be given by $W\left(\theta, T\right) = U\left(\theta, T\right) + NV\left(\theta, T\right) - c\left(\theta, T\right) - h\left(\theta, T\right)$, and the welfare maximization would require:

$$U_T\left(\theta_i, T_i^W\right) - h_T\left(\theta_i, T_i^W\right) = c_T\left(\theta_i, T_i^W\right) - NV_T\left(\theta_i, T_i^W\right). \tag{11}$$

In that case, from a social welfare perspective, it is no longer necessarily true that a monopolist newspaper is endowed with too little incentives to print (relatively to the social optimum). If the environmental externality is very significant, the opposite may be the case.

4.4.3 Welfare effect of asymmetric information

Now we turn our attention to the welfare impact of asymmetric information. In the case of a low demand, $(\theta = \theta_L)$, the existence of asymmetric information does not affect social welfare because the outcome is the same as in the case of perfect information.

In contrast, when the demand is high, $(\theta = \theta_H)$, the newspaper has incentives to print more copies under asymmetric information than in the case of perfect information. The following proposition summarizes the welfare characterization of such scenario.

Proposition 5 (Welfare analysis)

When we account for the impact of tirage on social welfare, we observe that:

(i) If $U_T(\theta_H, T_H^*) - h_T(T_H^*) > c_T(\theta_H, T_H^*) - NV_T(\theta_H, T_H^*) > 0$, *then* $T_H^* < T_i^W$, *which means that the newspaper should print and distribute more copies (insufficient printing);*

(ii) If $c_T(\theta_H, T_H^*) - NV_T(\theta_H, T_H^*) > U_T(\theta_H, T_H^*) - h_T(T_H^*)$, *then* $T_H^* > T_i^W$, *which means that the newspaper is printing and distributing too many copies (excess printing);*

(iii) If $c_T(\theta_H, T_H^*) - NV_T(\theta_H, T_H^*) = U_T(\theta_H, T_H^*) - h_T(T_H^*) > 0$, *then* $T_H^* = T_i^W$, *which means that the tirage is socially optimal.*

Proof. Follows directly from (11), together with (6)-(8). ■

In the light of the preceding Proposition, we observe that, for $\theta = \theta_H$, the newspaper's signalling cost is not necessarily welfare detrimental since this additional incentive to print may be a way to balance the insufficient incentives to print which arise in the case of perfect information. Whether the effect of asymmetric information on social welfare is positive or negative depends on the relative strength of two countervailing forces: the benefit to consumers associated with the increased tirage versus the signalling cost supported by the newspaper.

5 Concluding remarks

We have investigated whether, in a context of asymmetric information, a monopolist free daily has incentives to print additional copies with the sole objective of convincing advertisers that the readership of the newspaper is larger than it actually is.

Our framework is a signalling model in which the newspaper, knowing whether the potential readership is low or high, chooses the tirage, providing a signal to the advertisers about the type of readership. In line with the results on the signalling literature (Spence, 1973), we have found that the newspaper only deviates from the perfect information solution when the demand is high, to convince the advertisers that the demand is, in fact, high. When the demand is low, the newspaper chooses the perfect information tirage.

Besides shedding some light on a relevant economic issue, we expect that this work may have contributed to the incorporation of asymmetric information in the study of newspaper industries. Here, we have kept fixed the space available for ad-insertions. It would be interesting to study the case in which the newspaper can also choose the number of pages dedicated to advertising, taking into account the attitude of readers towards ads (they may be averse, neutral or attracted to ads (Kaiser and Song, 2009)). Such a scenario would be useful, for example, to investigate how the readers' attitude toward advertising may damp or enhance the incentives of the newspaper to overprint.

The research question addressed in this paper was partly inspired by some recent events related to the so-called "London freesheet war". This refers to the very aggressive competition between two free dailies in London: the London Lite and the London Paper, with both newspapers being accused of following anti-competitive and predatory strategies. From our viewpoint, one of the most striking episodes of this war occurred in April 2007, when London Lite argued that London Paper vendors were dumping copies of the paper they were distributing in the garbage. While the endogenous mechanisms we describe in this paper might have played some role in the context of the "London freesheet war", another ingredient must be introduced to fully understand these events: competition. In our future research, we aim to consider an oligopoly version of this model to understand the effects of competition on the tirage of free daily newspapers.

6 Appendix

Proof of Proposition 2: The tirage T_H^{SI}, with $T_H^{SI} > T_L^{SI}$, is optimal for $\theta = \theta_H$, therefore:

$$NV\left(\theta_H, T_H^{SI}\right) - c\left(\theta_H, T_H^{SI}\right) > NV\left(\theta_H, T_L^{SI}\right) - c\left(\theta_H, T_L^{SI}\right). \tag{12}$$

Since, by assumption, $V\left(\theta_H, T_L^{SI}\right) > V\left(\theta_L, T_L^{SI}\right)$, from (12) it follows that:

$$NV\left(\theta_H, T_H^{SI}\right) - c\left(\theta_H, T_H^{SI}\right) > NV\left(\theta_L, T_L^{SI}\right) - c\left(\theta_H, T_L^{SI}\right),$$

or, equivalently: $N\left(p_H^{SI} - p_L^{SI}\right) > c\left(\theta_H, T_H^{SI}\right) - c\left(\theta_H, T_L^{SI}\right) > 0.$

This implies that, for $\theta = \theta_H$, the newspaper always obtains higher profits with $\left(T_H^{SI}, p_H^{SI}\right)$ than with $\left(T_L^{SI}, p_L^{SI}\right)$. In spite of the information asymmetry, the advertisers still offer p_H^{SI} (as they believe that $\theta = \theta_H$).

Since advertisers believe that $\theta = \theta_H$ when confronted with $\left(T_H^{SI}, p_H^{SI}\right)$, then, for $\theta = \theta_L$, the newspaper deviates from $\left(T_L^{SI}, p_L^{SI}\right)$ to $\left(T_H^{SI}, p_H^{SI}\right)$ if and only if:

$$NV\left(\theta_H, T_H^{SI}\right) - c\left(\theta_L, T_H^{SI}\right) > NV\left(\theta_L, T_L^{SI}\right) - c\left(\theta_L, T_L^{SI}\right),$$

yielding condition (5). ■

Proof of Proposition 4: (i) Follows directly from the definition of least-cost separating allocation.

(ii) Under condition (5), the incentive compatibility restriction in the determination of T_H^* is binding. Therefore, the newspaper has a higher profit if $\theta = \theta_H$ while the advertisers remain with their reservation utility:

$$NV(\theta_H, T_H^*) - c(\theta_H, T_H^*) > NV(\theta_H, T_H^*) - c(\theta_L, T_H^*) = NV(\theta_L, T_L^*) - c(\theta_L, T_L^*),$$

$$p_H^* = V(\theta_H, T_H^*).$$

The Lagrangian of the maximization problem that yields T_H^* is:

$$\mathcal{L} = NV(\theta_H, T_H) - c(\theta_H, T_H) - \lambda \left[NV(\theta_H, T_H) - c(\theta_L, T_H) - \pi_L^* \right].$$

The first order condition is:

$$\frac{\partial \mathcal{L}}{\partial T_H} = 0 \quad \Leftrightarrow \quad NV_T(\theta_H, T_H) - c_T(\theta_H, T_H) - \lambda NV_T(\theta_H, T_H) + \lambda c_T(\theta_L, T_H) = 0 \;\Leftrightarrow$$
$$\Leftrightarrow \quad V_T(\theta_H, T_H) = c_T(\theta_H, T_H) - \frac{\lambda}{1-\lambda} \left[c_T(\theta_L, T_H) - c_T(\theta_H, T_H) \right].$$

Since $\lambda > 0$ (the restriction is binding): $V_T(\theta_H, T_H) < c_T(\theta_H, T_H)$.

Therefore, T_H^* is greater than T_H^{SI}. ■

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