Time-to-Market Capability as a Stackelberg Growth Option

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May 1997
Revised: April 1999

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Abstract

This paper examines the decision to invest in logistics, market profiling and distribution capabilities that allow a firm to seize market share by being able to deliver a product ahead of competitors under Cournot quantity competition. This has the strategic effect of restraining competitors' behavior, and may justify the early commitment capital even when waiting offers deferment option value due to demand uncertainty. We show that the value of such time-to-market investment is unambiguously increasing in such uncertainty. However, when all competitors share this investment opportunity, the resulting "rush to the market" consumes resources without enhancing profitability.

Introduction

The literature on strategic growth options examines the impact of investment to gain comparative advantages vis-à-vis competitors. The commitment of irreversible investment may confer strategic advantages as a result of a reduction in future expansion costs (Dixit, 1980) or operating costs (Kulatilaka and Perotti, 1998); which contain competitors' production strategy and market share. Smit and Trigeorgis (1997) show the impact of a broad range of possible advantages gained by strategic investment in R&D.

In general, strategic effects have been shown to increase the appeal of early investment. Interestingly, the value of strategic investment may often increase as uncertainty on market demand or cost increases; however, the impact of uncertainty is often ambiguous[1].

Our goal in this paper is to develop some deeper insight concerning these results by examining a particular class of strategic options: time-to-market options, in which there is a pure timing advantage gained by early irreversible investment. Undertaking such real investment in conditions of uncertainty over future market demand has the opportunity cost of the initial cost of acquiring a timing advantage, but leads to the acquisition of a strategic growth option in terms of stronger ex post market share, relative to the case of postponement of entry. There is a difference, however, compared with the previous literature which contrasts the investment in strategic growth options with the wait-to-invest option: in this case there is no opportunity later on to acquire a timing advantage via later investment, the growth opportunity option is either seized today or lost forever.

The strategic gains of acquiring such an option must be compared with the initial sunk investment cost. The most intriguing feature of the timing advantage option considered here is that greater (nonsystematic) uncertainty unambiguously favors the early commitment of capital investment. This is contrary to the conventional wisdom in capital budgeting, although arguably it is in part reflected in common practice. Corporate managers often think in terms of pre-emptive decisions, of "beating competitors to the market".

Usually, the ability to invest early is assumed to offer an advantage by affecting the ex post or future cost structure, which strengthens the post-entry strategic position of the incumbent in gaining market share (Dixit [1980]).[2] In this paper we emphasize the advantage gained by an investment in specialized time-to-market capability. The assumption that there are time lags in investment is realistic and has been widely employed to explain macroeconomic fluctuations In our approach however we focus not on a traditional fixed investment in productive capacity, but rather on the capability to influence the rapidity of production as well as on distribution capability that ensures a rapid delivery of the product. For example, Boeing's investment in logistic platforms

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[1] This may occur because entry thresholds for competitors introduce some discontinuity in marginal profitability (Kulatilaka and Perotti, 1998).

[2] In a related paper, Kulatilaka and Perotti (1998) model strategic growth options that arise from investment which reduces future costs. There, unlike the present context, the effect of uncertainty is no longer unambiguous.

consisting of information technology, communications networks, and other processes that integrate suppliers and manufacturing plants with designers has helped it bring the 777 to market at a pace that is much faster than its competitors. Another classic example is the well-researched infrastructure built by Wal-Mart in rapid collection of information on customer purchases at individual shops and the rapid-response distribution system which allowed the company a rapid expansion in the US retail market. In this category fall several types of investment, not just in physical assets but also in market knowledge and customer access and targeting.

The basic model we develop is as follows. Suppose two firms are potential competitors in a new market segment with uncertain demand (we describe a market segment rather than a new product since there is no fixed capacity investment required). In the absence of strategic timing investment, both firms compete in quantities as Cournot competitors. When there is a time-to-market investment opportunity, the firm has the option to acquire at some cost a logistic advantage to bring output faster to the market than its competitor. This is not because the firm simply builds the plant ahead of potential competitors; a later entrant does not have access to acquiring such a time-to-market option. Rather, the timing advantage option is the result of the acquisition of logistics, market profiling and distribution capabilities that allow a firm to be "first in the shops". This timing capacity is related to the concept of a core capability or a platform investment (see Baldwin and Clark, 1992 and Kogut and Kulatilaka, 1994).

As the market opens and demand gets revealed, the firm which has invested in logistic infrastructure for faster time-to-market delivery can bring its output to customers first (technically, it has acquired an enduring Stackelberg timing advantage). Although this strategic option does not prevent competitive entry in the absence of fixed costs, it grants the leader firm the ability to credibly commit to a larger output, which results in a higher market share and profits. A late follower, recognizing such incentives, is forced to restrain its output and accept a lower market share.

Of course, such investments require building platforms well before market uncertainty is resolved. This leads to a higher risk profile as profits may be low relative to the necessary investment cost. Therefore, the value of not committing funds increases with demand uncertainty. The real options literature, which addresses this issue in a context of fixed sunk investment and perfect competition, concludes that the value of the option to wait to invest increases with uncertainty. Yet in our context uncertainty means greater risk but also greater opportunities. Interestingly, in our context the value of the time-to-market Stackelberg option *unambiguously* increases more than the value of not investing. The reason is that prices rise with demand due to the oligopolistic market structure, so that profits are convex in demand. The effect of greater uncertainty is thus to increase the incentive to invest in time-to-market leadership.   Since its marginal profitability increases with demand by more than under the no-strategic investment case, by Jensen's inequality a mean-preserving increase in uncertainty favors investment in the strategic growth option over the waiting option. Thus more uncertainty (in the sense of a mean-preserving spread in demand) reduces the threshold of expected future demand at which acquiring the growth option has a positive NPV.

This result cannot be directly compared to the apparently contrary implications on the relative value of the waiting-to-invest option (McDonald and Siegel, 1986)[3], as by construction such an option here does not exist. There are two differences. First, early investment has a different market impact in the context of imperfect competition (Kulatilaka and Perotti, 1998; Grenadier, 1997). Under imperfect competition, profits are convex in demand, as firms respond to higher demand by increasing both output and prices. Second, our particular framework describes a situation where the time-to-market option can be acquired only today: it is thus the opposite situation than when waiting still allows retaining an investment option.

[3] See Dixit and Pindyck (1995) for excellent reviews of this literature.

Finally, we show that in the special case when all competitors equally share the opportunity to make a time-to-market investment, this opportunity does not enhance firm profitability. Although the ensuing “rush to the market” consumes investment resources and presumably enhances customer satisfaction (due to earlier or perhaps better targeted product delivery), it leaves all firms equally poised to serve the market producing no extra gain to compensate for the extra expense. In this case, firm profitability would be enhanced if all competitors could coordinate by suppressing all time-to-market investment. The value of time-to-market investment remains significant when some competitors have no access to such investment opportunities.

The rest of the paper is organized as follows. In the next section we present a simple two period model where a single firm has a monopoly over the investment opportunity. Investing in the first period results in gaining market share as a Stackelberg leader against a competitor who may enter in the second period. Not having the same speed to produce and deliver the product, a late entrant suffers from delays in reaching the market and is relegated to the role of a Stackelberg follower. We examine the payoff to such a strategy and its sensitivity to uncertainty. In section 2, we allow both firms to invest in the first period and analyze the resulting symmetric market equilibria.[4] In Section 3, we study the effect of increased uncertainty on the incentive to invest. We find that under both our models firms will have an increasing incentive to invest in time-to-market options as uncertainty increases. Section 4 offers some concluding remarks.

1. Monopoly over the Acquisition of the Time-To-Market Growth Option

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[4] There are also asymmetric equilibria in the simultaneous investment game, but we do not focus on them here.

We consider as a benchmark the extreme but simple case of a firm having monopoly in the investment opportunity. (We relax this assumption later.) At time 0, a single firm (indexed by L -- the leader) has the opportunity to make an initial irreversible investment of amount *I*, which confers it the capability of faster future production. When firm L invests an amount I at time 0, it may choose production immediately at time 1, while firm F (the follower) needs more time to complete production and deliver its product. Technically this is equivalent to the purchase of an option on Stackelberg leadership. We assume that all costs are variable with the marginal cost of production being constant and equal to c.

Until time 1, when the market opens, there is uncertainty over the degree of future demand. We assume that the demand for the good is linear in prices and increasing in the random variable θ (which can be interpreted as the maximum price any customer would pay for the product).

Let P(Q) be the inverse demand function expressing the market price as a function of total supply Q:

$$P(Q, \theta) = \theta - Q$$

where θ is distributed on $(0, \infty)$, with expected value $E_0[\theta] \equiv \theta_0 > 0$. Uncertainty is assumed to be fully resolved at time 1 prior to production.

If the leader firm L invests in timing capability today, it can act as a Stackelberg leader in that it can choose its output level to maximize profits knowing that its competitor will be able to complete its production and deliver it only afterwards.

Given that the follower firm F enters the market, firm L has the first move over output and will choose to produce the amount which maximizes its profit:

$$\underset{Q^L}{Max} \quad \left[q - Q^L - Q^F(Q^L) - c \right] Q^L$$

where $Q^F(Q^L)$ represent the anticipated output decision by F when L chooses an amount Q^L. The optimal output decision by L yields $Q^L = (\theta - c)/2$, and the profits associated with Stackelberg leadership are $p^L = \frac{(q-c)^2}{8}$.

By contrast, firm F's optimal output is given maximizing its profit subject to the constraint that its time-1 profits exceed the investment:

$$\begin{array}{l} Max \quad \left[q - Q^F - Q^L(Q^F) - c\right] Q^F \\ Q^F \\ s.t. \\ Q^F\left[q - Q^F - Q^L(Q^F) - c\right] > 0 \end{array}$$

The optimal output for the follower is $Q^F = (\theta - c)/4$, while its profits as a Stackelberg follower are $p^F = \frac{(q-c)^2}{16}$. Note that even if the competitor anticipates that firm L will choose its Stackelberg output, it will enter only as long as $\theta > c$.

Of course, firm L makes no initial investment then it has no strategic timing advantage ex post vis-à-vis its competitors. Hence, when both firms choose to produce, the resulting equilibrium is a symmetric Cournot quantity competition. Each producer will choose its quantity to maximize its profi, e.g., for firm L:

$$\begin{array}{l} Max \quad \left[q - Q^L - Q^F - c\right] Q^L \\ Q^L \end{array}$$

Imposing symmetry so that $Q^F = Q^L = Q^C$, we obtain the symmetric Cournot equilibrium where both firms will choose an output level $Q^C = (\theta - c)/3$ with associated profits

$p^C = \frac{(q-c)^2}{9}$.

Here, early investment is advantageous because it allows firm L to commit to a greater output than its potential entrant, raising its profits from the level of a symmetric Cournot competitor to those of a Stackelberg leader.[5]

Optimal Investment

We initially assume no systematic risk (or risk neutrality) and a zero interest rate. In this case, the net present value of the time-to-market investment to the leader is:

$$V^L \equiv E_0[p^L] - I = E_0[\frac{1}{8}(q-c)^2] - I$$

The correct investment criterion calls for a comparison between the net present value of making the investment with the NPV of not making the investment. The latter value is

$$V^C \equiv E_0[p^C] = E_0[\frac{1}{9}(q-c)^2]$$

The firm with the time-to-market investment opportunity will invest if $E\,\pi^L - I > E\,\pi^C$ or $E(\pi^L - \pi^C) > I$. In order to investigate the optimal investment decision we define the ex post net gain to investment (the relative value of this type of investment) as

$\Delta(q) = p^L - I - p^C = \dfrac{(q-c)^2}{72} - I$. Then the net present value of the decision to acquire the growth option (relative to not investing) is the expectations of $\Delta(\theta)$: $G(q) \equiv \dfrac{E(q-c)^2}{72} - I$. The level of expected demand $\theta = \theta^*$ such that $G(\theta^*) = 0$ is a point of indifference.

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[5] In addition to this post-entry advantage, there may be a pre-entry advantage due to discouragement of entry if there were fixed capacity costs. Firm F will not enter unless the level of demand satisfies the threshold condition $\theta > c$ independently of whether there is Stackelberg leadership or not.

It is easy to show that a unique value for θ^* exists under some simple regularity conditions, namely for the set of distributions with a strictly positive support on θ where higher mean implies first order stochastic dominance (i.e., for which given two random variables x_1, x_2, $E(x_1) > E(x_2)$ $\Leftrightarrow$ x_1 first-order stochastically dominates x_2).

Proposition 1: Strategic investment is optimal when θ_0 exceeds the unique expected demand threshold θ^*.

Proof: From the definition of *ex post* profit functions we know that $\lim_{q_0 \to 0} G(q_0) = -I < 0$ and $\lim_{q_0 \to \infty} G(q_0) = \infty$. It is sufficient to show that $d\{G(\theta_0)\}/d\theta_0 > 0$; then uniqueness is established by the intermediate value theorem. Since Δ is an increasing and differentiable function of θ, the condition $d/d\theta_0 \{E\, \Delta[\theta(\theta_0)]\} > 0$ is satisfied for all distributions of θ under consideration. Since $G(\theta_0) > 0$ for all $\theta_0 > \theta^*$, in this range investment in the time-to-market option has a higher NPV than the alternative of not investing. ■

Alternatively, we can examine the level of investment that would be made for a given level of initial demand, θ_0. Let I^* be the investment threshold which is a function of θ_0 and is determined by solving for $E[\Delta(I)] = 0$.

Proposition 2: There is a unique optimal amount of strategic investment I^* for a given level of current expected demand θ_0.

Proof: Follows similar to that of Proposition 1.

2. Simultaneous Investment in the Time-To-Market Option

We now consider the case where both firms can acquire the same logistic capability by both competitors. We focus here solely on symmetric equilibria. A general result is that at a low level of expected demand neither firm exercises the early investment option, while at a high level both firms would invest. In the latter case the two firms end up as symmetric Cournot competitors and they would actually be better off saving the time-to-market investment. The benefit of a quicker delivery time to market is captured by consumers (though we do not model this benefit explicitly). We focus on these two cases.

We define the net present value from the time-to-market investment as Λ. Consider first the case when the other firm is expected to invest with probability one. Then Λ equals the difference between the profit as a Cournot competitor minus the cost I (for investing) and the profit as a Stackelberg follower, i.e. $\Lambda = \pi^C - I - \pi^F = \frac{(q-c)^2}{9} - I - \frac{(q-c)^2}{16} = \frac{7}{144}(q-c)^2 - I$. This defines an investment threshold in terms of expected demand $\hat{q}_0$ s.t.

$$E[\Lambda | q_0 = \hat{q}_0] = E[p^C - I - p^F] = \frac{7}{144} E(q-c)^2 - I = 0 .$$

The firm will not invest for $q_0 < \hat{q}_0$. In that case the other firm would in fact be better off to invest if the NPV of its investment exceeds the difference between its profit as a Stackelberg leader versus as a Cournot competitor. This defines a second threshold $\hat{\hat{q}}_0$, given by:

$$E[\Lambda | q_0 = \hat{\hat{q}}_0] = E[p^L - I - p^C] = \frac{E(q-c)^2}{72} - I = 0 .$$

Notice that this threshold level $\hat{\hat{q}}_0$ is identical to threshold level q_0^* which occurs when L has a monopoly over the investment opportunity.

Since $\hat{q}_0 > \hat{\hat{q}}_0$, this implies that if $q_0 > \hat{q}_0$ then both firms will invest. Conversely, it is easy to see that if $q_0 < \hat{\hat{q}}_0$ then neither firm will invest even if the other firm is not investing with probability one.

For an intermediate level of expected demand θ there can be two symmetric equilibria defined by the interval $\hat{\hat{q}}_0 < q_0 < \hat{q}_0$ where

$\hat{\hat{q}}_0$: I = *E*(profit as Cournot competitor $|\hat{\hat{q}}_0$) - *E*(profit as Stackelberg follower | $\hat{\hat{q}}_0$)

and

$\hat{q}_0$: I = *E*(profit as Stackelberg Leader $|\hat{q}_0$) - *E*(profit as Cournot competitor $|\hat{q}_0$).

Following the same logic used in Proposition 1, it is straight-forward to show the uniqueness of $\hat{q}_0$ and $\hat{\hat{q}}_0$. Coincidentally, the threshold level of θ_0 above which both firm invest is identical to the threshold value obtained in the case when a single firm has a monopoly over the investment opportunity.

In the middle range $\hat{\hat{q}}_0 < q_0 < \hat{q}_0$ there are two symmetric equilibria. In this range both firms would prefer to coordinate on a pure strategy of no investment in timing advantage, as they both earn the same Cournot profits as if neither had invested while avoiding the cost. There is one such equilibrium from which neither firm deviates, since $q_0 < \hat{q}_0$

In addition to this preferred symmetric pure strategy equilibrium, there is another symmetric equilibrium in mixed strategy. If a firm fears that with some probability the other firm will invest, it will also play a mixed strategy, entering with some probability. The optimal randomized strategy is obtained by ensuring that the firm is indifferent between investing and not investing. Let x be the probability of investing (by the competitor). If a firm invests, its expected profits are given by:

$$x\ E_0 p^C + (1-x)\ E_0 p^L - I$$

If the firm does not invest its expected profits are

$$x\ E_0 p^F + (1-x)\ E_0 p^C$$

Substituting for the profit functions and equating the expected profits of both strategies, the optimal equilibrium mixing probability x is

$$x = \frac{I - E_q(p^L - p^C)}{E_0(p^C - p^F) - E_0(p^L - p^C)} = \frac{144I - 2E(q-c)^2}{7E(q-c)^2}$$

In conclusion, if $q_0 < \hat{\hat{q}}_0$ there is no entry, if $\hat{\hat{q}}_0 < q_0 < \hat{q}_0$ there may be either a pure no entry equilibrium or randomized entry with probability *x*, and if $q_0 > \hat{q}_0$ both firms will invest in the logistic timing option.

3. Effect of Increased Uncertainty

One key contribution of this paper is to examine the effect of increased uncertainty on the investment thresholds and the probability of investment *x* in the case of mixed equilibrium. We define an increase in uncertainty as a mean preserving spread as discussed in Rothschild and Stiglitz (1976). Specifically, we consider a set of distributions with a strictly positive support on θ where higher mean implies first-order stochastic dominance.

Consider first the case where a single firm has a monopoly over the investment opportunity. We showed that the threshold level of current demand above which immediate investment is optimal is given by θ_0^* such that $\Delta(q) = E[\Delta(q_0 = q_0^*)] = 0$, where

$\Delta(q) = \frac{(q-c)^2}{72} - I$. Since $\Delta(\theta)$ is a strictly convex function of θ, a simple application of Jensen's inequality gives the result that as uncertainty increases, θ_0^* decreases. In cases where the derivatives exist, $\partial\theta_0^*/\partial\sigma < 0$. In other words, when uncertainty over demand increases without affecting its mean, both firms begin to invest earlier at a lower level of demand, θ_0.

A similar analysis can be carried out in the case where the investment opportunity is symmetric across the two firms. In the two extreme cases where both firms invest or both do not invest, the critical levels of threshold demand are given by $\hat{q}$ and $\hat{\hat{q}}$, respectively. We have already shown that $\hat{\hat{q}} \quad (= q^*)$ decreases with increasing mean-preserving spreads. In the case of

$\hat{q}$, a similar result is obtained by noting that the net gain function $\Delta(q) \equiv 7(q-c)^2 - 144I$, is convex. Hence, the region over which neither firm invests ($q_0 < \hat{q}_0$) becomes smaller.

We can also examine the effect of increased uncertainty on the probability of investing, x, in the mixed equilibrium. Let $\partial E(\theta^2)/\partial\sigma = \Psi > 0$. Taking derivatives of x with respect to σ, we get

$$\frac{\partial x}{\partial s^2} = \frac{-10[E(q-c)^2]^2\Psi - 7E[(q-c)^2]\Psi(144I - 2E[(q-c)^2]}{49[E[(q-c)^2]]^2}$$

Since $x > 0$, we know that $144\, I - 2\, E(\theta - c)^2 > 0$. Hence, $\partial x/\partial\sigma^2 < 0$. At first glance this result seems to go against the previous intuition since it indicates that the incentive to invest decreases with increasing uncertainty. In order to understand this result, we must properly interpret mixed strategy equilibria. When σ^2 increases $\pi^C - \pi^F$ increases by a greater amount than the increase in $\pi^L - \pi^C$. i.e., the gain from investing rises more than the gain from not investing. Therefore, for a firm to remain indifferent between investing and not investing, the probability *x* of the other firm investing must fall. Thus greater uncertainty indeed results in a greater incentive to invest.

Our results run counter to the central result in McDonald and Siegel [1986]. Their result, obtained in the case of a perfectly competitive product market, implies that as volatility increases firms would require better market conditions to justify immediate investment. Our result shows that in the tradeoff between the option value of waiting to invest and the strategic advantage of early investment, the latter is more sensitive to volatility in the case of Cournot quantity competition. The favorable volatility effect of the option to wait to invest uncovered in the real option literature reflects a *flexibility* effect; however, under imperfect competition the *commitment* effect appears to dominate.[6]

Example: Log-normally Distributed Demand

In each of the above cases, we can obtain closed form solutions to the threshold levels when demand θ is log-normally distributed. When c = 0 the thresholds are $q_0^* = \hat{q}_0 = \sqrt{\dfrac{72I}{e^{s^2}}}$ and $\hat{\hat{q}}_0 = \sqrt{\dfrac{144I}{7e^{s^2}}}$. Clearly, the derivatives $\partial\theta_0^*/\partial\sigma < 0$ and $\partial\theta_0^{**}/\partial\sigma < 0$. Figure 1 plots these threshold levels of demand as a function of volatility. In all cases, as volatility increases the threshold expected demand triggering early strategic investment is reduced.

4. Concluding Remarks

Recently the net present value paradigm has been challenged by a richer approach which can evaluate investment timing options, i.e., the flexibility value of postponing a decision until more information is available (thus limiting the down-side risk). A main result has been to exalt the negative impact of volatility on investment commitment value. However, postponement may entail some loss of irretrievable market opportunity. A firm which commits to a long-term investment strategy may lose financial flexibility but gains an offsetting valuable capability to expand rapidly in favorable market conditions.

Postponing the exercise of a strategic investment option has really dramatic consequences in a market with strong competitors. A long term investment strategy *commits* the firm to a market

[6] Smit and Trigeorgis (1997) show that the impact of volatility may be different under reciprocating (Betrand) price competition than under Cournot quantity competition. They also

more firmly than competitors. The first effect of such investment in capability is that it exposes the firm to greater unhedged risk by increasing fixed costs. Nonetheless, it also grants access to considerable upside potential because it discourages, or at least blunts, future inroads by competitors. The proper comparison is therefore between the strategic commitment value of early investment against the option value of waiting.

A main result of our analysis is that the effect of increased uncertainty is to *increase* the value of early investment in productive capability. We interpret such a capability as an investment in a time-to-market option. A rise in uncertainty increases, as expected, the value of the option to wait to invest. However, the strategic value of early investment increases even more. The reason is that early investment "buys" a higher potential market share by establishing a comparative advantage vis-à-vis competitors; therefore, in a strong market the firm has the timing capability to capture greater profits. Such investment also involves more down-side risk, through greater fixed costs, but a distinctive trait of investment in capability is an enhanced ability to respond to market conditions. Firms which take a long-term view can develop an ability to adjust output in a weak market, so that losses are largely limited to the initial investment. The resulting convexity in payoffs benefits dramatically from an increase in uncertainty. Thus the notion of uncertainty should be revisited as potentially offering an exciting upside potential, rather than disparaged by exposing to down-side risk. Risk can in fact be seen as opportunity for investment in capability; it allows to capture upside potential with some control over the down-side risk.

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discuss the tradeoff between flexibility and commitment effefts.

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Figure 1
Effect of volatility increases on threshold levels