Supplemental Materials for Marco Haan, "Vaporware as a Means of Entry Deterrence", *The Journal of Industrial Economics* **" XX(x), Month Year, pp. XXX-XXX.**

Proof of theorem 2

Suppose (q_I^*, q_N^*) is a separating equilibrium. I drop the π_{inno} in the profit function of a type I, since he will always earn this amount, regardless of the strategy used. Since ooe beliefs are assumed equal, I write $\mu(q)$ for the ooe beliefs of both the consumers and the potential entrant. Thus, from definition 1, profits of a type I incumbent equal $\pi_I(q_I^*) = (1 + \mu(q)(3 - e(q))/6)(1 - q)q$, and that of a type N incumbent $\pi_N(q_N^*) = ((1 + \mu(q)(3 - e(q))/6)(1 - q)q + (9 - 5e(q))(1 - q)^2/36$. Also, note that in a separating equilibrium $\mu(q_I^*) = e(q_I^*) = 0$ and $\mu(q_N^*) = e(q_N^*) = 1$. First, we have

Lemma 1 *If a separating equilibrium exists, it necessarily has* $q_I^* = \frac{1}{2}$ *and* $\pi_N(q_N^*) \leq \frac{5}{16}$.

Proof. Suppose we have a separating equilibrium with $q_I^* \neq \frac{1}{2}$. In that case $\pi_I^*(q_I^*) < \frac{1}{4}$. But defecting to $q = \frac{1}{2}$ yields $(1 + \mu(\frac{1}{2})(3 - e(\frac{1}{2})/6)/4 \geq \frac{1}{4}$. Hence, no separating equilibrium can have $q_I^* \neq \frac{1}{2}$. We also need that q_N^* is such that it is not profitable for a type I incumbent to set the same quantity, given that receivers believe they face a type N incumbent when they observe q_N^*, i.e.

$$\frac{4}{3}(1 - q_N^*)\, q_N^* \leq \frac{1}{4}. \tag{1}$$

This implies

$$q_N^* \notin \left(\frac{1}{4}, \frac{3}{4}\right) \tag{2}$$

Given this restriction, the type N incumbent can earn at most $\frac{5}{16}$, by setting $q_N^* = \frac{1}{4}$. □

For every q, there is a $\tilde{\mu}(q)$ such that entry is just not profitable:

$$\tilde{\mu}(q) = \frac{9F}{(1 - q)^2}. \tag{3}$$

Consequently, the potential entrant does not enter if and only if $\mu(q) < \tilde{\mu}(q)$. We now have

Lemma 2 *A necessary condition for a type I incumbent not to defect to some* $q \neq q_I^*, q_N^*$, *is*

$$\mu(q) < \frac{3}{4}\frac{(1 - 2q)^2}{q(1 - q)}$$

Proof. First consider the case that ooe beliefs $\mu(q)$ are such that there will be no entry. For type I to stick to a separating equilibrium with $q_I^* = \frac{1}{2}$, we then need

$$(1 + \mu(q)/2)(1 - q)q < \frac{1}{4} \tag{4}$$

which implies

$$\mu(q) < \frac{1}{2}\frac{(1-2q)^2}{q\,(1-q)}. \tag{5}$$

Next consider the case that ooe beliefs are such that there will be entry. In that case, we need

$$(1+\mu(q)/3)\,(1-q)q < \frac{1}{4}, \tag{6}$$

hence

$$\mu(q) < \frac{3}{4}\frac{(1-2q)^2}{q\,(1-q)}. \tag{7}$$

Combining (5) and (7), it is easy to see that a necessary (though not sufficient) condition on out of equilibrium beliefs is for (7) to hold. □

Lemma 3 *For q smaller than, but sufficiently close to $\frac{1}{2}$, the ooe beliefs necessary for a type I incumbent not to defect from the separating equilibrium, are such that entry is deterred.*

Proof. Note that the RHS of (7) equals 0 for $q = \frac{1}{2}$, and is decreasing for $q < \frac{1}{2}$. Also, $\tilde{\mu}(q)$, as defined by (3), is increasing in q. With $\tilde{\mu}(\frac{1}{2}) = 36F > 0$, and continuity of both $\tilde{\mu}(q)$ and the RHS of (5), this implies that there is a q close enough to $\frac{1}{2}$, such that any q satisfying (7) has $\mu(q) < \tilde{\mu}(q)$, and, hence, entry is deterred. □

Now suppose the type N incumbent defects to such a q. From the previous lemma, the only ooe beliefs consistent with an equilibrium, have no entry. But by defecting to such a q, the type N incumbent earns

$$\pi_N(q) = (1+\mu(q)/2)\,(1-q)q + (1-q)^2/4, \tag{8}$$

which is larger than $\frac{5}{16}$ for any $q \in \left(\frac{1}{4}, \frac{1}{2}\right)$ and $\mu(q) \geq 0$. Hence, given the ooe beliefs necessary to sustain the equilibrium strategy of the type I incumbent, a type N incumbent will always find it profitable to defect to some q sufficiently close to $\frac{1}{2}$. Therefore, a separating equilibrium does not exist, which proves the theorem. □

Proof of corollary 1

First note that, for relevant values $\rho \in [0,1]$, the upper bound of interval 1 in theorem 3 is always higher than the upper bound of interval 2. Also the lower bound of interval 2 is always lower than the lower bound of interval 1. Thus, only the lower bound of interval 1, and the upper bound of interval 2 can be binding. Equating the two yields $\rho = \frac{1}{4}\left(3\sqrt{3}-5\right)$; for lower values of ρ, condition 1 and 2 cannot be jointly satisfied. For higher values of ρ, the higher bound of interval 2 does exceed the lower bound of interval 1, and the two conditions can be jointly satisfied. To also satisfy the third condition requires

$$q > 1 - \sqrt{\frac{9F}{\rho}} \tag{9}$$

Note that both the upper bound of interval 2, and the RHS of (9) are increasing in ρ. Also, for relevant values of ρ, the RHS of (9) has a higher slope than the upper bound of interval 2. Thus, if there is a q such that for the highest possible value of ρ, i.e. $\rho = 1$, (9) can be satisfied, then it can also be satisfied for any lower ρ, and (9) does not affect the existence of a pooling equilibrium. For this to be the case, we need $F > \frac{1}{675}\left(34 - 6\sqrt{21}\right)$. For lower values of F, the RHS of (9) intersects the upper bound of interval 2 at some $\rho^F < 1$, and a pooling equilibrium only exists for $\rho < \rho^F$. □

The Farrell-Grossman-Perry equilibrium

This equilibrium involves what Gertner, Gibbons and Scharfstein (1988) coin a *consistent interpretation* of a deviation. An interpretation is a subset of the type space. Possible interpretations in my model are $\{I\}$, $\{N\}$, and $\{I, N\}$. In a consistent interpretation, a type strictly prefers its payoff from offering the deviation to its equilibrium payoff, if and only if he is a member of the hypothesized subset. A *Farrell-Grossman-Perry equilibrium* is an equilibrium for which there is no deviation with a consistent interpretation. We have

Theorem 5 *A pooling equilibrium q^P is a Farrell-Grossman-Perry equilibrium if and only if $q^P \in \left[\frac{1+\rho}{3+2\rho}, \frac{1}{2}\right]$, provided there is a pooling equilibrium that satisfies this condition. If that is not the case, the only possible Farrell-Grossman-Perry equilibrium is $q = 1 - 3\sqrt{F/\rho}$.*

The intuition is the following. The lower and upper limit on the range of surviving equilibria are the pooling equilibria in which profits of a type N resp. a type I are maximized. Since profit functions are concave, if we are outside this interval, both types can improve by setting a q closer to that interval, when doing so yields beliefs ρ. But then $\{I, N\}$ is a consistent interpretation that indeed yields beliefs ρ. Hence, such a situation is not a Farrell-Grossman-Perry equilibrium. If there is no pooling equilibrium in the interval mentioned above, $1 - 3\sqrt{F/\rho}$ is the lowest q that is a pooling equilibrium.

The formal proof proceeds as follows. First, consider the interpretation $\{I, N\}$. With that interpretation, ooe beliefs equal a priori probabilities. Profits for the type I incumbent from defecting to some $q^D$are then given by

$$\pi_I^D(q^D) = (1 + \rho/2)(1 - q^D)q^D, \tag{10}$$

which are maximized for $q^D = \frac{1}{2}$. Since π_I^D is strictly concave, profits are increasing for $q^D < \frac{1}{2}$, and decreasing for $q^D > \frac{1}{2}$. For a type N incumbent, profits from defecting to q^D are

$$\pi_N^D(q^D) = (1 + \rho/2)(1 - q^D)q^D + (1 - q^D)^2/4, \tag{11}$$

which are maximized for $q^D = \frac{1+\rho}{3+2\rho}$. Given concavity, profits are increasing for $q^D < \frac{1+\rho}{3+2\rho}$, and decreasing for $q^D > \frac{1+\rho}{3+2\rho}$. Combining these two results, and observing that $\frac{1+\rho}{3+2\rho} < \frac{1}{2}$ for all $\rho \in [0,1]$, ooe profits of both types of incumbent are increasing for $q^D < \frac{1+\rho}{3+2\rho}$, and decreasing for $q^D > \frac{1}{2}$. Next, note that beliefs in a pooling equilibrium equal those in a deviation with interpretation $\{I, N\}$. Hence, with $q^P < \frac{1+\rho}{3+2\rho}$, with a deviation to e.g. $q^D = \frac{1+\rho}{3+2\rho}$, the interpretation $\{I, N\}$ is consistent. Hence q^P is not a Farrell-Grossman-Perry equilibrium. With a similar argument, no $q^P > \frac{1}{2}$ can be a Farrell-Grossman-Perry equilibrium either. Thus, the only candidates are $q^P \in \left[\frac{1+\rho}{3+2\rho}, \frac{1}{2}\right]$. For those values to be a Farrell-Grossman-Perry equilibrium, we need that neither $\{N\}$ nor $\{I\}$ can be a consistent interpretation. For $\{I\}$ to be consistent, we need that, given that interpretation, type I is willing to defect to some q^D, thus $\exists q^D : (1 - q^D)q^D > (1 + \rho/2)\left(1 - q^P\right) q^P$. But this contradicts condition 1 in theorem 3, which is necessary for a pooling equilibrium. For $\{N\}$ to be consistent, we need a q^D such that type I does not have an incentive to deviate to q^D, whereas type N does. Thus

$$(1 + \rho/2)\,(1 - q^P)q^P > 4/3(1 - q^D)q^D \tag{12}$$

and

$$(1 + \rho/2)\,(1 - q^P)q^P + (1 - q^P)^2/4 < 4/3(1 - q^D)q^D + (1 - q^D)^2/9 \tag{13}$$

Combining these inequalities implies as the necessary condition $(1 - q^P)^2/4 < (1 - q^D)^2/9$, thus $(1 - q^P)/2 < (1 - q^D)/3$, or

$$q^D < \frac{3q^P - 1}{2}. \tag{14}$$

All possible defections from a $q^P \in \left[\frac{1+\rho}{3+2\rho}, \frac{1}{2}\right]$ that are consistent with (14) thus have $q^D < \frac{1}{2}$. Since the profits of defection (i.e. the RHS of (13)) are increasing for $q^D < \frac{5}{11}$ the best deviation a type N can possibly choose that is consistent with (14), is $q^D = \left(3q^P - 1\right)/2$. Plugging that into (13) yields as a necessary condition

$$(1 + \rho/2)\,(1 - q^P)q^P + (1 - q^P)^2/4 < \left(1 - q^P\right)\left(3q^P - 1\right) + \left(1 - q^P\right)^2/4, \tag{15}$$

which simplifies to

$$(2 - \rho/2)\,q^P > 1 \tag{16}$$

But this inequality does not hold for $q^P = \frac{1}{2}$. Given that the LHS is increasing in q^P, it does not hold for smaller q^P either. Thus, the best a type N can do, given (14), violates (13), which implies that there is no q^D such that both (12) and (13) are satisfied, given that $q^P \in \left[\frac{1+\rho}{3+2\rho}, \frac{1}{2}\right]$. This, combined with the previous subresult, implies that all pooling equilibria $q^P \in \left[\frac{1+\rho}{3+2\rho}, \frac{1}{2}\right]$ are Farrell-Grossman-Perry equilibria.

If there is no pooling equilibrium $q^P \in \left[\frac{1+\rho}{3+2\rho}, \frac{1}{2}\right]$, then necessarily condition 3 in theorem 3 is violated. Thus, if pooling equilibria exist, they have $q^P > \frac{1}{2}$, with the lowest possible pooling equilibrium $q^P = 1 - 3\sqrt{F/\rho}$. With interpretation $\{I, N\}$, ooe profits of both types are now decreasing in q^D, which implies that for any $q^P > 1 - 3\sqrt{F/\rho}$, both types have an incentive to deviate to $q^D = 1 - 3\sqrt{F/\rho}$, which implies that $q^P = 1 - 3\sqrt{F/\rho}$ is the only possible Farrell-Grossman-Perry equilibrium. Yet, it is not necessarily such an equilibrium. It can be shown that, in this case, both $\{I, N\}$ and $\{N\}$ can be consistent interpretations of an ooe action. For example, with $q^P = 1 - 3\sqrt{F/\rho}$ high enough both types can have an incentive to defect to $q^D = \frac{1}{2}$, even though this induces entry and therefore lowers the price consumers are willing to pay in the first period. □

Definition of the Unilateral Intuitive Criterion

Suppose an ooe message m is observed. Receiver r attaches zero belief to the event that m was sent by a type i sender, when the following two conditions are satisfied. First, the profits a type i can earn by sending such a message are smaller than the profits he earns in equilibrium, regardless of r's ooe beliefs, *but given that the other receiver, s, has beliefs ρ*. Second, the other type of sender, j, *can* earn higher profits by sending m, regardless of r's ooe beliefs, but given that beliefs of s equal ρ. An equilibrium survives the Unilateral Intuitive Criterion when no type of incumbent is willing to play an ooe action, given that ooe beliefs satisfy the Unilateral Intuitive Criterion. In the context of my model, we have the following. Define $\pi_i(q, \mu, \eta)$ as the profits for a type i incumbent from playing q, when this induces beliefs μ for consumers and η for the potential entrant. We then have

Definition 4 *A pooling equilibrium q^P satisfies the Unilateral Intuitive Criterion, when q^P is a sequential equilibrium and ooe beliefs satisfy*

$$\mu(q) = \begin{cases} 1 & \text{if} \quad \pi_N(q^P, \rho, \rho) < \pi_N(q, 1, \rho) \quad \text{and} \quad \pi_I(q^P, \rho, \rho) > \pi_I(q, 1, \rho), \\ 0 & \text{if} \quad \pi_N(q^P, \rho, \rho) > \pi_N(q, 1, \rho) \quad \text{and} \quad \pi_I(q^P, \rho, \rho) < \pi_I(q, 1, \rho), \\ \rho & \quad \text{otherwise,} \end{cases}$$
$$\eta(q) = \begin{cases} 1 & \text{if} \quad \pi_N(q^P, \rho, \rho) > \pi_N(q, \rho, 0) \quad \text{and} \quad \pi_I(q^P, \rho, \rho) < \pi_I(q, \rho, 0), \\ 0 & \text{if} \quad \pi_N(q^P, \rho, \rho) < \pi_N(q, \rho, 0) \quad \text{and} \quad \pi_I(q^P, \rho, \rho) > \pi_I(q, \rho, 0), \\ \rho & \quad \text{otherwise.} \end{cases} \tag{17}$$

This can be seen as follows. First, note that $\pi_i(q^p, \rho, \rho)$ are the profits a type i incumbent receives in pooling equilibrium q^p. From the point of view of any incumbent, the best possible beliefs consumers can have are $\mu = 1$. Hence, when consumers observe ooe action q, they should infer that this signal is sent by a type N incumbent when, given beliefs $\mu = 1$ and $\eta = \rho$, he stands to gain from choosing q, whereas a type I incumbent would not. When the opposite is true, consumers should infer they face a type I incumbent. Otherwise, I assume consumers stick to their a priori belief ρ. This gives the conditions on $\mu(q)$.

For any type of incumbent, the (weakly) best possible beliefs a potential entrant can have are $\eta = 0$, which implies that she never enters. According to my criterion, when the potential entrant observes ooe action q, she should infer that this signal is sent by a type N when, given beliefs $\eta = 0$ and $\mu = \rho$, he stands to gain from choosing q, whereas a type I incumbent does not. When the opposite is true, she should infer that this signal is sent by a type I. Again, if neither of these conditions are satisfied, the potential entrant sticks to her prior beliefs ρ.

Proof of theorem 4

First note that, for ooe payoffs, we have $\pi_N(q, 1, \rho) = \frac{3}{2}(1 - q)q + (1 - q)^2/4$ if entry occurs, and $\pi_N(q, 1, \rho) = \frac{3}{2}(1-q)q$ if entry does not occur at q. Entry will occur if $F < \eta(q)(1-q)^2/9$, thus consumers believe that entry will occur if $q < 1 - 3\sqrt{F/\rho}$. With $\eta = 0$, entry does not occur, thus $\pi_N(q, \rho, 0) = (1 + \rho/2)(1 - q)q + (1 - q)^2/4$, and $\pi_I(q, \rho, 0) = (1 + \rho/2)(1 - q)q$. Since by construction the pooling equilibrium q^P deters entry, any $q > q^P$ also does. Also note that $\pi_i(q, \mu, \eta)$ is strictly increasing in μ for all i, q, η. Finally, when the potential entrant does not enter when holding beliefs η, we have $\pi_i(q, \mu, \eta) = \pi_i(q, \mu, 0)$ for all i, q, μ.

The proof proceeds in six steps. First, I show that no pooling equilibrium $q^P < \frac{1+\rho}{3+2\rho}$ survives the Unilateral Intuitive Criterion. Then I show that the same holds for any $q^P \in \left[\frac{1+\rho}{3+2\rho}, \frac{1}{2}\right)$. In the third step I show that no $q^P > \frac{1}{2}$ survives the Unilateral Intuitive Criterion. Then I show that with $q^P = \frac{1}{2}$ no type of incumbent has an incentive to defect to some $q < \frac{1}{2}$, and that with $q^P = \frac{1}{2}$ no type of incumbent has an incentive to defect to some $q > \frac{1}{2}$. Finally, I show that, also with this refinement on ooe beliefs, there is no separating equilibrium. Taken together, this establishes theorem 4.

1. Consider a pooling equilibrium with $q^P < \frac{1+\rho}{3+2\rho}$. Following the proof of theorem 5, we then have $\pi_N(q^P, \rho, \rho) < \pi_N(q, \rho, \rho)$ for any $q \in \left(q^P, \frac{1+\rho}{3+2\rho}\right)$. This implies that for these values we also have $\pi_N(q^P, \rho, \rho) < \pi_N(q, 1, \rho)$. Also, we have $\pi_I(q^P, \rho, \rho) < \pi_I(q, \rho, \rho)$ for $q \in \left(q^P, \frac{1}{2}\right]$, thus $\pi_I(q^P, \rho, \rho) < \pi_I(q, 1, \rho)$. Also, for such values of q and q^P we have $\pi_I(q^P, \rho, \rho) < \pi_I(q, \rho, \rho) = \pi_I(q, \rho, 0)$ and $\pi_N(q^P, \rho, \rho) < \pi_N(q, \rho, \rho) = \pi_N(q, \rho, 0)$. Thus, for $q^P < \frac{1+\rho}{3+2\rho}$, both types are better off defecting to some $q \in \left(q^P, \frac{1+\rho}{3+2\rho}\right]$, inducing beliefs $\mu = \eta = \rho$.

2. Consider a pooling equilibrium with $q^P \in \left[\frac{1+\rho}{3+2\rho}, \frac{1}{2}\right)$. Now, a defection to some $q = q^P + \varepsilon$, with ε small enough, yields $\pi_N(q^P, \rho, \rho) > \pi_N(q, \rho, 0)$, and $\pi_I(q^P, \rho, \rho) < \pi_I(q, \rho, 0)$ implying $\eta(q) = 0$. Again, $\pi_N(q^P, \rho, \rho) < \pi_N(q, 1, \rho)$ and $\pi_I(q^P, \rho, \rho) < \pi_I(q, 1, \rho)$, thus

$\mu(q) = \rho$. Given these out of equilibrium beliefs, type I is indeed willing to defect, whereas N is not, thus destroying the equilibrium.

3. Consider the case in which we have some pooling equilibrium $q^P > \frac{1}{2}$. By assumption $q = \frac{1}{2}$ is a pooling equilibrium, which implies that $q^P - \varepsilon$ also is, for small enough ε. Thus, when observing $q^P - \varepsilon$ and holding beliefs ρ, the potential entrant does not enter. Consider a defection to $q^P - \varepsilon$. Since $q^P > \frac{1}{2}$, we have both $\pi_N(q^P, \rho, \rho) < \pi_N(q^P - \varepsilon, 1, \rho)$ and $\pi_I(q^P, \rho, \rho) < \pi_I(q^P - \varepsilon, 1, \rho)$. Also, $\pi_N(q^P, \rho, \rho) < \pi_N(q^P - \varepsilon, \rho, 0)$ and $\pi_I(q^P, \rho, \rho) < \pi_I(q^P - \varepsilon, \rho, 0)$. Thus, $\mu(q^P - \varepsilon) = \eta(q^P - \varepsilon) = \rho$. Both types of incumbent then have an incentive to defect, thus destroying the equilibrium.

4. Consider $q^P = \frac{1}{2}$ and a defection to some $q > \frac{1}{2}$. This induces $\eta = \rho$, since neither incumbent can be better off by any change in beliefs of the potential entrant this may induce. Hence, the potential entrant will not enter when observing such a defection. To determine μ, first note that for $q > \frac{1}{2}$,

$$\pi_N\left(\frac{1}{2}, \rho, \rho\right) = (1 + \rho/2)/4 + 1/16, \tag{18}$$

$$\pi_N(q, 1, \rho) = (3/2)(1 - q)q + (1 - q)^2/4, \tag{19}$$

$$\pi_I\left(\frac{1}{2}, \rho, \rho\right) = (1 + \rho/2)/4, \tag{20}$$

$$\pi_I(q, 1, \rho) = (3/2)\,(1 - q)q. \tag{21}$$

Thus, in the relevant interval, $\pi_I(\frac{1}{2}, \rho, \rho) > \pi_I(q, 1, \rho)$ if and only if $q > \frac{1}{2} + \frac{1}{6}\sqrt{3(1-\rho)}$, and $\pi_N(\frac{1}{2}, \rho, \rho) > \pi_N(q, 1, \rho)$ if and only if $q > \frac{2}{5} + \frac{1}{10}\sqrt{(11 - 10\rho)}$. Since $\frac{1}{2} + \frac{1}{6}\sqrt{3(1-\rho)} > \frac{2}{5} + \frac{1}{10}\sqrt{(11 - 10\rho)}$ $\forall \rho \in (0, 1)$, we thus have $\mu(q) = 0$ for $\frac{1}{2} + \frac{1}{6}\sqrt{3(1-\rho)} > q > \frac{2}{5} + \frac{1}{10}\sqrt{(11 - 10\rho)}$ and $\mu(q) = \rho$ for other $q > \frac{1}{2}$. Yet, together, these beliefs imply that no type of incumbent has an incentive to defect to any $q > \frac{1}{2}$.

5. Consider a defection from $q^P = \frac{1}{2}$ to some $q < \frac{1}{2}$. Note that we can never have ooe beliefs $\mu = 1$. This can be seen as follows. For such ooe beliefs, we need $\pi_N(\frac{1}{2}, \rho, \rho) < \pi_N(q, 1, \rho)$ and $\pi_I(\frac{1}{2}, \rho, \rho) > \pi_I(q, 1, \rho)$. Yet, from (18) through (21) we have that $\pi_N(\frac{1}{2}, \rho, \rho) < \pi_N(q, 1, \rho)$ immediately implies $\pi_I(\frac{1}{2}, \rho, \rho) < \pi_I(q, 1, \rho)$. Hence the two inequalities cannot be satisfied simultaneously, and we cannot have $\mu = 1$. Therefore, the highest possible value of μ equals ρ. Second, for any defection to some $q < \frac{1}{2}$, we have $\pi_I(\frac{1}{2}, \rho, \rho) > \pi_I(q, \rho, 0)$. Thus, when observing some $q < \frac{1}{2}$, $\eta(q)$ either equals ρ or 1. To have $\eta = \rho$, we also need

$$\pi_N(\frac{1}{2}, \rho, \rho) > \pi_N(q, \rho, 0). \tag{22}$$

But a type N is only willing to defect if $\pi_N(\frac{1}{2}, \rho, \rho) < \pi_N(q, \mu, \rho)$. With $\eta = \rho$ and $\mu \leq \rho$, we have $\pi_N(q, \mu, \rho) \leq \pi_N(q, \rho, 0)$, thus $\pi_N(\frac{1}{2}, \rho, \rho) < \pi_N(q, \rho, 0)$, which contradicts (22). Thus, the only belief η that can possibly destroy the equilibrium is $\eta = 1$. The highest possible payoff from defecting then equals $\pi_N(q, \rho, 1)$, which is smaller than $\pi_N(\frac{1}{2}, \rho, \rho)$ for any ρ for which $q^P = \frac{1}{2}$ is a pooling equilibrium. Hence, there is no $q < \frac{1}{2}$ to which a type N is willing to defect, given ooe beliefs this induces. To show that a type I is not willing to defect, note that the highest possible profit from such is defection is $\pi_I(q, \rho, \eta)$, again using the fact that $\mu = 1$ is not a feasible ooe belief. But this expression is maximized by setting $q = \frac{1}{2}$, which implies that the type I also does not have an incentive to defect from a pooling equilibrium $q^P = \frac{1}{2}$.

6. Suppose a separating equilibrium exists. Equilibrium profits of a type I then equal $\pi_I(q_I^*, 0, 0)$, while those of a type N equal $\pi_N(q_N^*, 1, 1)$. In lemma 1 I show that, if a separating equilibrium exists, it necessarily has $q_I^* = \frac{1}{2}$ and $\pi_N(q_N^*, 1, 1) \leq \frac{5}{16}$. In proving these results, I did not impose any structure on ooe beliefs. Yet, the remainder of that proof did hinge on the assumption that ooe beliefs are identical. Consider a defection to $\frac{1}{2} - \varepsilon$, with ε small. Obviously, $\pi_I(\frac{1}{2} - \varepsilon, \rho, 0) > \pi_I(\frac{1}{2}, 0, 0)$. Using the fact that $\pi_N(q, \rho, 0) = (1 + \rho/2)(1 - q)q + (1 - q)^2/4$, it can be shown that $\pi_N(\frac{1}{2} - \varepsilon, \rho, 0) = \frac{5}{16} + \frac{1}{8}\rho\left(1 - 4\varepsilon^2\right) + \frac{1}{4}\varepsilon\left(1 - 3\varepsilon\right)$, thus for small enough ε, $\pi_N(\frac{1}{2} - \varepsilon, \rho, 0) > \frac{5}{16} \geq \pi_N(q_N^*, 1, 1)$. Hence, $\eta(\frac{1}{2} - \varepsilon) = \rho$. Also, $\pi_N(\frac{1}{2} - \varepsilon, 1, \rho) > \pi_N(q_N^*, 1, 1)$ and $\pi_I(\frac{1}{2} - \varepsilon, 1, \rho) > \pi_I(\frac{1}{2}, 0, \rho)$. Thus $\mu(\frac{1}{2} - \varepsilon) = \rho$. Given these beliefs, a type I has an incentive to defect to $\frac{1}{2} - \varepsilon$, thus destroying the equilibrium. □

Welfare effects

I first calculate expected consumer surplus in my model, first for the case of complete information, then for the strong vaporware equilibrium. Consider the case of complete information. With a type N, $q_1 = \frac{5}{11}$. Consumers buying in the first period pay an implicit rental price of $r_1 = \frac{6}{11}$ for use in period 1. Thus, their CS (consumer surplus) in that period equals $\frac{25}{242}$. In period 2, both Cournot competitors supply $\frac{1}{11}$, implying a total stock equal to $Q_2 = \frac{9}{11}$, and $p_2 = \frac{2}{11}$, yielding CS in period 2 of $\frac{81}{242}$. Total CS over both periods then equals $\frac{53}{121}$. A type I sets $q_1 = \frac{1}{2}$ in period 1, yielding CS $\frac{1}{8}$. Expected CS with complete information thus equals

$$E(CS^{CI}) = \rho\left(\frac{53}{121}\right) + (1 - \rho)\left(\frac{1}{8}\right) = \frac{303}{968}\rho + \frac{1}{8}. \qquad (23)$$

Now consider the case in which vaporware is used to deter entry. With quantity $q_1 = \frac{1}{2}$ set in the first period, we have $p_1 = \frac{1}{2}\left(1 + \frac{\rho}{2}\right)$. Consider the case with a type I incumbent. Had consumers known in advance that there would be a new good in period 2, the price the marginal consumer would have been willing to pay was only $1 - q$. At price p_1 only $q_I^* = 1 - p_1$ would have bought the product, rather than the $q = \frac{1}{2}$ who buy it now. Hence, only q_I^* consumers have a positive CS, whereas the remaining $q - q_I^*$ have a negative CS. The positive CS of the first group equals $\frac{1}{8}\left(1-\frac{\rho}{2}\right)^2$, the negative CS of the second $\frac{1}{8}\left(\frac{\rho}{2}\right)^2$, so total CS in period 1 equals $\frac{1}{8}(1-\rho)$. A type N incumbent maximizes profits in the second period by setting $q_2=\frac{1}{4}$, hence $Q_2=\frac{3}{4}$, thus $p_2=\frac{1}{4}$. The implicit rental price consumers in period 1 pay equals $r_1=p_1-p_2=\frac{1}{4}(1+\rho)$. Expected first period rental price equals $p_1-E(p_2)=\frac{1}{2}$, which is bigger. Thus, first period CS equals the usual triangle above $p=\frac{1}{2}$, plus a rectangle below that, which captures the total difference between what consumers have to pay, and what they a priori expected they had to pay. Total CS in period 1 thus equals $\frac{1}{8}+\frac{1}{8}(1-\rho)$. In period 2, CS simply equals $\frac{1}{2}\left(\frac{3}{4}\right)^2=\frac{9}{32}$. The expected consumer surplus in a strong vaporware equilibrium thus equals

$$\begin{aligned} E(CS^{vap}) &= \rho\left(\frac{1}{8}+\frac{1}{8}(1-\rho)+\frac{9}{32}\right)+(1-\rho)\left(\frac{1}{8}(1-\rho)\right) \\ &= \frac{9}{32}\rho+\frac{1}{8}. \end{aligned} \tag{24}$$

Comparing this with (23), we have that $E(CS^{vap})>E(CS^{CI})$ for any $\rho>0$. □

For the dynamic welfare effects, suppose we add a stage 0 to the model, in which the incumbent has to decide whether or not to spend an amount R on R&D. If he does not spend this amount, he will not obtain an innovation in the next period. If the incumbent does spend R, he obtains an innovation, only observable to himself, with probability $1-\rho$, so we are back to the model in this paper. WeIn that case, for a range of values of R, the incumbent is willing to invest when there is a possibility of vaporware, whereas he is not willing to do so when that possibility does not exist, simply because expected profits are higher in the vaporware equilibrium than they are with complete information. The fact that the monopoly does not invest may in turn imply a lower expected consumer surplus. Thus, in a static framework, consumers are always worse off in a strong vaporware equilibrium. When incentives to innovate are also taken into account, this is not necessarily the case.

Suppose the monopolist does not spend R. His profits then equal $\pi_{noR\&D}=\frac{4}{11}$, as given by theorem 1. When vaporware is not possible, the expected gross profits of R&D are, using theorem 1,

$$E\left(\pi^{nv}_{R\&D}\right) = \rho\pi^{CI}_N+(1-\rho)\pi^{CI}_I \tag{25}$$

$$= \frac{5}{44}\rho+\frac{1}{4}+(1-\rho)\,\pi_{inno}. \tag{26}$$

The incumbent is willing to spend on R&D iff $E\left(\pi^{nv}_{R\&D}\right)>\pi_{noR\&D}+R$, thus iff

$$R<(1-\rho)\left(\pi_{inno}-\frac{5}{44}\right). \tag{27}$$

In a strong vaporware equilibrium, the profits of a type I incumbent are $\pi_I=(1+\rho/2)/4$, and that of a type N incumbent $\pi_N=(1+\rho/2)/4+1/16$. Expected profits of doing R&D thus equal

$$\begin{aligned} E\left(\pi^{v}_{R\&D}\right) &= (1-\rho)\left((1+\rho/2)/4+\pi_{inno}\right)+\rho\left((1+\rho/2)/4+1/16\right) \\ &= \frac{1}{4}+\frac{3}{16}\rho+(1-\rho)\,\pi_{inno}, \end{aligned} \tag{28}$$

and the incumbent is willling to spend on R&D if and only if

$$R < \frac{3}{16}\rho - \frac{5}{44} + (1-\rho)\,\pi_{inno}. \tag{29}$$

Comparing (27) and (29), the critical R with vaporware is higher than that without. Thus, for a range of values of R, the incumbent is willing to invest when there is a possibility of vaporware, whereas he is not willing to invest when that possibility does not exist. For this range of values, expected consumer surplus may be higher with the possibility of vaporware. If vaporware cannot occur, we always have a type N incumbent, and consumer surplus equals $\frac{53}{121}$. With vaporware, there may be a type I incumbent, and expected consumer surplus equals $\frac{9}{32}\rho + \frac{1}{8} + (1-\rho)\,CS_{inno}$. The latter value may be higher, depending on the value of CS_{inno}.