Online Appendix: News Aggregators and Competition Among Newspapers on the Internet

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PROOF OF PROPOSITION 4 (II):

If newspaper i opts out its best deviation quality would be $\mu_i = \frac{\delta+\beta-\frac{\delta(\mu^{**}\Delta u+u_T)}{t}}{4c-2\delta\beta}$. And its market share changes from $\alpha^{**} = \frac{1}{2}-\beta\mu^{**}-\frac{u_T}{t}$ to $\alpha_i = \frac{1}{2}-\frac{(\mu^{**}-\mu_i)\Delta u+u_T}{2t}$. As a result, the gain from deviation is

$$
\begin{aligned}
d(\mu_i,\mu^{**}) \equiv & \alpha_i(1+\delta\mu_i) - c\mu_i^2 - \alpha^{**}(1+\delta\mu^{**}) \\
& - 2\delta(\frac{u_T}{t} + \beta\mu^{**})\mu^{**} + c{\mu^{**}}^2 \\
= & (\alpha_i - \alpha^{**})(1+\delta\mu_i) - (\mu^{**}-\mu_i)\left[-c(\mu^{**}+\mu_i) + \delta\alpha^{**}\right] \\
& - 2\frac{\delta}{t}(u_T + \mu^{**}\Delta u)\mu^{**} \\
= & (\alpha_i - \alpha^{**}) + \frac{\delta u_T}{2t}\mu_i + \frac{\delta\beta}{2}\mu_i\mu^{**} + \frac{\delta\beta}{2}\mu_i^2 \\
& - (\mu^{**}-\mu_i)\left[-c(\mu^{**}+\mu_i) + \delta\alpha^{**}\right] - 2\frac{\delta}{t}(u_T+\mu^{**}\Delta u)\mu^{**} \\
= & (\alpha_i - \alpha^{**}) + \frac{\delta\beta}{2}\mu_i\mu^{**} \\
& - (\mu^{**}-\mu_i)\left[-c(\mu^{**}+\mu_i) + \delta + \frac{\delta u_T}{2t} + \frac{\delta\beta}{2}(\mu_i+\mu^{**})\right] \\
& - \frac{3\delta}{2t}(u_T+\mu^{**}\Delta u)\mu^{**} \\
= & \frac{1}{2t}(\mu^{**}\Delta u + u_T + \mu_i\Delta u) + \frac{1}{2t}(\delta\mu_i\mu^{**}\Delta u) - \frac{3}{2t}\delta\mu^{**}(\mu^{**}\Delta u + u_T) \\
& - (\mu^{**}-\mu_i)\left[-c(\mu_i+\mu^{**}) + \delta/2 - \frac{\delta(\mu^{**}-\mu_i)\Delta u}{2t} - \frac{\delta u_T}{2t}\right].
\end{aligned}
$$

By adding $-\frac{1}{2}Q(\mu^{**})$ (from (A8)), and $c\mu_i = \delta+\beta-\frac{\delta(\mu^{**}\Delta u+u_T)}{t}+\frac{\delta\beta}{2}\mu_i$ to the last term, we get:

$$
\begin{aligned}
(2t)d(\mu_i,\mu^{**}) = & (\mu^{**}\Delta u + u_T + \mu_i\Delta u) + \delta\mu_i\mu^{**}\Delta u - 3\delta\mu^{**}(\mu^{**}\Delta u + u_T) \\
-(\mu^{**}-\mu_i)[&{\mu^{**}}^2\delta\Delta u + \mu^{**}(\Delta u + \delta u_T) - \frac{5}{2}\mu^{**}\delta\Delta u - \frac{3}{2}u_T\delta + u_T - \Delta u/2].
\end{aligned}
$$

We can rearrange it to

$$(2t)d(\mu_i,\mu^{**}) = u_T + 2\mu^{**}\Delta u - 2\delta{\mu^{**}}^2\Delta u - 3\delta\mu^{**}u_T$$
$$-(\mu^{**}-\mu_i)[{\mu^{**}}^2\delta\Delta u + \mu^{**}(\Delta u + \delta u_T - \frac{3}{2}\delta\Delta u) - \frac{3}{2}u_T\delta + u_T + \Delta u/2].$$

From (A8), we know $-\mu^{**}(4c-2\delta\beta) = {\mu^{**}}^2(2\delta\beta) + 2\mu^{**}(\beta - \delta\beta + \frac{u_T\delta}{t}) - \delta - \frac{2u_T}{t}(\delta - 1)$. Also $\mu_i(4c-2\delta\beta) = \delta + \beta - \frac{\delta(\mu^{**}\Delta u + u_T)}{t}$. Adding them up gives us (B1)

$$(\mu_i - \mu^{**})(4c-2\delta\beta) = \frac{1}{t}\left[2{\mu^{**}}^2\delta\Delta u + 2\mu^{**}(\Delta u - \frac{3}{2}\delta\Delta u + u_T\delta) - 3u_T\delta + 2u_T + \Delta u\right].$$

Hence, the gain[23] is

$$\text{(B2)} \qquad u_T + 2\mu^{**}\Delta u - 2\delta{\mu^{**}}^2\Delta u - 3\delta\mu^{**}u_T + \frac{t}{2}(4c-2\delta\beta)(\mu^{**}-\mu_i)^2,$$

or equivalently

$${\mu^{**}}^2\left(\frac{t}{2}(4c-2\delta\beta) - 2\delta\Delta u\right) + \mu^T\left(2\Delta u - 3\delta u_T - t\mu_i(4c-2\delta\beta)\right) + u_T + \frac{t}{2}(4c-2\delta\beta)\mu_i^2$$

We first show the gain is decreasing in μ^{**}, and then it is negative for $\mu^{**} = \mu^*$. Therefore, opt-out is not profitable for $\mu^{**} \geq \mu^*$.

CLAIM 1: *The gain from opt-out is decreasing in μ^{**}:*

The derivative of the gain with respect to μ^{**} is

$$t(4c-2\delta\beta)(\mu^{**}-\mu_i) - 4\delta\Delta u\mu^{**} + 2\Delta u - 3\delta u_T - t\mu^{**}(4c-2\delta\beta)\mu_i' + t\mu_i(4c-2\delta\beta)\mu_i'.$$

We can replace $(4c-2\delta\beta)\mu_i'$ by $-\delta\beta$ and $t(4c-2\delta\beta)(\mu^{**}-\mu_i)$ from (B1). Hence,

$$- 2{\mu^{**}}^2\delta\Delta u - 2\mu^{**}\Delta u + 3\delta\Delta u\mu^{**} - 2\delta u_T\mu^{**}$$
$$+ 3u_T\delta - 2u_T - \Delta u - 3\delta\Delta u\mu^{**} + 2\Delta u - 3\delta u_T - \delta\Delta u\mu_i,$$

or equivalently

$$-2{\mu^{**}}^2\delta\Delta u - 2\mu^{**}\Delta u - 2\delta u_T\mu^{**} - 2u_T + \Delta u - \delta\Delta u\mu_i,$$

which is negative since $2u_T \geq \Delta u$.

[23]Since t is a constant, we can consider the gain as $\frac{d(\mu_i,\mu^{**})}{2t}$.

CLAIM 2: *The gain from opt-out is negative for $\mu^{**} = \mu^*$:*

We know:

$$\begin{aligned}\delta\mu^{**} > 1 \Rightarrow Q(\frac{1}{\delta}) > 0 \quad &\Rightarrow \quad c < \frac{\delta^2}{4} + \frac{\delta^2 u_T}{2t} + \frac{\delta}{t}(\Delta u - u_T) - \beta \\ &\Rightarrow \quad c < \frac{\delta^2}{4} + \delta\beta - \beta + \frac{\delta^2 u_T}{2t} - \frac{\delta u_T}{t} \\ &\Rightarrow \quad c < \left(\frac{3\delta^2}{8} + \frac{5\delta\beta}{8}\right) + \left(\delta^2\left(-\frac{1}{8} + \frac{u_T}{2t}\right) + \frac{\delta}{t}\left(\frac{3\Delta u}{8} - u_T)\right) - \beta\right)\end{aligned}$$

The last term is negative, according to A1, and A2. Therefore,

$$c < \frac{3\delta^2}{8} + \frac{5\delta\beta}{8} \Rightarrow \delta\mu^* > \frac{2}{3}$$

If $\mu^{**} = \mu^*$, then $t(4c - 2\delta\beta)(\mu^* - \mu_i) = \delta u_T$. Using (B2), the gain from opt-out when $\mu^{**} = \mu^*$ is

$$-\delta\mu^*(u_T + 2\mu^*\Delta u + \frac{3}{2}u_T) + u_T + 2\mu^*\Delta u - \frac{\delta u_T}{2}\mu_i,$$

which is less than

$$-\frac{2}{3}u_T - \frac{4}{3}\mu^*\Delta u - u_T + u_T + 2\mu^*\Delta u - \frac{\delta u_T}{2}\mu_i = -\frac{2}{3}(u_T - \mu^*\Delta u) - \frac{\delta u_T}{2}\mu_i < 0.$$

Therefore, the gain from opt-out is negative for all $\mu^{**} \geq \mu^*$. And since $\delta\mu^{**} > 1$ implies $\mu^{**} > \mu^*$ opt-out is not beneficial if $\delta\mu^{**} > 1$.

PROOF OF PROPOSITION 5:

(ii) First, we show $\pi^{**} - \pi^*$ is decreasing with c. Given $\delta\mu^{**} > 1$, we consider two cases:

a) $c \geq \frac{u_T}{t}(\frac{\delta}{2} - 1) + \frac{\delta}{2} + \frac{3}{4}\delta\beta - \frac{\beta}{2}$: In this case, $\mu^* < \mu^{**} < \frac{1}{2}$. From (9), we have

$$\pi^{**} - \pi^* = h(c) = (\mu^{**} - \mu^*)\left(-c(\mu^{**} + \mu^*) + \frac{\delta}{2}\right) + \left(\beta\mu^{**} + \frac{u_T}{t}\right)(\delta\mu^{**} - 1).$$

To show $\pi^{**} - \pi^*$ is decreasing in c, we write $\frac{\partial(\pi^{**} - \pi^*)}{\partial c}$ as

$$\begin{aligned}h'(c) =& \mu^{**'}\left(-2c\mu^{**} + 2\delta\beta\mu^{**} + \frac{\delta}{2} - \beta + \frac{\delta u_T}{t}\right) \\ &+ \mu^{*'}\left(2c\mu^* - \frac{\delta}{2}\right) - \left(\mu^{**^2} - \mu^{*^2}\right).\end{aligned}$$

From proposition 1, we know $c\mu^* = \frac{\delta}{4} + \frac{\beta}{4} + \frac{\delta\beta}{4}\mu^*$. Moreover, full differentiating of $Q(\mu^{**}(c), c)$ in (A7), and multiplying it by μ^{**} gives us

$$\text{(B3)}\quad \mu^{**'}\left(-2c\mu^{**} + 2\delta\beta\mu^{**}\right) = \mu^{**'}\left(\beta\mu^{**} + 2\delta\beta{\mu^{**}}^2 + \frac{\delta u_T}{t}\mu^{**}\right) + 2{\mu^{**}}^2.$$

Hence,

$$\begin{aligned} h'(c) =& \mu^{**'}\left(2\delta\beta{\mu^{**}}^2 + \beta\mu^{**} + \frac{\delta}{2} - \beta + \frac{\delta u_T}{t}\mu^{**} + \frac{\delta u_T}{t}\right) \\ &+ \mu^{*'}\left(\frac{\beta}{2} + \frac{\delta\beta}{2}\mu^*\right) + {\mu^{**}}^2 + {\mu^*}^2. \end{aligned}$$

Since $\mu^{**'} = \frac{-2\mu^{**}}{2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t}}$, and $\mu^{*\prime} = \frac{-4\mu^*}{4c - \delta\beta}$, we get

$$\begin{aligned} h'(c) =& \mu^{**}\frac{-2\delta\beta{\mu^{**}}^2 + \mu^{**}(-\frac{\delta u_T}{t} - \beta + 2c - 2\delta\beta) - \delta + 2\beta - 2\frac{\delta u_T}{t}}{2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t}} \\ &+ \mu^*\frac{-2\beta - 2\delta\beta\mu^* + \delta + \beta}{4c - \delta\beta} \\ =& \mu^{**}\frac{-3\delta\beta{\mu^{**}}^2 - 2\beta\mu^{**} - \frac{\delta}{2} + 2\beta - 2\frac{\delta u_T}{t}\mu^{**} - \frac{u_T}{t}(\delta + 1)}{2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t}} \\ &+ \mu^*\frac{-\beta - 2\delta\beta\mu^* + \delta}{4c - \delta\beta}, \end{aligned}$$

where for the second equality, we use (A7). The left term on the R.H.S. of the equality is always negative since $c > \delta\beta$[24], and

$$2\beta - \frac{u_T}{t} - \frac{\delta u_T}{t} < 2\beta - \frac{\beta}{2} - \frac{3\beta}{2} = 0$$

where the first inequality is implied by A1, $u_T \geq \Delta u \max\{\frac{3}{2\delta}, \frac{1}{2}\}$. Negativity of right term, $\mu^*\frac{-\beta - 2\delta\beta\mu^* + \delta}{4c - \delta\beta}$, implies $h(c)$ is decreasing in c, and the proof

[24]In (a), we assumed $c \geq \frac{u_T}{t}(\frac{\delta}{2} - 1) + \frac{\delta}{2} + \frac{3}{4}\delta\beta - \frac{\beta}{2}$. Since $\delta \geq 2$, we can conclude $c \geq \frac{\delta}{2} + \frac{3}{4}\delta\beta - \frac{\beta}{2} = (\frac{\delta}{4} + \frac{3}{4}\delta\beta) + (\frac{\delta}{4} - \frac{\beta}{2}) \geq \delta\beta + \frac{\delta}{4} - \frac{\beta}{2} \geq \delta\beta$, where the two last inequalities are implied by the fact $\beta \leq 1$, and $\delta \geq 2$.

is done. Therefore, we assume the right term is positive. Hence,

$$\begin{aligned} h'(c) <& \mu^{**} \frac{-3\delta\beta {\mu^{**}}^2 - 2\beta\mu^{**} - \frac{\delta}{2} + 2\beta - 2\frac{\delta u_T}{t}\mu^{**} - \frac{u_T}{t}(\delta+1)}{2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t}} \\ &+ \mu^{**} \frac{-\beta - 2\delta\beta\mu^{*} + \delta}{4c - \delta\beta}, \end{aligned}$$

or equivalently

$$\begin{aligned} \frac{h'(c)}{\mu^{**}} <& \frac{-3\delta\beta {\mu^{**}}^2 - 2\beta\mu^{**} - \frac{\delta}{2} + 2\beta - 2\frac{\delta u_T}{t}\mu^{**} - \frac{u_T}{t}(\delta+1)}{2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t}} \\ &+ \frac{-\beta - 2\delta\beta\mu^{*} + \delta}{4c - \delta\beta}. \end{aligned}$$

Now, we show the left term on the R.H.S. of the inequality is decreasing in μ^{**}.

CLAIM 3: $f(\mu^{**}) = \frac{-3\delta\beta {\mu^{**}}^2 - 2\beta\mu^{**} - \frac{\delta}{2} + 2\beta - 2\frac{\delta u_T}{t}\mu^{**} - \frac{u_T}{t}(\delta+1)}{2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t}}$ *is decreasing in* μ^{**}.

PROOF:

$$\begin{aligned} f'(\mu^{**}) &= \frac{-6\delta^2\beta^2{\mu^{**}}^2 - 6\delta\beta^2\mu^{**} - 12\delta\beta c\mu^{**} + 12\delta^2\beta^2\mu^{**} - 2\beta^2 - 4\beta c + \delta^2\beta}{(2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t})^2} \\ &\quad + \frac{-2\delta\beta\frac{u_T}{t} - 4\delta c\frac{u_T}{t} + 6\delta^2\beta\frac{u_T}{t} - 2\delta^2\frac{u_T^2}{t^2} - 6\delta^2\beta\mu^{**}\frac{u_T}{t}}{(2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t})^2} \\ &= \frac{-2\delta^2\beta - 2\beta^2 - 4c\beta + 4\delta\beta\frac{\delta u_T}{t} - 4\delta c\frac{\delta u_T}{t} - 2\delta^2\frac{u_T^2}{t^2}}{(2\delta\beta\mu^{**} + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t})^2} < 0, \end{aligned}$$

where the last equality and inequality are implied by (A7), $2c\mu^{**} = {\mu^{**}}^2(-\delta\beta) + \mu^{**}(-\beta - \frac{\delta u_T}{t} + 2\delta\beta) + \frac{\delta}{2} + \frac{u_T}{t}(\delta - 1)$, and $c \geq \frac{u_T}{t}(\frac{\delta}{2} - 1) + \frac{\delta}{2} + \frac{3}{4}\delta\beta - \frac{\beta}{2} > \beta$.

Therefore, we can write

$$
\begin{aligned}
\frac{h'(c)}{\mu^{**}} &< \frac{-3\delta\beta(\frac{1}{\delta})^2 - 2\beta(\frac{1}{\delta}) - \frac{\delta}{2} + 2\beta - 2\frac{\delta u_T}{t}(\frac{1}{\delta}) - \frac{u_T}{t}(\delta+1)}{2\delta\beta(\frac{1}{\delta}) + \beta + 2c - 2\delta\beta + \frac{\delta u_T}{t}} \\
&\quad + \frac{-\beta - 2\delta\beta\mu^* + \delta}{4c - \delta\beta} \\
&= \left(\frac{1}{\delta}\right)\frac{-\frac{\delta^2}{2} + 2\delta\beta - 5\beta - \frac{\delta u_T}{t}(3+\delta)}{3\beta + 2c - 2\delta\beta + \frac{\delta u_T}{t}} + \frac{-\beta - 2\delta\beta\mu^* + \delta}{4c - \delta\beta}.
\end{aligned}
$$

Hence,

$$
\begin{aligned}
\frac{\delta h'(c)}{\mu^{**}} &< \frac{-\delta^2 + 4\delta\beta - 10\beta - 2\frac{\delta u_T}{t}(3+\delta)}{6\beta + 4c - 4\delta\beta + 2\frac{\delta u_T}{t}} + \frac{-\beta - 2\delta\beta\mu^* + \delta}{4c - \delta\beta} \\
&< \frac{-\delta^2 + \delta\beta - 10\beta - 2\frac{\delta^2 u_T}{t}}{6\beta + 4c - 4\delta\beta + 2\frac{\delta u_T}{t}} + \frac{-\beta - 2\delta\beta\mu^* + \delta}{4c - \delta\beta},
\end{aligned}
$$

where the last inequality is implied by $u_T \geq \frac{\Delta u}{2}$. The derivative of R.H.S with respect to u_T is

$$
\frac{2\delta}{t}\frac{-\delta\left[6\beta + 4c - 4\delta\beta\right] + \delta^2 - 4\delta\beta + 10\beta}{(6\beta + 4c - 4\delta\beta + 2\frac{\delta u_T}{t})^2},
$$

and this is negative, since $c > \frac{\delta}{4} - \frac{\beta}{2} + \delta\beta$[25], and $\delta > \frac{1}{\mu^{**}} \geq 2$. Therefore, The R.H.S is decreasing in u_T. Hence,

$$
\begin{aligned}
\frac{\delta h'(c)}{\mu^{**}} &< \frac{-\delta^2 + \delta\beta - 10\beta}{6\beta + 4c - 4\delta\beta} + \frac{-\beta - 2\delta\beta\mu^* + \delta}{4c - \delta\beta} \\
&< \frac{-\delta^2 + \delta\beta - 10\beta}{4c - \delta\beta} + \frac{-\delta\beta - 2\delta^2\beta\mu^* + \delta^2}{4c - \delta\beta} \\
&= \left(\frac{1}{4c - \delta\beta}\right)\left(-10\beta - 2\delta^2\beta\mu^*\right) < 0.
\end{aligned}
$$

This implies $h'(c)$ is negative, or equivalently $h(c)$ is decreasing in c.

b) $\frac{\delta}{2} + \frac{\beta}{2} + \frac{\delta\beta}{4} \leq c < \frac{u_T}{t}(\frac{\delta}{2} - 1) + \frac{\delta}{2} + \frac{3}{4}\delta\beta - \frac{\beta}{2}$: In this case, $\frac{\delta+\beta}{4c-\delta\beta} = \mu^* < \mu^{**} = \frac{1}{2}$.

[25] In (a), we assumed $c \geq \frac{u_T}{t}(\frac{\delta}{2} - 1) + \frac{\delta}{2} + \frac{3}{4}\delta\beta - \frac{\beta}{2}$. Since $\delta \geq 2$, we can conclude $c \geq \frac{\delta}{2} + \frac{3}{4}\delta\beta - \frac{\beta}{2} = (\frac{\delta}{4} + \frac{3}{4}\delta\beta) + (\frac{\delta}{4} - \frac{\beta}{2}) \geq \delta\beta + \frac{\delta}{4} - \frac{\beta}{2}$, where the last inequality is implied by the fact $\beta \leq 1$.

We can write (9) as:

$$h(c) = \frac{1}{4}(\delta - c) - \frac{\delta}{2}\mu^* + c\mu^{*^2} + (\frac{\delta}{2} - 1)(\frac{\beta}{2} + \frac{u_T}{t}).$$

Hence,

$$\begin{aligned} h'(c) = -\frac{1}{4} - \frac{\delta}{2}\mu^{*'} + 2c\mu^*\mu^{*'} + \mu^{*^2} &= -\frac{1}{4} + \mu^{*^2} + \mu^{*'}\left(-\frac{\delta}{2} + 2c\mu^*\right) \\ &= -\frac{1}{4} + \mu^{*^2} + \mu^{*'}\left(\frac{\beta}{2} + \frac{\delta\beta}{2}\mu^*\right) < 0, \end{aligned}$$

where the inequality is obtained from $-\frac{1}{4} + \mu^{*^2} < 0$, and $\mu^{*'} < 0$.

c) $c < \frac{\delta}{2} + \frac{\beta}{2} + \frac{\delta\beta}{4}$: In this case, $\mu^* = \mu^{**} = \frac{1}{2}$. Thus, $\pi^{**} - \pi^* = (\frac{\beta}{2} + \frac{u_T}{t})(\frac{\delta}{2} - 1) > 0$.

So far we have shown $\pi^{**} - \pi^*$ is strictly decreasing with c, and gets positive values for $c < \frac{\delta}{2} + \frac{\beta}{2} + \frac{\delta\beta}{4}$. To prove (ii) it is sufficient to show $\pi^{**} - \pi^*$ gets negative values for some values of c. Assume c is such that $\mu^* \leq \mu^{**} = \frac{1}{\delta}$, and

$$\begin{aligned} \pi^{**} - \pi^* &= (\mu^{**} - \mu^*)\left(-c(\mu^{**} + \mu^*) + \frac{\delta}{2}\right) \\ &< (\mu^{**} - \mu^*)\left(-2c\mu^* + \frac{\delta}{2}\right) \\ &= (\mu^{**} - \mu^*)\left(-\frac{\delta\beta}{2}\mu^* - \frac{\beta}{2}\right) < 0 \end{aligned}$$

B1. Extension I: asymmetric issues

In the baseline model, we assumed that all issues are of equal importance in terms of probability of click, which is not realistic. We discuss here what happens if we assume that some issues (such as those covering major events) have a higher probability of click than the other issues. Let $\mathcal{S} \equiv \mathcal{S}_A \cup \mathcal{S}_B$ where $\mathcal{S}_A \cap \mathcal{S}_B = \emptyset$. Given a high-quality article, the probability for a reader to click its link is p_A (p_B) if the issue covered by the article belongs to $\mathcal{S}_A$ ($\mathcal{S}_B$), with $p_A > p_B$. The probability of click is zero for low-quality articles. If the difference between p_A and p_B is large enough and the measure of $\mathcal{S}_A$ is not too large, regardless of the presence of the aggregator, both newspapers will cover all issues in $\mathcal{S}_A$ with high quality (i.e., both newspapers cover major events with high-quality articles). Therefore, we can interpret u_0 as the utility from reading a home page and high-quality articles covering major events, which makes the assumption $u_0 > t$ more easily satisfied. In addition, assumption A3 is relaxed as follows:

$$C\left(\mu(\mathscr{s}_i)\right) = \begin{cases} \infty & \mu(\mathscr{s}_i) > \mu(\mathcal{S}_A) + \mu(\mathcal{S}_B)/2 \\ c\mu(\mathscr{s}_i)^2 & \mu(\mathscr{s}_i) \leq \mu(\mathcal{S}_A) + \mu(\mathcal{S}_B)/2. \end{cases}$$

Since this extension is isomorphic to the baseline model, we can conclude that the aggregator induces newspapers to specialize in the coverage of the issues belonging to $\mathcal{S}_B$ (i.e., those which are not major events of the day but have important social concerns such as climate change, income inequality etc.) and to increase the quality of the articles on these issues.

B2. Extension II: imperfect certification technology

When each newspaper provides an article of different quality on a given issue, let $(1+\Delta P)/2$ (respectively, $(1-\Delta P)/2$) represent the probability for the aggregator to provide the link to the high-quality article (respectively, to the low-quality article) where $\Delta P \in [0,1]$. $\Delta P = 1$ corresponds to the case of perfect certification technology in the baseline model. Our main results extend to the case of imperfect certification technology; the detailed analysis can be found in the supplementary materials.

First, Proposition 3 extends to the case of imperfect certification technology. We show that the specialization strategy is a dominant strategy under A1. Assuming that i's profit is concave with respect to μ_i,[26] we also prove that there exist two thresholds of δ such that $\mu^{**} = 0$ for all $\delta \leq \underline{\delta}(\Delta P)$ and $\mu^{**} = \frac{1}{2}$ for all $\delta \geq \bar{\delta}(\Delta P)(> \underline{\delta}(\Delta P)$ and that μ^{**} strictly increases with δ for $\delta \in \left[\underline{\delta}(\Delta P), \bar{\delta}(\Delta P)\right]$.

In order to perform quality comparison, we also rely on the result from the empirical papers (Athey, Mobius and Pal (2015) and Chiou and Tucker (2012)). Namely, an increase in the third-party content u_T increases traffic to the two newspapers for a given equilibrium quality of the newspapers. This implies

$$\frac{\partial \pi^A(\mu^{**}, \mu^{**}|\max)}{\partial u_T}\ |_{\mu^{**}=cst} > 0 \Leftrightarrow \Delta P \delta \mu^{**} > 1.$$

Using this condition, we find that Proposition 4(i) extends such that the presence of the aggregator increases quality. Furthermore, we find that the newspaper quality increases with the certification quality (i.e., $\partial\mu^{**}/\partial\Delta P$) as noisier certification weakens the readership-expansion effect.

Finally, we find that the effect of ΔP on newspapers' profits is ambiguous. However, as the aggregator's certification technology becomes less accurate, the business-stealing effect is more likely to dominate the readership-expansion effect,

[26]We did not assume concavity when $\Delta P = 1$. We can prove that the profit is concave for ΔP large enough under the assumption of $u_T > \Delta u$, which is stronger than the second part of A1.

which tends to decrease newspapers' profits. This finding offers a possible explanation for newspapers' complaint against Google News: they may find Google's algorithm to select news articles too noisy, resulting in low profits for them.

From now on, we prove the results we previously described about the extension. The utility that a reader with location x obtains from the aggregator is:

$$\begin{aligned}
U^{Agg}(x) &= \mu(\mathfrak{s}_1 - \mathfrak{s}_2)\left(\frac{1+\Delta P}{2}(\Delta u + u_0 - xt) + \frac{1-\Delta P}{2}(u_0 - (1-x)t)\right) \\
&+ \mu(\mathfrak{s}_2 - \mathfrak{s}_1)\left(\frac{1+\Delta P}{2}(\Delta u + u_0 - (1-x)t) + \frac{1-\Delta P}{2}(u_0 - xt)\right) \\
&+ \mu(\mathfrak{s}_2 \cap \mathfrak{s}_1)\left(\Delta u + u_0 - \frac{t}{2}\right) + (1 - \mu(\mathfrak{s}_2 \cup \mathfrak{s}_1))\left(u_0 - \frac{t}{2}\right) + u_T \\
&= u_0 + u_T + \Delta u\left(\frac{1+\Delta P}{2}\mu(\mathfrak{s}_2 \cup \mathfrak{s}_1) + \frac{1-\Delta P}{2}\mu(\mathfrak{s}_2 \cap \mathfrak{s}_1)\right) \\
&+ \Delta P(\mu_2 - \mu_1)xt - \frac{t}{2}(1 + \Delta P(\mu_2 - \mu_1)) \\
&= u_0 + u_T + \frac{\Delta u}{2}(\mu_1 + \mu_2 + \Delta P(\mu_1 + \mu_2 - 2\mu_{12})) \\
&+ \Delta P(\mu_2 - \mu_1)xt - \frac{t}{2}(1 + \Delta P(\mu_2 - \mu_1))\,.
\end{aligned}$$

The utility from newspaper 1 is not affected by ΔP.

$$U^1(x) = u_0 + \mu(\mathfrak{s}_1)\Delta u - xt.$$

Therefore, market share of newspaper 1 is given by:

$$0 < \alpha_1 = \frac{1}{2} - \frac{\frac{\beta}{2}\left[\mu_2 - \mu_1 + \Delta P(\mu_1 + \mu_2 - 2\mu_{12})\right] + \frac{u_T}{t}}{1 + \Delta P(\mu_2 - \mu_1)} \leq \frac{1}{2},$$

and by computing $\partial\alpha_1/\partial\mu_1$, we can show there exists a unique threshold $\hat{P}$ in $(0,1)$ such that $\partial\alpha_1/\partial\mu_1 \leq 0$ if and only if $\Delta P \geq \hat{P}$.

$$\frac{\partial\alpha_1}{\partial\mu_1} = \frac{\beta}{2}\frac{-2(\Delta P)^2(\mu_2 - \mu_{12}) - \Delta P(1 + 2\frac{u_T}{\Delta u}) + 1}{(1 + \Delta P(\mu_2 - \mu_1))^2}.$$

In Step 3 and Step 4 of the proof, we restrict attention to the case in which the quality without aggregator is interior (i.e., $\mu^* < 1/2$), which is equivalent to $c > \frac{\delta}{2} + \frac{\delta\beta}{4} + \frac{\beta}{2}$.

Step 1. — The profit of newspaper 1 is:

$$\begin{aligned}
\pi_1(\mathscr{s}_1) =& (1+\delta\mu(\mathscr{s}_1))\alpha_1 \\
&+ \delta(1-\alpha_1-\alpha_2)\left(\frac{1+\Delta P}{2}\mu(\mathscr{s}_1-\mathscr{s}_2)+\frac{1}{2}\mu(\mathscr{s}_2\cap\mathscr{s}_1)\right)-c\mu(\mathscr{s}_1)^2 \\
=& (1+\delta\mu(\mathscr{s}_1))\alpha_1 \\
&+ \frac{\delta}{2}(1-\alpha_1-\alpha_2)\left(\mu(\mathscr{s}_1)+\Delta P\left(\mu_1(\mathscr{s}_1)-\mu(\mathscr{s}_1\cap\mathscr{s}_2)\right)\right)-c\mu(\mathscr{s}_1)^2 \\
=& h(\mu(\mathscr{s}_1),\mu(\mathscr{s}_2))+\frac{\delta\beta\Delta P^2\mu(\mathscr{s}_1\cap\mathscr{s}_2)}{1-\Delta P^2\left(\mu(\mathscr{s}_1)-\mu(\mathscr{s}_2)\right)^2}\left[\mu(\mathscr{s}_1\cap\mathscr{s}_2)-g(\mu(\mathscr{s}_1),\mu(\mathscr{s}_2))\right],
\end{aligned}$$

where

$$\begin{aligned}
h(\mu(\mathscr{s}_1),\mu(\mathscr{s}_2)) =& \frac{1}{2}+\frac{\delta}{2}\mu(\mathscr{s}_1)-\frac{\frac{\beta}{2}\left[\mu(\mathscr{s}_2)-\mu(\mathscr{s}_1)+\Delta P(\mu(\mathscr{s}_1)+\mu(\mathscr{s}_2))\right]+\frac{u_T}{t}}{1+\Delta P(\mu(\mathscr{s}_2)-\mu(\mathscr{s}_1))} \\
&+\frac{\delta\mu(\mathscr{s}_1)}{2}\frac{\frac{\beta}{2}\left[\mu(\mathscr{s}_1)-\mu(\mathscr{s}_2)+\Delta P(\mu(\mathscr{s}_1)+\mu(\mathscr{s}_2))\right]+\frac{u_T}{t}}{1+\Delta P(\mu(\mathscr{s}_1)-\mu(\mathscr{s}_2))}(1+\Delta P) \\
&-\frac{\delta\mu(\mathscr{s}_1)}{2}\frac{\frac{\beta}{2}\left[\mu(\mathscr{s}_2)-\mu(\mathscr{s}_1)+\Delta P(\mu(\mathscr{s}_1)+\mu(\mathscr{s}_2))\right]+\frac{u_T}{t}}{1+\Delta P(\mu(\mathscr{s}_2)-\mu(\mathscr{s}_1))}(1-\Delta P) \\
&-c\mu(\mathscr{s}_1)^2,
\end{aligned}$$

(B4)
$$\begin{aligned}
g(\mu(\mathscr{s}_1),\mu(\mathscr{s}_2)) =& -\frac{3}{2}\mu(\mathscr{s}_1)^2+\mu(\mathscr{s}_1)\left(2\mu(\mathscr{s}_2)-\frac{1}{\delta}+\frac{3}{2}\right) \\
&-\frac{\mu(\mathscr{s}_2)}{2}\left(\mu(\mathscr{s}_2)-1-\frac{2}{\delta}\right)+\frac{1}{\Delta P}\left(\frac{u_T}{\Delta u}-\frac{1}{\delta}\right).
\end{aligned}$$

There are two cases:

a) $\mu_1 \leq \mu_2$: Maximum differentiation is a dominant strategy if and only if $\mu_1 \leq g(\mu_1,\mu_2)$, or equivalently:

$$\begin{aligned}
a(\mu_1,\mu_2) =& -\frac{3}{2}\mu_1^2+\mu_1\left(2\mu_2-\frac{1}{\delta}+\frac{1}{2}\right)-\frac{\mu(\mathscr{s}_2)}{2}\left(\mu(\mathscr{s}_2)-1-\frac{2}{\delta}\right) \\
&+\frac{1}{\Delta P}\left(\frac{u_T}{\Delta u}-\frac{1}{\delta}\right)\geq 0.
\end{aligned}$$

For $\mu_1 = 0$, $a(0,\mu_2) = -\frac{\mu(\mathscr{s}_2)}{2}\left(\mu(\mathscr{s}_2)-1-\frac{2}{\delta}\right)+\frac{1}{\Delta P}\left(\frac{u_T}{\Delta u}-\frac{1}{\delta}\right)$ is positive as long as $\frac{u_T}{\Delta u}\geq\frac{1}{\delta}$. And $a(\mu_2,\mu_2)>0$ if $\mu_2+\frac{1}{\Delta P}\left(\frac{u_T}{\Delta u}-\frac{1}{\delta}\right)>0$. Therefore, if $\frac{u_T}{\Delta u}\geq\frac{1}{\delta}$, maximum differentiation is a dominant strategy for any given

(μ_1, μ_2) satisfying $\mu_1 \leq \mu_2$.

b) $\mu_1 \geq \mu_2$: Newspaper 1 prefers maximum differentiation if and only if $\mu_2 \leq g(\mu_1, \mu_2)$. This is equivalent to:

$$b(\mu_1, \mu_2) = -\frac{3}{2}\mu_1^2 + \mu_1 \left(2\mu_2 - \frac{1}{\delta} + \frac{3}{2}\right) - \frac{\mu(\mathfrak{z}_2)}{2}\left(\mu(\mathfrak{z}_2) + 1 - \frac{2}{\delta}\right) + \frac{1}{\Delta P}\left(\frac{u_T}{\Delta u} - \frac{1}{\delta}\right) \geq 0.$$

$b(\mu_2, \mu_2) > 0$ as long as $\mu_2 + \frac{1}{\Delta P}\left(\frac{u_T}{\Delta u} - \frac{1}{\delta}\right) > 0$. Thus, $b(\mu_1, \mu_2) > 0$ for any given (μ_1, μ_2) satisfying $\mu_1 \geq \mu_2$ if $b(\frac{1}{2}, \mu_2) > 0$. We have:

$$b(\frac{1}{2}, \mu_2) = -\frac{1}{2}\mu_2^2 + \mu_2(\frac{1}{2} + \frac{1}{\delta}) + \frac{3}{8} - \frac{1}{2\delta} + \frac{1}{\Delta P}\left(\frac{u_T}{\Delta u} - \frac{1}{\delta}\right).$$

$\frac{u_T}{\Delta u} \geq \frac{3}{2\delta}$ implies $b(\frac{1}{2}, \mu_2) > 0$.

To conclude, $\frac{u_T}{\Delta u} \geq \frac{3}{2\delta}$ is the sufficient condition for the maximum differentiation to be a dominant strategy for any given (μ_1, μ_2).

Step 2. — Given the uniqueness of newspaper 1's best response to newspaper 2's quality μ_2,[27] it could take three values, 0, $\frac{1}{2}$ or the solution of $\pi'(\mu_1, \mu_2) = 0$ depending on the value of δ. Therefore, the symmetric equilibrium, μ^{**}, is:

2.1) $(0, 0)$: This is as an equilibrium, if $\pi_i'(\mathfrak{z}_i \mid \mu_i = \mu_j = 0) < 0$ for $i, j \in \{1, 2\}$. This is equivalent to $\delta \leq \underline{\delta}(\Delta P) \equiv \max\left\{\frac{\Delta P\left(u_T + \frac{\Delta u}{2}\right) - \frac{\Delta u}{2}}{\frac{t}{2} + u_T \Delta P}, 0\right\}$.

2.2) $(\frac{1}{2}, \frac{1}{2})$: This is an equilibrium, if $\pi_i'(\mathfrak{z}_i \mid \mu_i = \mu_j = \frac{1}{2}) > 0$ for $i, j \in \{1, 2\}$. This is equivalent to $\delta > \bar{\delta}(\Delta P) \equiv \frac{2tc + \Delta u \Delta P^2 - \Delta u(1 - \Delta P) + 2u_T \Delta P}{\frac{\Delta u}{2}(1 + 2\Delta P^2) + t + u_T \Delta P}$

2.3) $(\hat{\mu}, \hat{\mu}) \in (0, \frac{1}{2})^2$: For all δ satisfying $\underline{\delta}(\Delta P) < \delta \leq \bar{\delta}(\Delta P)$, we have $\pi_i'(\mathfrak{z}_i \mid \mu_i = \mu_j = \frac{1}{2}) < 0 < \pi_i'(\mathfrak{z}_i \mid \mu_i = \mu_j = 0)$. Therefore, $(\hat{\mu}, \hat{\mu})$ is an equilibrium, where $\hat{\mu}$ is the positive solution of $Q(\mu)$ defined as follows:

$$\begin{aligned} Q(\mu) \equiv \pi'(\mathfrak{z}_1 \mid \mu_1 = \mu_2 = \mu) \;=\; & \mu^2(-\delta\beta\Delta P^2) \\ & + \mu\left(-\beta\Delta P^2 + \frac{\delta\beta}{2}(1 + 3\Delta P^2) - \delta\Delta P\frac{u_T}{t} - 2c\right) \\ & + \frac{\delta}{2} + \frac{\beta}{2}(1 - \Delta P) + \frac{u_T}{t}(\delta - 1)\Delta P. \end{aligned}$$

[27] Under the assumption $u_T > \Delta u$, which is stronger than the second part of A1, we can find $\hat{\Delta P}$ such that for all $\Delta P > \hat{\Delta P}$ the profit function is concave. Therefore, the best response is unique.

STEP 3. — Now, we prove that μ^{**} is increasing in δ. For $\delta < \underline{\delta}$, μ^{**} is zero, and for $\delta < \bar{\delta}$, μ^{**} is 1/2. So it is sufficient to prove that μ^{**} is increasing in δ for $\delta \in [\underline{\delta}, \bar{\delta}]$. If $\delta \in [\underline{\delta}, \bar{\delta}]$, μ^{**} is the positive solution of $Q(\mu) = 0$. By fully differentiating $Q(\mu^{**}(\delta), \delta)$, we obtain

$$\mu^{**'}\left(-2\mu^{**}\delta\beta\Delta P^2 - \beta\Delta P^2 - \frac{\delta\Delta P}{t}(u_T - \frac{\Delta P\Delta u}{2}) + \frac{\delta\beta}{2}(1+2\Delta P^2) - 2c\right)$$
$$+\beta\Delta P^2\mu^{**}(1-\mu^{**}) + \mu^{**}(1+\Delta P^2)\frac{\beta}{2} + 1/2 + \Delta P u_T/t(1-\mu^{**}) = 0$$

As $c > \frac{\delta}{2} + \frac{\delta\beta}{4}$, the right term in the first line is negative. This together with the positivity of the second line implies $\mu^{**'}$ is positive.

STEP 4. — In this step, we compare the quality of newspapers, μ^{**} to the case of no aggregator, μ^*. We know $2c\mu^* - \frac{\delta\beta}{2}\mu^* = \frac{\delta}{2} + \frac{\beta}{2}$. Substituting it into $Q(\mu^{**}) = 0$ we get,

$$2(\mu^{**}-\mu^*)(c-\frac{\delta\beta}{4}) = \frac{\beta\Delta P}{2}(\Delta P\delta\mu^{**}-1) + \left(\frac{u_T}{t}\Delta P + \Delta P^2\beta\mu^{**}\right)(\delta-1-\delta\mu^{**}) \geq 0,$$

where we use $\Delta P\delta\mu^{**} > 1$ to prove that the first term on the R.H.S. is positive. For the second term on the R.H.S. to be positive, it is sufficient to have $\delta \geq 2$ since $\delta - 1 - \delta\mu^{**} \geq \frac{\delta}{2} - 1$. And $\delta \geq 2$ is implied by $\delta > \frac{1}{\Delta P\mu^{**}} \geq 2$. As a result, the aggregator improves the quality in the case of imperfect technology as well: we have $\mu^{**} > \mu^*$.

We now show how quality is affected by ΔP in this case. We have:

$$\frac{\partial Q}{\partial\Delta P} = \frac{\partial\mu^{**}}{\partial\Delta P}\left(\frac{1}{2}\delta\beta(1+2\Delta P^2) - 2c - \beta\Delta P^2 - 2\delta\beta\Delta P^2\mu^{**} - \frac{\delta\Delta P}{t}(u_T - \frac{\Delta P\Delta u}{2})\right)$$
$$+2\beta\Delta P(-\delta\mu^{**} - 1 + \frac{5}{4}\delta)\mu^{**} + \frac{\beta}{2}(\Delta P\delta\mu^{**} - 1) + \frac{u_T}{t}(\delta - 1 - \delta\mu^{**}) = 0.$$

The second term in the first line is negative since $c > \frac{\delta\beta}{4} + \frac{\delta}{2}$. The term in the second line is positive since $\Delta P\delta\mu^{**} > 1$ and $-\delta\mu^{**} - 1 + \frac{5}{4}\delta > \frac{3\delta}{4} - 1 > 0$. This implies $\frac{\partial\mu^{**}}{\partial\Delta P} > 0$.

We also find that the effect of ΔP on newspapers' profits in case of imperfect technology is ambiguous too. Using the envelope theorem, we find:

$$\frac{d\pi_1}{d\Delta P} = \frac{\partial\pi_1}{\partial\mu_1^{**}}\frac{\partial\mu_1^{**}}{\partial\Delta P} + \frac{\partial\pi_1}{\partial\mu_2^{**}}\frac{\partial\mu_2^{**}}{\partial\Delta P} + \frac{\partial\pi_1}{\partial\Delta P} = \frac{\partial\pi_1}{\partial\mu_2^{**}}\frac{\partial\mu_2^{**}}{\partial\Delta P} + \frac{\partial\pi_1}{\partial\Delta P}.$$

Using the condition from the empirical results $\Delta P\delta\mu^{**} > 1$, we can show that the direct effect for given quality of newspapers is positive (i.e., $\frac{\partial \pi_1}{\partial \Delta P} > 0$). This is so as newspapers benefit more from readership-expansion effect. However, the indirect effect through the rival's quality increase has an ambiguous sign due to $\partial \pi_1 / \partial \mu_2^{**}$. We can write

$$\frac{\partial \pi_1}{\partial \mu_2^{**}} = (1 + \delta \mu_1) \frac{\partial \alpha_1}{\partial \mu_2^{**}} + \frac{\delta}{2} \mu_1 (1 + \Delta P) \frac{\partial \alpha_{Agg}}{\partial \mu_2^{**}}$$

The aggregator's market share increases with the quality of newspaper 2 (i.e., $\frac{\partial \alpha_{Agg}}{\partial \mu_2^{**}} > 0$) while 1's market share decreases with the rival's quality (i.e., $\frac{\partial \alpha_1}{\partial \mu_2^{**}} < 0$). As ΔP increases, the former is more likely to dominate the latter such that for large ΔP, $\frac{\partial \pi_1}{\partial \mu_2^{**}}$ is positive.

B3. Extension III: Paywall

So far we assumed that advertising is the only source of revenue for newspapers. In this subsection, we consider the baseline model and allow each newspaper to charge a price. We assume that prices cannot be strictly negative.

In the presence of the aggregator, we find a sufficient condition for each newspaper to find charging zero price profit-maximizing. For this purpose, we analyze the following three-stage game:

- Stage 1: each newspaper i simultaneously chooses $\mathfrak{s}_j$.
- Stage 2: each newspaper i simultaneously chooses the price $p_i \geq 0$.
- Stage 3: each consumer chooses one among the two newspapers and the aggregator.

We assume that upon choosing a positive price, a newspaper blocks any incoming traffic from the aggregator. We have:

PROPOSITION 6: *Suppose A1-A3. In the presence of the aggregator, for any given pair of quality, $(\mu(\mathfrak{s}_1), \mu(\mathfrak{s}_2)) \in [0, 1/2]^2$, it is a dominant strategy for each newspaper i ($i = 1, 2$) to choose $p_i = 0$ if $t \leq \frac{4}{3}$.*

The proof is provided at the end of this subsection. The proposition shows a very intuitive result: if competition among newspapers is strong enough, each newspaper finds charging zero price profit-maximizing. It also explains why newspapers with market power such as Financial Times or Wall Street Journal want to erect a paywall.

In the case of the three-stage game without the aggregator, we study the symmetric equilibrium in which both newspapers choose the same quality μ^P and charge a strictly positive price p^P. We have:

PROPOSITION 7: *Suppose that there is no aggregator.*

(i) *There exists a symmetric equilibrium in which both newspapers choose the same quality* $\mu^P = \frac{\Delta u + \delta}{6c}$ *and charge a strictly positive price* p^P *if* $p^P = t - 1 - \delta\mu^P > 0$.

(ii) *If* $t \leq \frac{4}{3}$, *the newspapers choose a higher quality without a paywall than with a paywall (i.e.,* $\mu^* > \mu^P$*).*

(iii) *If* $t \leq \frac{4}{3}$ *and* $2\Delta u > \delta$, *then the newspapers' profits are higher with a paywall than without a paywall.*

The two propositions show that the aggregator may make the existence of a paywall equilibrium more difficult in the sense that if $t \leq \frac{4}{3}$, the equilibrium with paywalls can exist without the aggregator, but does not exist with the aggregator. In addition, the last proposition shows that without the aggregator, paywalls soften quality competition such that newspapers choose lower quality and earn higher profits than without paywalls, under a reasonable assumption that $2\Delta u > \delta$.[28] Therefore, our result that the aggregator increases newspapers' quality is robust to allowing for paywalls as long as competition between the newspapers is fierce enough. Our finding also provides another explanation for why newspapers complain about Google News: news aggregator intensifies competition among newspapers such that it is more difficult to erect paywalls.

We below provide the proofs of the two propositions of this extension.

PROOF OF PROPOSITION 6:

Assume for the moment that newspaper 2 chooses $p_2 = 0$ and does not block the traffic from the aggregator. Then, the market share of newspaper 1 is

(B5)
$$\alpha_1 = \frac{1}{2} - \frac{1}{t}\frac{(\mu(s_2) - \mu(s_1))\,\Delta u + u_T + p_1}{1 + \mu(s_2)},$$

and its profit is given by

(B6)
$$\pi_1 = \alpha_1(1 + \delta\mu_1 + p_1) - c\mu_1^2.$$

Since the profit function is concave with respect to price, it is sufficient to show $\frac{\partial \pi_1}{\partial p_1}\mid_{p_1=0} < 0$. We have

$$\left.\frac{\partial \pi_1}{\partial p_1}\right|_{p_1=0} < 0 \Leftrightarrow \frac{t}{2}(1 + \mu_2) - \delta\mu_1 - 1 + (\mu_1 - \mu_2)\Delta u - u_T < 0.$$

[28]If newspaper i's quality increases, i can appropriate it by increasing its price p_i but, under the assumption, the price gap $p_i - p_j$ (for $i \neq j$) increases as well and thereby reduces 1's market share. When competition is strong enough, the second effect dominates the first effect such that paywalls soften quality competition.

This is satisfied for any $(\mu_1, \mu_2) \in [0, 1/2]^2$, if $t < 4/3$. Since $t < 4/3$ implies

$$\frac{t}{2}(1+\mu_2) - 1 < 0,$$

we have

$$\frac{t}{2}(1+\mu_2) - \delta\mu_1 - 1 + (\mu_1 - \mu_2 - 1/2)\Delta u < 0.$$

Hence, from A1 we can conclude $\left.\frac{\partial \pi_1}{\partial p_1}\right|_{p_1=0} < 0$. This shows that if $t < 4/3$, $p_1 = 0$ is a best response to $p_2 = 0$. In addition, our proof proves that $p_1 = 0$ is best response for $p_2 > 0$ since $p_2 > 0$ (and hence blocking the traffic from the aggregator) corresponds to the special case of $\mu_2 = 0$ and the proof works for this case.

Proof of Proposition 7. — (i) When both newspapers charge prices, the market share of newspaper 1 is

$$\alpha_1 = \frac{1}{2} + \frac{(\mu_1 - \mu_2)\Delta u + (p_2 - p_1)}{2t}. \tag{B7}$$

Newspaper's 1 profit is

$$\pi_1 = \alpha_1(1 + \delta\mu_1 + p_1) - c\mu_1^2.$$

Given μ_1, and μ_2, from the first-order condition with respect to p_1, we find 1's best response price as follows.

$$BR_1(p_1, \mu_1, \mu_2) = \frac{t}{2} + \frac{\Delta u}{2}(\mu_1 - \mu_2) + \frac{p_2}{2} - \frac{1}{2} - \frac{\delta\mu_1}{2}.$$

$BR_2(\cdot)$ is similarly obtained. Therefore, the equilibrium price of 1 for given qualities is

$$p_1 = t + \frac{\Delta u}{3}(\mu_1 - \mu_2) - 1 - \frac{2\delta\mu_1}{3} - \frac{\delta\mu_2}{3}, \tag{B8}$$

implying

$$p_2 - p_1 = \frac{1}{3}(\mu_2 - \mu_1)(2\Delta u - \delta),$$

$$\alpha_1 = \frac{1}{2} + \frac{(\mu_1 - \mu_2)(\Delta u + \delta))}{6t}, \tag{B9}$$

(B10)
$$\pi_1 = \frac{1}{2t}\left(t + \frac{1}{3}(\mu_1 - \mu_2)(\Delta u + \delta)\right)^2 - c\mu_1^2$$

From the first order condition with respect to μ_1, we obtain the equilibrium quality under paywall, μ^P, in the symmetric equilibrium, $\mu_1 = \mu_2$, as follows.

(B11)
$$\mu^P = \frac{\Delta u + \delta}{6c}.$$

The equilibrium profit under paywall is

$$\pi^P = \frac{t}{2} - c\mu^{P^2}$$

(ii) We have

$$\begin{aligned}
\mu^P &< \mu^* \Leftrightarrow \\
\frac{\Delta u + \delta}{6c} &< \frac{\frac{\Delta u}{t} + \delta}{4c - \delta\frac{\Delta u}{t}} \Leftrightarrow \\
4c(\Delta u + \delta) - \delta\frac{\Delta u}{t}(\Delta u + \delta) &< 6c\frac{\Delta u}{t} + 6c\delta \Leftrightarrow \\
c(4\Delta u - 2\delta - 6\frac{\Delta u}{t}) &< \delta\frac{\Delta u}{t}(\Delta u + \delta)
\end{aligned}$$

Since the R.H.S. is always positive, it is sufficient to show that the L.H.S. is negative. We show $(4 - 6/t)\,\Delta u < 0$.

(B12)
$$t < \frac{4}{3} \Leftrightarrow -\frac{1}{t} < -\frac{3}{4} \Leftrightarrow 4 - \frac{6}{t} < 4 - \frac{18}{4} = -\frac{1}{2}.$$

(iii)

$$\begin{aligned}
\pi^P &> \pi^* \Leftrightarrow \\
\frac{t}{2} - c\mu^{P^2} &> \frac{1}{2} + \frac{\delta}{2}\mu^* - c\mu^{*^2} \Leftrightarrow \\
(\mu^* - \mu^P)\left(c\mu^* + c\mu^P\right) + \left(\frac{t}{2} - \frac{1}{2} - \frac{\delta}{2}\mu^*\right) &> 0 \Leftrightarrow \\
(\mu^* - \mu^P)\left(c\mu^* + c\mu^P - \frac{\delta}{2}\right) + \left(\frac{t}{2} - \frac{1}{2} - \frac{\delta}{2}\mu^P\right) &> 0 \Leftrightarrow
\end{aligned}$$

We know $t - 1 - \delta\mu^p$ is the equilibrium price and therefore is positive. We also know $\mu^* > \mu^P$. Therefore, $\pi^P > \pi^*$, if $c\mu^* + c\mu^P - \frac{\delta}{2} > 0$. We have:

$$c\mu^* + c\mu^P - \frac{\delta}{2} > 2c\mu^P - \frac{\delta}{2} = \frac{\Delta u + \delta}{3} - \frac{\delta}{2} = \frac{2\Delta u - \delta}{6} > 0. \tag{B13}$$