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Riding Free on the Signals of Others

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ABSTRACT

This paper looks at the incentives to free–ride on the information *signaling* of others and shows how this can lead to delay in productive activity and to a cascade of activity once information is signaled. In the presence of increasing returns to scale to a profitable project, an initial pioneer may have to incur short–term losses to signal the opportunity to others. Agents may prefer to defer entry in the hope that others will incur those losses and thereby convey the information. Free–riding incentives can be so strong that profitable projects may not be undertaken. Free–riding is worsened when potential entrants must first acquire a costless signal about the project, and this information acquisition is observed: not acquiring the information commits an agent not to incur the entry costs.

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Introduction

A series of recent papers examines how agents make inferences from their observations of the actions of others whose information they may lack and explores the consequences for behavior.[1] In this "herding" or "information cascade" literature, the behavior of one agent can induce other agents, who observe this action, to take similar actions.

Caplin and Leahy (1994a,b) and Chamley and Gale (1994), in particular, explore the incentives of agents to free–ride on the costly information *acquisition* of others and show how this can lead to socially undesirably low levels of investment in information acquisition. In turn, this under–investment leads to delay in productive activity as agents wait to learn from the productive actions of others and to a cascade of activity once good news is revealed.

This paper focuses on a subtly different information problem. We look at the incentives of agents to free–ride on the information *signaling* of others and show how this can lead to delay in productive activity and to a cascade of activity once information is signaled. Indeed, we show how the benefits of free–riding on the signaling activities of others can lead agents not to undertake a project that they know to be profitable.

To fix ideas consider a firm A that is contemplating locating in the inner city. Firm A investigates the profitability of such a move and recognizes that other firms may be undertaking similar investigations. Suppose A's study reveals that if several shops start up in the city core then they will certainly be profitable. However, any venture in the inner city only becomes profitable once several stores locate there and firm A has no idea which stores would find relocation profitable. Now firm A can always be the pioneer, locate in the inner city and thereby signal that it is profitable to relocate. However, a pioneer incurs losses until other firms respond and enter. While the discounted stream of profits from being the first entrant may be positive, firm A may prefer to wait and hope that others will

[1] Banerjee (1992), Bikhchandani *et al.* (1992), Bulow and Klemperer (1994), Caplin and Leahy (1994a,b) and Chamley and Gale (1994) among others.

enter first. That is, firm A may prefer to free–ride on the information signaling of other firms. Since other potential entrants have similar incentives to free–ride the consequence may be that no firm enters and the profitable opportunity is missed. The free–riding problem *worsens* when firms must first decide whether to obtain a *costless* signal and this information acquisition action is publicly observed. This is because *not* acquiring the signal commits a firm not to incur the entry costs.

Firm A's optimal action depends in part on how likely it is that other firms know that the long–term profits from entry are positive. If it is highly unlikely, then firm A may enter and initially incur losses in order to signal this information to others. If other firms are more likely to know of the profitable opportunity, then firm A may mix over entering and not, where the equilibrium mixing probability leaves other informed firms indifferent between entering and not. Of course, if most firms are likely to know of the opportunity, then firm A may find it optimal to enter immediately. Finally, coordination problems may be so severe that entry never occurs, even though informed firms know that with probability one entry would be profitable were *all* informed firms to enter immediately.

The key features of the environment are

- Incomplete information about the long–run profitability.
- Increasing returns to scale, at least over small scales of development.
- Entry takes time, so that a single pioneer initially incurs losses.
- Informed agents can only communicate their information to others through entry — perhaps because they do not know the identities of the other potential entrants.
- Entry timing is endogenous.

Our model is consistent with many economic phenomena. For instance, it can account for the pattern of gentrification of decayed urban areas. Some developers and home buyers may know which neighborhoods will be the next to recover from decline. Yet they may wait for others to renovate and live in the initially unsafe neighborhoods, while they plan to 'buy in' as soon as the higher–quality neighborhood is established. Other potential home buyers who are unfamiliar with the area will not learn of its potential until gentrification begins. Again, the problem need not be that informed buyers are uncertain about the return from investing, but rather that they have no way to communicate their information about the neighborhood except by actually investing and incurring the initial costs.

Or consider investment in LDCs. Investment may only be profitable once infrastructural externalities are realized. The requisite scale of investment may be beyond the scope of any single firm. Since infrastructural externalities will be realized independent of the inherent prospects for profitability, information may only be credibly revealed through entry. Again, firms may have an incentive to wait for others to incur the initial "pioneering" losses. This can again inefficiently delay the development and exploitation of that market.

This phenomenon may also characterize new markets for products and services that feature large complementarities. For instance, it is reasonable that, anticipating advertising spillovers and changes in tastes, a potential publisher of health food books will benefit from following rather than leading the entry of health food stores into the market — and *vice versa*. Again, several firms may know that the market will be profitable, but their inability to identify and/or credibly communicate with other potential entrants leaves entry as the only method by which to signal this information.

Inefficient delay can arise for reasons other than those we consider. For example, Farrell and Saloner (1985) characterize the problem of excess inertia (and of excess momentum) that arises when agents face risks of product incompatibility and sunk costs, or when network externalities exist. Their model assumes incomplete information about the payoff stream another agent faces in adopting a particular standard or technology. Delay is driven by the trade–off between setting a standard of one's choice as an early entrant and the risk of adopting a standard not followed by others. Farrell (1987) and Farrell and Saloner (1988) focus on communicating to overcome the coordination problem faced by potential entrants to potentially congested markets.

Caplin and Leahy (1991) model environments where investment reveals information about production costs. Rob (1991) develops a model of entry and exit that features learning about market capacity. In particular, firms are uncertain about whether fixed costs of investment can be recovered. Whenever such market congestion is possible, investment exhibits strategic substitutability — the more likely A is to enter, the less attractive entry is to B. In this regard, these models are similar to the standard and technology adoption models.

Caplin and Leahy (1994b) provide an information cascade explanation for delayed entry on Sixth Avenue in Manhattan — an observation with which our model is also consistent. In their model, agents delay not because they want to free-ride on the signals of others, but because they face uncertainty about the state and investment is irreversible. Caplin and Leahy argue that in models featuring increasing returns to scale, an agent who knows the state with certainty is more likely to enter when it is more likely that other agents will do the same. We show that this is generally not true. That is, when one or more agents know the state with certainty and there is both a cost to signaling and a positive crowding effect, their decisions to enter remain strategic substitutes over a range of reasonable parametrizations.

Chamley and Gale (1994) consider delay in an environment where agents' payoffs do *not* depend upon the actions of others. The strategic effects are due only to the benefit of information about the state acquired by observing those actions. Gale (1995) considers the polar case in which information is complete and delay arises only because agents' payoffs depend on the actions of others. In this context, our model explores the middle ground. Fully informed as to the state, agents delay in an attempt to free-ride on the signaling of others and realize profits that depend on the actions of others.

The outline of the paper is as follows: Sections 2 and 3 outline the basic two–period model. In Section 4 we show that when the time horizon for entry is extended, firms are initially more reluctant to enter. Section 5 details how the free–riding problem *worsens* when agents must first decide whether to obtain a *costless* signal about market conditions, and this information acquisition is publicly observed. Section 6 concludes. All proofs are in an appendix.

2. Model

Consider an economy with N risk-neutral firms contemplating entry to a market. Firms discount profits at rate ρ. Period profits to entry depend both on the state of the market and on the number of market participants. For simplicity, suppose that the state of the market is either good or bad, and that the bad state is sufficiently bad that it is unprofitable to enter unless market conditions have been revealed to be good.

To ease the analysis suppose that only firms 1 and 2 receive signals about the state of the market. With probability δ, firm i, $i = 1, 2$, learns that market conditions are good. With probability $1 - \delta$, firm i receives an uninformative signal. We initially suppose that these signals are independent. If market conditions are good then entry by all N firms is profitable. Let $\pi(j)$ denote per period profits of an entrant when there are $j = 1, 2, ...N$ firms in the market. To capture the conditions of interest, we assume that

$$\pi(1) \leq \pi(2) \leq \pi(N); \text{ and } \pi(1) < 0 < \pi(N).$$

That is, there are increasing returns to scale, it is unprofitable to be the sole entrant, but it is profitable to enter if others enter the market when conditions are good.

These assumptions simplify the analysis, but do not qualitatively affect the results. They imply that

1. Firm i, $i = 1, 2$ pioneers entry only if it learns that market conditions are good.
2. All firms enter as soon as they observe the entry of firm 1 or firm 2.

The only way a firm can signal that market conditions are profitable is by entering the market. As a consequence, the analysis turns only on the equilibrium action of a firm that knows market conditions are good, when no firm has yet entered. The informed firm trades off the certain gains from entering and thereby signaling the state to others while possibly incurring short–term losses, against free–riding off the possible entry of the other informed firm.

Let $m_{it} \in [0,1]$ denote the probability that firm $i, i = 1, 2$, enters the (good) market at date t given that no entry has occurred by t. We look at Bayes–Nash equilibria to this entry game.

3. Two–Date Economy

In the two–date economy any firm that does not know market conditions are good will not enter at date one. However, if it observes either firm 1 or firm 2 entering the market, then it infers that market conditions must be good, so that it will enter at date two.

Let m_{-i1} denote the probability the other potentially–informed firm enters at date one given that it knows market conditions are good. The profits firm $i, i = 1, 2$, expects from entering at date one when market conditions are good are

$$(1 - \delta m_{-i1})\pi(1) + \delta m_{-i1}\pi(2) + \rho\pi(N).$$

Profits reflect that with probability $(1 - \delta m_{-i1})$ the other potentially–informed firm will not enter at date one and that with probability δm_{-i1} the other firm will both receive the informative good signal and enter. Firm i's expected payoff from not entering at date one is $\delta m_{-i1}\rho\pi(N)$, the expected payoff from the other firm entering at date one and revealing the good news.

In examining firms' equilibrium strategies, it helps to decompose the analysis into two cases:

1. $\pi(1) + \rho\pi(N) > 0$ (profitable single firm entry)
2. $\pi(1) + \rho\pi(N) < 0$ (unprofitable single firm entry)

If $\pi(1) + \rho\pi(N) > 0$, then long-run profits to entry by a single firm are positive even though a sole entrant initially incurs losses. If $\pi(1) + \rho\pi(N) < 0$ then if a firm is the lone initial entrant, future profits are not sufficient to cover its entry costs.

Case 1: $\pi(1) + \rho\pi(N) > 0$ (profitable single firm entry)

Proposition 1: Suppose that $\pi(1) + \rho\pi(N) \geq 0$. In the unique symmetric equilibrium a firm i that knows market conditions are good enters with probability:

$$m_{i1}^* = \begin{cases} 1 & \text{if } \delta \leq \delta^* = \dfrac{\rho\pi(N) + \pi(1)}{\rho\pi(N) + \pi(1) - \pi(2)} \\ \dfrac{\rho\pi(N) + \pi(1)}{\delta[\rho\pi(N) + \pi(1) - \pi(2)]} & \text{if } \delta > \delta^* \end{cases}$$

If there is entry at date one, all remaining firms enter at date two. If there is no entry at date one, no firm finds it profitable to enter at date two.[2] ■

If there are sufficient scale economies when there are two firms, *i.e.* if $\pi(2) > 0$, then $\delta^* > 1$. Hence,

Corollary 1: If $\pi(2) \geq 0$, then a firm that receives a good signal enters with certainty at date one. ■

For $\delta \leq \delta^*$, in equilibrium, any firm that learns market conditions are good enters at date one. This is either because coordination is good ($\pi(2) > 0$), or because δ is small enough that firm i recognizes that most likely it alone knows market conditions are good. Consequently, it enters to signal the good news. Because $\pi(1) + \rho\pi(N) > 0$, it is always profitable to incur the expected initial entry costs in order to inform others, independent of the action of the other potentially–informed firm.

When it is unprofitable for two firms to operate in the market, *i.e.* $\pi(2) < 0$, then $\delta^* < 1$. That is, there is an incentive to free–ride on the possible signal of good news revealed by entry of the other firm. Hence, if the other firm is sufficiently likely to receive a signal of good news, *i.e.* $\delta > \delta^*$, firms mix over their entry decisions in equilibrium. The consequence is that with positive probability the profitable opportunity is foregone:

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[2] If $\pi(2) < 0$ and $\delta > \delta^*$ then there also exists an asymmetric equilibrium in which one firm always enters at date one if informed, and the other firm always delays. No other equilibria exist.

Corollary 2: If $\pi(2) < 0$ and the other firm is sufficiently likely to know that market conditions are good, then with positive probability an informed firm chooses not to enter at date one. For $\delta > \delta^*$, firms mix so as to keep the probability of entry constant:

$$\delta m_{i1}^* = \frac{\pi(1) + \rho\pi(N)}{\rho\pi(N) + \pi(1) - \pi(2)}.$$

With probability $\left[\frac{\pi(2)}{\rho\pi(N)+\pi(1)-\pi(2)}\right]^2$ no firm enters and the profitable opportunity is missed. ■

If it is unprofitable for the two informed firms to operate in the market, *i.e.* $\pi(2) < 0$, then it becomes attractive to free–ride on the possible entry of the other firm. Entry offers negative first period profits, but it signals the good state to all firms. Delay offers the benefit that no signaling costs are incurred, but has the cost that the other potentially–informed firm might not enter so that a profitable opportunity is foregone. Note that if the signals the two firms receive are perfectly correlated rather than independent, then if $\pi(2) < 0$ the equilibrium with entry *necessarily* features mixing:

$$m_{i1}^* = \frac{\pi(1) + \rho\pi(N)}{\rho\pi(N) + \pi(1) - \pi(2)}.$$

If one firm is more likely than the other to learn that market conditions are good, *i.e.* $\delta_1 \neq \delta_2$, then if both firms mix over entry, they mix so as to equate their probabilities of entry: $\delta_1 m_{11} = \delta_2 m_{21}$, where

$$m_{i1}^* = \min\left\{1, \frac{\pi(1) + \rho\pi(N)}{\delta_{-i}[\rho\pi(N) + \pi(1) - \pi(2)]}\right\}.$$

Case 2: $\pi(1) + \rho\pi(N) < 0$ (unprofitable single firm entry)

Consider now the possibility that $\pi(1) + \rho\pi(N) < 0$, so that it is unprofitable for a single firm to enter. Consequently, there always exists a trivial equilibrium in which neither firm enters because each believes that the other will not, and entry by a single firm is unprofitable. If $\pi(2) < 0$, this equilibrium is unique, even though firms may expect strictly positive profits if both firms always entered upon observing good news:

Proposition 2: Suppose $\pi(1) + \rho\pi(N) < 0$, and $\pi(2) < 0$. Then even if $\delta\pi(2) + (1-\delta)\pi(1) + \rho\pi(N) > 0$, the unique equilibrium features no entry. ∎

If $\pi(2) < 0$, then the unique equilibrium features no entry — even though when $\delta\pi(2) + (1-\delta)\pi(1) + \rho\pi(N) > 0$ firms would expect strictly positive profits if they could both commit to entering upon observing good market conditions. The equilibrium does not feature entry because each potentially–informed firm receives a strictly higher payoff from not entering independent of the entry decision of the other potentially–informed firm. Because of these incentives to free–ride, neither firm enters even though joint entry would be strictly profitable.

To see this most clearly, suppose firms 1 and 2 receive perfectly correlated signals that indicate market conditions are good. Then because $\rho\pi(N) > \pi(2) + \rho\pi(N) > 0 > \pi(1) + \rho\pi(N)$, no entry occurs. If firm 1 believes firm 2 will enter, then firm 1 will not, since it gains by waiting for firm 2 to signal: $\rho\pi(N) > \pi(2) + \rho\pi(N)$. If firm 1 believes that firm 2 will not enter then since $0 > \pi(1) + \rho\pi(N)$, entry at date one by a single firm is unprofitable, and it is not profitable for firm 1 to signal the good news. Even though the two firms know that can earn positive profits, they fail to exploit their opportunity.

Of course, if $\pi(2) > 0$ then firms want to coordinate entry so a pure strategy equilibrium exists:

Proposition 3: Suppose $\pi(1)+\rho\pi(N) < 0$ and $\pi(2) > 0$. Then a pure strategy equilibrium exists:

$$m_{i1}^* = \begin{cases} 1 & if\ \delta\pi(2) + (1-\delta)\pi(1) + \rho\pi(N) > 0 \\ 0 & if\ \delta\pi(2) + (1-\delta)\pi(1) + \rho\pi(N) < 0 \end{cases}$$ ∎

If $\pi(2) > 0$, there is no coordination problem because each firm has an incentive to exploit the increasing returns to scale and enter if it believes the other will enter. The more likely informed firm 2 is to enter, the more profitable it is for firm 1 to enter.

4. Multi-Date Horizon

We now detail how entry decisions are affected when the horizon over which firms can enter is extended. The longer is the horizon, the lower is the cost of a failure to enter at date one because future profitable entry is not precluded.

In order to characterize the effects of extending the number of dates at which agents' entry decision may be made, we suppose that payoffs are such that firms face the same expected payoff from date one entry in the T–date economy as when there are two dates. If we denote the per-period payoff of the T–date horizon by $\pi_T(N)$, then $\sum_{t=1}^{T-1} \rho^t \pi_T(N) = \rho\pi_2(N)$. To simplify the presentation we assume that $\pi(1) = \pi(2) \equiv \pi(L) < 0$.

Define $\bar{T}$ to be the last date t such that entry is profitable:

$$\bar{T} = \max\left\{t \middle| \pi(L) + \sum_{\tau=t+1}^{T} \rho^{\tau-t}\pi_T(N) > 0\right\}.$$

Let m_t^* be the symmetric probability with which firms 1 and 2 mix over entry at date t given that neither has entered at previous dates. When entry does not occur, an informed firm revises downward its beliefs that another firm is informed. Consequently, it increases the probability with which it enters as long as future expected profits are positive. Let

$$\gamma_t^* = \left[\frac{\delta \prod_{\tau=1}^{t-1}(1-m_\tau^*)}{1-\delta+\delta\prod_{\tau=1}^{t-1}(1-m_\tau^*)}\right]$$

represent the conditional probability that i places on firm $-i$ being informed given that there has been no entry, where we adopt the convention that $\prod_{\tau=1}^{0}(1-m_\tau^*) = 1$.

Proposition 4 characterizes the symmetric equilibrium in a T–date economy:

Proposition 4: Suppose that $\pi(L) + \sum_{t=2}^{T} \rho^{t-1}\pi_T(N) > 0$ so that entry is profitable. Suppose further that

$$\delta > \delta^* = 1 - \frac{\pi(L)}{\rho[\pi(L) - \pi_T(N)]},$$

so that equilibrium is not characterized by probability one entry if good news is observed. Then there exists a symmetric equilibrium in which, given that entry has not yet taken place, a firm that knows market conditions are good enters with increasing probability as $t \leq \bar{T}$ increases:

$$m^*_{\bar{T}}\gamma^*_{\bar{T}} = \frac{\pi(L) + \sum_{\tau=\bar{T}+1}^{T} \rho^{\tau-\bar{T}}\pi_T(N)}{\sum_{\tau=\bar{T}+1}^{T} \rho^{\tau-\bar{T}}\pi_T(N)}$$

$$m^*_t\gamma^*_t = \min\Big\{1, z^*_t\Big\}, \quad t < \bar{T}$$

where

$$z^*_t = \frac{\rho\pi_T(N) + (1-\rho)\pi(L)}{\rho(\pi_T(N) - \pi(L))}.$$

The probability of entry at date $t < \bar{T}$ is smaller the longer the horizon, T, for entry. ■

From firm i's perspective, the probability that $-i$ enters, $z^*_t = m^*_t\gamma^*_t$, does not vary with t. However, since γ^*_t declines monotonically over time (reflecting that i grows increasingly pessimistic with time that $-i$ is informed), the entry mixing probability, m^*_t, must increase with time.

The value of $\pi_T(N)$ equates the discounted expected payoff stream at $t = 1$ for horizons of different length, T. As a consequence, the cost of not entering falls as T increases. Hence, (abusing notation) $z^*_t(T)$ falls. Since $z^*_1(T)$ falls as T increases, $m^*_1(T)$ falls and $\gamma^*_2(T)$ rises. This, in turn, implies that $m^*_2(T)$ falls and so on. It follows that the probability of entry, if positive, falls at all dates $t < \bar{T}(T)$ as the horizon increases. Note too, that as T increases, it is less attractive to enter for sure at date 1: $\delta^*(T)$ is decreasing in T. Since $\bar{T}(T)$ is also an increasing function of T, firms will continue to enter at later dates: effectively, the impact of a longer horizon is to spread out the probability distribution over dates at which entry occurs. Figure 1 illustrates how the mixing probabilities increase more rapidly for shorter horizons than longer horizons for the particular case of five and ten period horizons.

5. Observable Signal Acquistion

We now return to a two–date economy and add an information acquisition stage. We suppose that the two potentially–informed firms first independently decide whether to obtain a signal that reveals the state and then decide whether to enter. The other $N-2$ firms do *not* have access to the signal. Before deciding whether to enter, firm i *observes* whether firm $-i$ obtained a signal. To highlight the consequences of this observable information–acquisition stage, we suppose that it is *costless* to acquire the signal.

Ex ante the state is good with probability p. Each firm must decide whether to acquire the costless signal that *perfectly* reveals the state. If a firm acquires a signal and the state is good, it must then decide whether to enter at the first date. The bad state is still sufficiently unprofitable that no uninformed firm ever considers entering the market prior to observing informed entry.

Since information acquisition is costless, the key change to our environment is that now firms can strategically choose to remain uninformed, and this choice is observed prior to the time at which entry decisions are made. That is, firms can credibly commit to not being the first to enter. Were information acquisition *not* observable, then firms could not make this commitment so that the analysis would be identical to that in previous sections.

If $\pi(2) > 0$, then strategic behavior is uninteresting because the firms seek to coordinate entry. Both firms acquire signals with probability one and if the state is revealed to be profitable both enter with probability one at the first date and earn the positive first period profits.

Strategic interaction is richer when entry by two firms is unprofitable. Particularly interesting is the equilibrium in which both firms mix over information acquisition. There are two sources of inefficiency.[3] First, neither firm may acquire information. Second,

[3] If there is ever entry in equilibrium, then there always exist pure strategy equilibria in which one firm always acquires information about market conditions, and enters with certainty if the news is good. The other firms free–ride on this information, and earn greater profits.

information that market conditions are good may not be exploited, as each firm waits for the other to enter and reveal the good news:

Proposition 5: Assume that $\pi(1) + \rho\pi(N) > 0$, and that $\pi(2) < 0$, so that entry by a single informed firm is profitable but that firms do not have dominant strategies to acquire information. In the symmetric information acquisition equilibrium, firm i, $i = 1, 2$, acquires information with probability

$$\psi^* = \frac{\pi(1) + \rho\pi(N)}{m_1^{*2}(\rho\pi(N) - \pi(2) + \pi(1)) + (1 - m_1^*)(2\rho\pi(N) + \pi(1))} \leq m_1^*.$$

If the state is unprofitable, neither firm enters. If the state is profitable, an informed firm enters with probability

$$m_1^* = \begin{cases} 1 & \text{if it is the only informed firm.} \\ \frac{\pi(1)+\rho\pi(N)}{\rho\pi(N)+\pi(1)-\pi(2)} & \text{if both firms have acquired signals.} \end{cases}$$

The probability that the profitable venture is exploited,

$$\psi^{*2}[1 - (1 - m_1^*)^2] + 2\psi^*(1 - \psi^*)$$

is strictly less than the probability that the venture is exploited when firms do not have to acquire the costless signal,

$$[1 - (1 - m_1^*)^2].$$

For $\pi(1) < \pi(2)$, firm i's profits, $i = 1, 2$, are strictly lower when the costless signal must be acquired than when it does not. ∎

If both firms acquire the market information, then both know that each firm knows whether entry is profitable. In this case, when the state is good they mix over entry in an attempt to free–ride on the information revealed by the other firm's costly entry. At the node where both have acquired information, the situation corresponds to that where they did not have to acquire information, and so the equilibrium entry probabilities are also the same.

If only one firm acquires the signal then it enters with probability one in the next stage. That firm knows that no other firm has the information. Hence, it knows that in order to exploit the profitable opportunity it must incur the initial solo entry costs in order to convey the news to other firms.

This *observable* stage in which agents must acquire information introduces a second avenue for coordination failure. With positive probability, firms fail to acquire costless information that could reveal a profitable investment. By not acquiring information, firms credibly commit not to enter. This forces any informed firm to incur the signalling costs of entry with probability one, and eliminates the possibility that all informed firms will fail to enter. It is this ability to commit that further reduces the probability that information is acquired: $\psi^* < m_1^*$ as long as $\pi(1) < \pi(2) < 0$.[4] The probability of entry given the good state, $\psi^{*2}[1-(1-m_1^*)^2] + 2\psi^*(1-\psi^*)$, is lower because firms must first decide whether to obtain information and then whether to enter.

The introduction of the information–acquisition stage unambiguously lowers firm profits as long as $\pi(1) < \pi(2) < 0$. The information–acquisition stage does provide a benefit when $2\pi(2) < \pi(1)$ because aggregate "entry" costs may be reduced by the coordination facilitated by the conditioning of entry probabilities on the number of firms acquiring information. However, for $\pi(1) < \pi(2) < 0$ the cost of decreased probability that the opportunity is exploited exceeds this potential benefit. Figure 2 illustrates expected aggregate firm profits for different relative values of $\pi(2) = \alpha\pi(1)$, $\alpha \in [0,1]$, $\pi(1) < 0$.

[4] If $\pi(1) = \pi(2)$ then $\psi^* = \frac{\pi(1)+\rho\pi(N)}{\rho\pi(N)} = m_1^*$.

6. Conclusion

This paper considers a project that may be profitably exploited if enough agents choose to do so. However, only a few agents are aware of the opportunity. A single agent can take on the project, incur initial losses and signal to uninformed agents by its action that the project is profitable. We show that a free–rider problem can emerge: agents may delay taking on the opportunity in the hope that others will enter and thereby signal to others. This free–rider problem is even worse when agents must first decide whether to acquire information about the opportunity, and this information acquisition is publicly observed. This is true even when information acquisition is costless. We show how the incentives to free–ride may be so severe that agents never exploit an opportunity they know to be profitable. We speculate that delay of this nature may characterize several economic environments, including investment, gentrification, and urban development.

References

Bannerjee, Abhijit V. "A Simple Model of Herd Behavior." *Quarterly Journal of Economics*, August 1992, 107(3), pp.797-817.

Bulow, Jeremy and Paul Klemperer. "Rational Frenzies and Crashes.", *Journal of Political Economy*, January, 1994,

Caplin, Andrew and John Leahy. "State-Dependent Pricing and the Dynamics of Money and Output." *Quarterly Journal of Economics*, August 1991, 106(3), pp.683-708.

Caplin, Andrew and John Leahy. "Business as Usual, Market Crashes and Wisdom After the Fact," *American Economic Review*, June 1994a, 84(3), pp.548-565.

Caplin, Andrew and Leahy, John. "Miracle on Sixth Avenue: Information Externalities and Search," *mimeo*, 1994b.

Chamley, Christophe and Douglas Gale. "Information Revelation and Strategic Delay in a Model of Investment," *Econometrica*, September 1994, 62(5), pp.1065-1085.

Farrell, Joe "Cheap Talk, Coordination and Delay," *Rand Journal of Economics*, 1987, 18, pp.34-39.

Farrell, Joe and Garth Saloner "Standardization, Compatibility and Innovation," *Rand Jouranl of Economics*, 1985, 16, pp.70-83.

Gale, Douglas "Dynamic Coordination Games," *Economic Theory*, 1995, 5, pp.1-18.

Rob, Rafael. "Learning and Capacity Expansion under Demand Uncertainty," *Review of Economic Studies*, July 1991, 58(4), pp.655-75.

Proof to Proposition 1: Immediate. Profits from entry equal $\rho\pi(N)+m^*_{-i1}\delta\pi(2)+(1-m^*_{-i1}\delta)\pi(1)$. Profits from delay equal $m^*_{-i1}\delta\rho\pi(N)$. If $\delta > \delta^*$, then m^*_{i1} is the unique mixing entry probability for a signalled firm that leaves the other firm indifferent between entry and delay. ■

Proof to Proposition 2: Immediate. ■

Proof to Proposition 3: Immediate. ■

Proof to Proposition 4: If $\delta > \delta^*$, signalled firms mix over entry, or choose not to enter. That is, they enter with probability $m_t \in (0,1)$ until they reach date $\bar{T}+1$, at which point the discounted stream of profits is less than the expected cost of entering.

Equating the expected value of entry to that of delay for $t < \bar{T}$, the equilibrium value of z_t^* solves

$$\pi(L)+\sum_{\tau=t+1}^{T}\rho^{\tau-t}\pi_T(N) = z_t^*\sum_{\tau=t+1}^{T}\rho^{\tau-t}\pi_T(N)+[1-z_t^*]\left[\rho\pi(L)+\sum_{\tau=t+2}^{T}\rho^{\tau-t}\pi_T(N)\right].$$

Solving for z_t^* yields the result. Note that one can solve iteratively for the values of z_t^* beginning with z_1^* which determines γ_2^*, and so on. ■

Proof to Proposition 5: Given that a firm has acquired a signal and the state has been revealed to be good, that firm must decide whether to enter at date 1. If it alone has acquired the information, the informed firm enters with certainty since $\pi(1)+\rho\pi(N) > 0$. However, if both firms have obtained signals, then they mix over entry in the symmetric equilibrium. This mixing probability is determined by

$$(1-m_1)\pi(1)+m_1\pi(2)+\rho\pi(N) = m_1\rho\pi(N).$$

This condition is the same as the indifference condition when the two firms are known to have obtained information and, given the perfect correlation in their signals, they know market conditions are good ($\delta = 1$). Solving recursively, in the unique symmetric equilibrium both firms acquire a signal with probability ψ^*. This mixing probability is defined implicitly by the following indifference condition

$$p[((1-\psi)+\psi(1-m_1^*)m_1^*)\pi(1)+\psi m_1^{*2}\pi(2)+[(1-\psi)+\psi[1-(1-m_1)^{*2}]]\rho\pi(N) = p[\psi\rho\pi(N)].$$

Solving yields the value of ψ given in the proposition. Substituting for m_1^* into ψ and re–arranging yields

$$\psi = \frac{(\pi(1) + \rho\pi(N))(\pi(1) + \rho\pi(N) - \pi(2))}{(\pi(1) + \rho\pi(N))^2 - 2\rho\pi(N)\pi(2) - \pi(1)\pi(2)}.$$

Hence

$$\psi < m_1^* = \frac{\pi(1) + \rho\pi(N)}{\pi(1)\rho\pi(N) - \pi(2)}$$

if and only if

$$(\pi(1) + \rho\pi(N) - \pi(2))^2 < (\pi(1) + \rho\pi(N))^2 - 2\rho\pi(N)\pi(2) - \pi(1)\pi(2).$$

Re–arranging, $\psi < m_1^*$ if and only if $\pi(2)(\pi(2) - \pi(1)) < 0$.

Total expected profits of firms 1 and 2 when there is no information–acquisition stage equal

$$2[m_1(1 - m_1)][\pi(1) + 2\rho\pi(N)] + m_1^2[2\pi(2) + 2\rho\pi(N)] = 2m_1\rho\pi(N).$$

Expected total profits when there is an information–acquisition stage equal

$$2[\psi(1 - \psi)][\pi(1) + 2\rho\pi(N)] + \psi^2 2m_1\rho\pi(N).$$

Subtracting yields

$$\begin{aligned}
&2[[\psi(1 - \psi)][\pi(1) + 2\rho\pi(N)] - (1 - \psi^2)m_1\rho\pi(N)] \\
&= 2(1 - \psi)[\psi[\pi(1) + 2\rho\pi(N)] - (1 + \psi)\frac{\pi(1) + \rho\pi(N)}{\rho\pi(N) + \pi(1) - \pi(2)}\rho\pi(N)] \\
&\leq 2(1 - \psi)[\psi[\pi(1) + 2\rho\pi(N)] - (1 + \psi)(\pi_1 + \rho\pi(N))] \\
&= 2(1 - \psi)[\psi\rho\pi(N) - \pi(1) - \rho\pi(N)] \leq 0,
\end{aligned}$$

since

$$\psi\rho\pi(N) \leq m_1\rho\pi(N) = \pi(1) + \rho\pi(N) - m_1(\pi(2) - \pi(1)) \leq \pi(1) + \rho\pi(N). \quad \blacksquare$$

Figure 1. Comparing Five and Ten Period Games
($\rho = .9$, $\delta = .7$, $\pi(L) = -.4$, $\pi_2(N) = 1$)

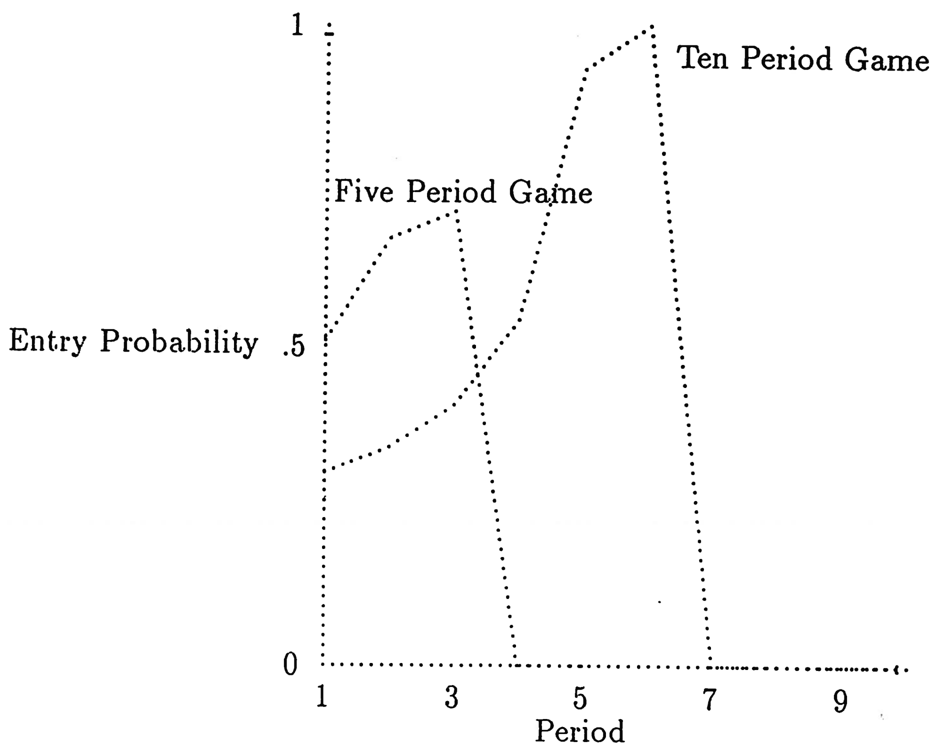

Figure 2. Joint Expected Profits of Informed Firms
($\rho\pi(N) = 1$, $\pi(1) = -.4$, $\pi(2) = \alpha\pi(1)$)