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Platform Preannouncement Strategies: The Strategic Role of Information in Two-Sided Markets Competition

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Online Appendix

Proofs of Lemmas 1-3 are provided in Appendix A in the paper. In this Appendix, we provide the proofs of the remaining Lemmas and Propositions.

Proofs of Lemma 4

We derive the proof for this Lemma by considering the Informal strategy (as opposed to formal for the no-switching case) so that the reader might see that the solution techniques employed are consistent across the different strategies while avoiding redundancies. In order to derive the optimal prices and licensing fees for when firms preannounce informally, we derive the user demand function from the Hotelling specification using equation (17). As earlier, we find the location of the indifferent user by equating $U_{u,I}^{i} - tn_{u,I}^{i} = U_{u,I}^{-i} - t\left[1 - n_{u,I}^{i}\right]$ and derive the user-side demand as

$$n_u^i = \frac{1}{2} - \frac{t\left[p^i - p^{-i}\right] + 2\beta\mu\left[l^i - l^{-i}\right]}{2\left[t\left[t - 2\mu\alpha\right] - 4\mu\delta\beta^2\right]} \tag{B1}$$

Similarly, the developer-side demand (using equation (18)) as a function of prices and fees is

$$n_d^i = \frac{1}{2} - \frac{2\delta\beta\left[p^i - p^{-i}\right] + \left[t - 2\mu\alpha\right]\left[l^i - l^{-i}\right]}{2\left[t\left[t - 2\mu\alpha\right] - 4\mu\delta\beta^2\right]} \tag{B2}$$

Substituting equations (B1) and (B2) in equation (19) gives us the profit function of firm i and differentiating with respect to p^i and l^i gives the best response of the focal firm. Similarly, we can construct the objective function of the other firm $\max\limits_{p^{-i},l^{-i}} \pi_I^{-i}$, and differentiating with respect to p^{-i} and l^{-i}, we get its response function. As earlier, for these to be SPNE, we need also to simultaneously determine the feasibility bounds considering profits from both the Formal and No-preannouncement strategies.

Once again, the constraints are imposed by agent participation, concavity conditions, positive tariffs, and profits. Further, we must ensure that $U^{i}_{u,I}$ realized $\geq U^{-i}_{u,I}$ realized and $U^{i}_{d,I}$ realized $\geq U^{-i}_{d,I}$ realized so that consumers do not change their platform adoption decision post release. It is sufficient to check these conditions for the indifferent consumer alone, and the location of the indifferent consumer does not change post platform release (due to symmetric platforms). Similar to the steps in Lemmas 1-3, from equations (17) and (B1) for the users and equations (18) and (B2) for the developers, we get bounds that satisfy user participation as

$$t < \frac{2\left[\theta + \mu\left[3\alpha + \beta\right] + 2\delta\beta\right]}{3}; \qquad t < \frac{2\left[\theta + \left[2\mu + \delta\right]\beta\right]}{3}$$

Positive profits require $t \geq \dfrac{kc + 2\mu\left[\alpha + \beta\right] + 2\delta\beta}{2}$

Concavity conditions and positive tariffs require

$$\begin{array}{ll} t > 2\mu\alpha; & t\left[t - 2\mu\alpha\right] > 4\mu\delta\beta^2 \\ t > 2\mu\alpha + 2\delta\beta; & t > 2\mu\beta \end{array}$$

Considering all these constraints together, through reduction, we can characterize the potential bounds where II is SPNE to be defined as:

$$t_{\,I,I} \in \left(\begin{array}{l} \max\left(2\mu\alpha + 2\delta\beta,\ 2\mu\beta,\ \mu\alpha + \left[\mu + \delta\right]\beta + \dfrac{kc}{2}\right), \\ \dfrac{2\left[\theta + \left[2\mu + \delta\right]\beta\right]}{3} \end{array} \right) \tag{B3}$$

In a similar fashion, we can have the potential bounds for the other two cases as:

$$\begin{array}{c} t_{\,F,F} \in \left(\max\left(2\alpha + 2\beta,\ \alpha + 2\beta + \dfrac{c}{2}\right), \dfrac{2\theta}{3} + 2\beta\right) \\ t_{\,N,N} \in \left(0, \dfrac{2\theta}{3}\right) \end{array} \tag{B4}$$

Therefore, now incorporating the optimal prices and licensing fees and considering them along with these feasibility bounds. Thus, the Formal strategy equilibrium bounds characterized over t is

$$t^*_{F,F} \in \left(\frac{2\left[\theta + \left[2\mu + \delta\right]\beta\right]}{3}, \frac{2\theta}{3} + 2\beta \right) \tag{B5}$$

Similarly, we can derive the bounds for the other two equilibrium outcomes as

$$t^*_{I,I} \in \left(\frac{2\theta}{3}, \frac{2\left[\theta + \left[2\mu + \delta\right]\beta\right]}{3} \right) \tag{B6}$$

$$t^*_{N,N} \in \left(0, \frac{2\theta}{3} \right) \tag{B7}$$

Therefore, we have Lemma 4.

Proofs of Proposition 1

From Lemmas 1-3 and Lemma 4, we know the prices and licensing free of SH-NSW and SH-SW markets. The profits respectively (we only illustrate the Informal case) are

$$\begin{aligned} \pi^{i^*\ SH-NSW}_{I,I} &= 2t - kc - \mu\left[\alpha + \beta\right] - \delta\beta \\ \pi^{i^*\ SH-SW}_{\{I,I\}} &= 2t - kc - 2\mu\left[\alpha + \beta\right] - 2\delta\beta \end{aligned}$$

Comparing the two cases and considering the parameter constraints, we have

$$\pi^{i*\ SH-NSW}_{I,I} - \pi^{i*\ SH-SW}_{I,I} = \mu\left[\alpha + \beta\right] + \delta\beta > 0$$

$$\begin{aligned} p^{i*\ SH-NSW}_{I,I} - p^{i*\ SH-SW}_{I,I} &= \mu\alpha + \delta\beta > 0 \\ l^{i*\ SH-NSW}_{I,I} - l^{i*\ SH-SW}_{I,I} &= \mu\beta > 0 \end{aligned}$$

We can similarly verify that this is true for the FF and NN cases as well.

Proof of Lemma 5 and Proposition 2

We derive the proof for Lemma 5 by considering the Informal strategy (a similar technique can be used for Formal and No-preannouncement strategies as well). In order to derive the optimal prices and licensing fees when firms preannounce informally, we derive the user demand function from the Hotelling specification using equation (21). As earlier, we find the location of the indifferent user by equating $U^i_{u,I} - tn^i_{u,I} = U^{-i}_{u,I} - t\left[1 - n^i_{u,I}\right]$ and derive the user-side demand as

$$n_u^i = \frac{1}{2} + \frac{-t\left[p^i - p^{-i}\right] - \beta\mu\left[l^i - l^{-i}\right] + \Delta m_u\left[\mu\alpha t + \delta\beta^2\mu\right] + \Delta m_d \mu\beta t}{2\left[t\left[t - \alpha\mu\right] - \beta^2\mu\delta\right]} \tag{B8}$$

Similarly, the developer side demands for single and multi-homing developers (using equation (20)) are

$$\begin{aligned} n_d^i &= \frac{\left[\begin{array}{l} 2t^3 - \beta^2\delta\left[l^i - 2\beta\delta\right]\mu + t^2\left[\left[2m_u^i - 3\right]\beta\delta - 2\alpha\mu\right] \\ -t\beta\delta\left[p^i - p^{-i} + \left[\left[2 - \Delta m_d\right]\beta - 2\alpha\right]\mu\right] + l^{-i}\left[2t^2 - 2\mu\alpha t - \beta^2\delta\mu\right] \end{array}\right]}{2t\left[t\left[t - \mu\alpha\right] - \mu\delta\beta^2\right]} \\ n_d^{i,-i} &= \frac{2\delta\beta - \left[l^i + l^{-i}\right] - t}{t} \end{aligned} \tag{B9}$$

Substituting (B8) and (B9) in equation (22), gives us the profit function of firm i and differentiating with respect to p^i and l^i gives the best response of the focal firm. Similarly, we can construct the objective function of the other firm $\max_{p^{-i},l^{-i}} \pi_I^{-i}$, and differentiating with respect to p^{-i} and l^{-i}, we get its response function. As earlier, for these to be SPNE, we also need to simultaneously determine the feasibility bounds taking into account profits from both the Formal and No-preannouncement strategies.

Once again, the constraints are imposed by agent participation, concavity conditions, positive tariffs, and profits. Similar to the steps in Lemmas 1-3, from equations (21) and (B8) for the users and equations (20) and (B9) for the developers, we get bounds that satisfy user participation as

$$\begin{aligned} t &< \frac{4\theta + 12\mu\alpha + \left[6\mu + \delta\right]\beta - \sqrt{\begin{array}{l} 80\delta \;\; 3\mu + \delta \;\; \beta^2 \\ + \;\; 4\theta + 6\mu \;\; 2\alpha + \beta \;\; + \delta\beta \;\; ^2 \end{array}}}{20}, \\ t &< \frac{2\left[\theta + \left[\mu + \delta\right]\beta\right]}{3} \end{aligned}$$

Positive profits require $\frac{33}{16}t - kc - 2\mu\alpha - \frac{\beta^2\left[\mu^2 + \delta^2 + 6\mu\delta\right]}{4t} \geq 0$

Concavity conditions and positive tariffs require

$$t\left[t - \mu\alpha\right] > \mu\delta\beta^2, \; 2t - 2\mu\alpha - \frac{\delta\beta}{4} - \frac{\delta\left[3\mu + \delta\right]\beta^2}{2t} > 0$$

Further, the market coverage on the developer side of the market require $n_d^i + n_d^{-i} + n_d^{i,-i} = 1$ and $0 < n_d^{i,-i} < 1$. This translates to the following condition.

$$\frac{3t-2}{2\left[\mu+\delta\right]} < \beta < \frac{3t}{2\left[\mu+\delta\right]}$$

Considering all these constraints together, through reduction, we can characterize the potential bounds where II is SPNE to be defined as:

$$t_{I,I} \in \left(\frac{4\theta + 12\mu\alpha + \left[6\mu+\delta\right]\beta - \sqrt{80\delta\left[3\mu+\delta\right]\beta^2 + \left[4\theta+6\mu\left[2\alpha+\beta\right]+\delta\beta\right]^2}}{20}, \frac{2\left[\theta+\left[\mu+\delta\right]\beta\right]}{3} \right) \tag{B10}$$

Similarly, considering the utility functions, profit functions concavity conditions and others, we can have the potential bounds for the other two cases as:

$$t_{F,F} \in \left(\frac{4\theta + 12\alpha + 7\beta - \sqrt{320\beta^2 + \left[4\theta+6\left[2\alpha+\beta\right]+\delta\beta\right]^2}}{20}, \frac{2\left[\theta+2\beta\right]}{3} \right) \quad t_{N,N} \in \left(0, \frac{2\theta}{3}\right) \tag{B11}$$

Now incorporating the optimal prices and licensing fees and considering them along with these feasibility bounds, the Formal strategy equilibrium bounds characterized over t is

$$t^*_{F,F} \in \left(\frac{2\left[\theta+\left[\mu+\delta\right]\beta\right]}{3}, \frac{2\left[\theta+2\beta\right]}{3} \right) \tag{B12}$$

Similarly, we can derive the bounds for the other two equilibrium outcomes as

$$t^*_{I,I} \in \left(\frac{2\theta}{3}, \frac{2\left[\theta+\left[\mu+\delta\right]\beta\right]}{3} \right) \tag{B13}$$

$$t^*_{N,N} \in \left(0, \frac{2\theta}{3}\right) \tag{B14}$$

Therefore, we have Lemma 5 for the MH-NSW setting.

Using a similar technique for the MH-SW setting (above), we can derive equilibrium candidate prices, licensing fees, demands from users/developers and firm profits for the different preannouncement strategies. Again, for brevity, we derive these conditions for the Informal strategy in the proof (similar conditions can be found for Formal and No preannouncement strategies). As earlier, in order for these to be SPNE, we need also to simultaneously determine the feasibility bounds taking into account profits from both the Formal and No-preannouncement strategies. Once again, the constraints are imposed by agent participation, concavity conditions, positive tariffs, and profits.

The conditions that ensure agent participation are

$$\theta - \frac{5t}{2} + \frac{4\mu\left[5\alpha+\beta\right]+\delta\beta}{4} + \frac{2\beta^2\delta\left[6\mu+\delta\right]}{4t} \geq 0,$$
$$\theta - \frac{3t}{2} + \beta\left[2\mu+\delta\right] \geq 0$$

Market coverage on user and developer side require

$$\frac{2t}{3\left[2\mu+\delta\right]} < \beta < \frac{4t}{\left[2\left[2\mu+\delta\right]\right]}$$

Further, non-negative firm profits and concavity in prices and licensing fees (positive tariffs) require

$$-\frac{16ckt - 33t^2 + 64t\alpha\mu + 4\beta^2 \quad \delta^2 + 12\delta\mu + 4\mu^2}{16t} \geq 0,$$
$$t\left[t - 2\mu\alpha\right] > 2\mu\delta\beta^2,$$
$$t > 2\mu\alpha + \beta + \frac{2\delta\beta^2\left[6\mu+\delta\right]}{8t}$$

In the above analysis, note that there is no differentiation between firms in terms of strength of network effects or market characteristics. We find that for such identical firms, all the conditions stated above cannot be satisfied simultaneously. In other words, there is no pair of non-negative price and licensing fees for which all the remaining constraints can be satisfied. This holds true for the remaining symmetric strategies FF, NN as well. Thus, there is no SPNE in symmetric strategies in MH-SW setting when firms are identical across all parameters. However, even if some of the strength of network effects were different, e.g., μ^i, μ^{-i} or δ^i, δ^{-i} then such differentiation between firms may enable the necessary conditions to be true. This gives us Proposition 2 for the MH-SW setting.

Proof of Propositions 3 and 4

From equations (25) and (26), we can compute the consumer and social welfare for the single-homing settings. In the multi-homing setting, however, the developer welfare includes utilities derived by both single and multi-homing developers. Specifically, if $y_1 \;\; y_2$ is the locations of the developer indifferent between single-homing with firm $i \;\; -i$ and multi-homing, then

$$w_{d,\;\;s,s} = \int_0^{y_1} U_{d,s}^{i} dx + \int_{y_1}^{y_2} U_{d,s}^{i,-i} dx + \int_{y_2}^{1} U_{d,s}^{-i} dx \text{ where } s \in \;\; F, I, N \;\; .$$

Below we list the consumer and social welfare of symmetric strategies in the different settings (SH-NSW, SH-SW, and MH-NSW).

SH-NSW:

$$w_{F,F} = 2\theta + 2\alpha + 4\beta - \frac{5t}{2}, W_{\{F,F\}} = 2\theta - 2c + \frac{3t}{2}$$
$$w_{I,I} = 2\theta + \left[1+\mu\right]\alpha + \left[2+\mu+\delta\right]\beta - \frac{5t}{2}, W_{\{I,I\}} = 2\theta + \left[1-\mu\right]\alpha + \left[2-\mu-\delta\right]\beta - 2kc + \frac{3t}{2}$$
$$w_{N,N} = 2\theta + \alpha + 2\beta - \frac{5t}{2}, W_{\{N,N\}} = 2\theta + \alpha + 2\beta + \frac{3t}{2}$$

SH-SW:

$$w_{F,F} = 2\theta + 3\alpha + 6\beta - \frac{5t}{2}, W_{\{F,F\}} = 2\theta - \alpha - 2c + \frac{3t}{2}$$
$$w_{I,I} = 2\theta + \left[1+2\mu\right]\alpha + 2\left[1+\mu+\delta\right]\beta - \frac{5t}{2}, W_{\{I,I\}} = 2\theta + \left[1-2\mu\right]\alpha + 2\left[1-\mu-\delta\right]\beta - 2kc + \frac{3t}{2}$$
$$w_{N,N} = 2\theta + \alpha + 2\beta - \frac{5t}{2}, W_{\{N,N\}} = 2\theta + \alpha + 2\beta + \frac{3t}{2}$$

MH-NSW:

$$w_{\{F,F\}} = \frac{7\theta}{4} - \frac{19t}{8} + 3\alpha + \frac{3\beta}{4} + \frac{\beta\left(4\beta + \theta\right)}{t}, W_{\{F,F\}} = 2\theta - 2c - \alpha + \frac{31t}{16}$$

$$w_{\{I,I\}} = \frac{\left[2t\left[7\theta + \left[4 + \delta - 2\mu\right]\beta + \left[4 + 8\mu\right]\alpha\right] + 4\beta\left[\begin{matrix}\left[2 - \delta + \mu\right]\theta \\ +\beta\left[\mu\left[2 + \mu\right] + \left[2 + 3\mu\right]\delta\right]\end{matrix}\right] - 19t^2\right]}{8t},$$

$$W_{\{I,I\}} = \frac{\left[\begin{matrix}7t^2 - 8ckt + 2\beta\left[2 - \delta\right]\left[\theta + \beta\delta\right] + 2\beta\left[\theta + \beta\left[2 - 3\delta\right]\right]\mu \\ +t\left[4\alpha + \beta\left[4 + \delta\right] + 7\theta - 2\left[4\alpha + \beta\right]\mu\right]\end{matrix}\right]}{4t}$$

$$w_{\{N,N\}} = \frac{7\theta}{4} + \frac{\beta\theta}{t} - \frac{19t}{8} + \alpha + \beta,$$

$$W_{\{N,N\}} = \frac{\left[7t^2 + 4\beta\theta + t\left[4\alpha + 4\beta + 7\theta\right]\right]}{4t}$$

Inspecting the consumer and social welfare above for the same setting (SH-NSW, SH-SW or MH-NSW), we can verify that $w_{\{N,N\}} < w_{\{I,I\}} < w_{\{F,F\}}$ and $W_{\{N,N\}} > W_{\{I,I\}} > W_{\{F,F\}}$ (Proposition 3). Note that in the MH-NSW setting, this order is driven by $t > \alpha + \beta$, a conditions necessary for non-negative prices (see prices in Lemma 5) and concavity of profit function with respect to prices and licensing fees (see Proof of Lemma 5). For the existence of our equilibrium solutions, it is ensured that the platform i's indifferent consumer's utility continues to be greater than or equal to what he may have derived from the other platform. The equilibria $\left(s^{i*}, s^{-i*}\right) \in \left\{\left(F,F\right), \left(I,I\right), \left(N,N\right)\right\}$ derived in the paper ensures that this condition is always met.

$w^{SH-SW}_{F,F} - w^{SH-NSW}_{F,F} = \alpha + 2\beta > 0$, $w^{SH-SW}_{N,N} - w^{SH-NSW}_{N,N} = 0$. Further, for informal preannouncement, $w^{SH-SW}_{I,I} - w^{SH-NSW}_{I,I}$ is monotonically decreasing in μ and δ. In other words, the impact of switching on welfare decreases with more information available to users and developers. Thus, $w^{SH-SW}_{s,s} \geq w^{SH-NSW}_{s,s}$.

Similarly, $W^{SH-SW}_{F,F} - W^{SH-NSW}_{F,F} = -\alpha < 0$, $W^{SH-SW}_{N,N} - W^{SH-NSW}_{N,N} = 0$ and $W^{SH-SW}_{I,I} - W^{SH-NSW}_{I,I}$ is monotonically decreasing in μ and δ. Thus, consumer and social welfare across SH-NSW and SH-SW cases for a given equilibrium strategy, consumer welfare is higher when the installed base of agents can switch. However, the social welfare is greater when agents cannot switch (Proposition 4(i)).

Next, we compare consumer and social welfare across SH-NSW and MH-NSW cases, for the equilibrium strategies. $w_{F,F}^{MH-NSW} - w_{F,F}^{SH-NSW} = \frac{1}{4}\left[t - 4\alpha + 3\beta - \theta + \frac{4\beta\theta}{t}\right] > 0$ from the necessary condition for non-negative prices/licensing fees.

Similarly, $w_{N,N}^{MH-NSW} - w_{N,N}^{SH-NSW} > 0$ from the necessary condition for non-negative prices/licensing fees. Further, for informal preannouncement, $w_{I,I}^{MH-NSW} - w_{I,I}^{SH-NSW} > 0$ when $\frac{3t-2}{2\left[\mu+\delta\right]} < \beta < \frac{3t}{2\left[\mu+\delta\right]}$ (necessary condition as shown in the proof of Lemma 5).

Similarly, $W_{F,F}^{MH-NSW} - W_{F,F}^{SH-NSW} > 0$ to ensure non-negative licensing fees, $W_{N,N}^{MH-NSW} - W_{N,N}^{SH-NSW} > 0$ for non-negative utility, and $W_{I,I}^{MH-NSW} - W_{I,I}^{SH-NSW} > 0$ in the range of β where multi-homing is feasible. Thus, *for a given symmetric SPNE strategy, both consumer and social welfare is higher when developers can multi-home compared to the case when developers only single-home* (Proposition 4 (ii)).