First Follower's Real Option to revert to the Competitive Strategy

Low & High Price Point Collusion Capacities

Deepak Dhayanithy
Doctoral Student, Strategic Management Area
Fellow Programme in Management (FPM)
Indian Institute of Management, Lucknow, INDIA
deepakd@iiml.ac.in, +91 94154 32576
(Corresponding author)

M. Akbar
Professor, Strategic Management Area
Indian Institute of Management, Lucknow, INDIA
ma@iiml.ac.in

First Follower's Real Option to revert to the Competitive Strategy

Low & High Price Point Collusion Capacities

Abstract

Drawing from ideas of collusion in option games model with Cournot competition and price competition in a differentiated duopoly, we model, in a binomial framework, the latent collusion opportunity open to a first-follower. The first-follower is faced with investment decision in production capacity under market uncertainty as well as competitive uncertainty. The first-follower has an opportunity to collude with the incumbent in the Bertrand pricing game which will ensue with the first-follower's entry; on the basis of a non-binding agreement. The investment decision is faced by only one firm – the first follower; unlike other papers where both firms are faced with the same decision albeit with asymmetry in information or cost structure. Focus on collusion in Bertrand game in a differentiated duopoly leads to the insight that for a given degree of collusion (the extent by which Nash Equilibrium payoffs are improved for each of the players), there are two price pairs; which we call the high price point and the low price point. The capacity required to follow the high price point strategy is even lesser than that required to play the low price point strategy. The strategy to go in for low capacity in the initial period and scale up subsequently if need be has costs – variable costs are lower at higher capacity levels, scaling up requires installing appropriate technology and there is a possibility of the first-follower's capacity constraint becoming binding. We find that under different market demand volatility, elasticity and high/ low price point scenarios, the value of the option to revert to the competitive strategy (the option to scale up capacity) is significant. This insight can aid capacity creation decision of first-follower firms. Existence of low and high price points for collusion follows from an interesting Quartic equation in the price of either of the players.

Introduction

The three broad areas of strategic interest of the real options perspective are real options as an organizational decision making process (Bowman & Hurry, 1993; McGrath, 1997) real (growth) options perspective on market value of assets and firms (Grenadier, 1996; Quigg, 1993; Berger et al.,1996; Garner et al., 2002) and the real options approach to the analysis of investments under uncertainty (Dixit & Pindyck, 1994; Trigeorgis, 1996). This paper is part of the research work which deals with the latter two of the above-mentioned areas of interest; and focuses on modeling the capital investment decision facing a small first-follower biopharmaceutical firm in an option game framework.

A distinguishing feature of investment opportunities facing research oriented biopharmaceutical companies in India, and other third-world countries, is their focus on first-follower research; targeted at drugs going off-patent in the near future. If their research programs are successful, they have to commit capital in production capacities. Not only do they face uncertainty regarding the size of the market, but they also face competitive uncertainty in terms of the product's price-market share scenario which is likely to emerge in the resulting duopoly consisting of the incumbent (the innovator) and the first-follower. So far, the approach of a number of Indian companies has been to simply go in for a rock bottom price strategy. This involves heavy capital outlay to begin with, under high degree of market and competitive uncertainty. In the particular case we examine, the rock bottom price strategy does not support the kind of investments required. Discussions with the top management of one such company, FSM, reveal that a 'more cooperative pricing approach may enhance the revenue from the drug'.

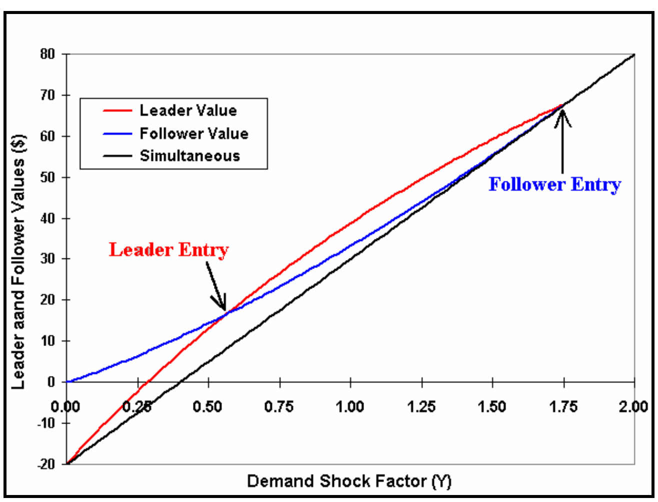
A more 'cooperative', or collusive pricing strategy potentially requires lesser installed capacity to execute. We bring together two important aspects of the option games literature – collusion (Huisman & Kort, 1999)and price competition in differentiated product markets (Vives, 2001) – in a discrete time setting. Whereas collusion has been discussed in a Cournot competition setting with firms competing to invest under uncertainty (Huisman & Kort, 1999) (Joaquin & Butler, 2000), we explore the collusion possibility in Bertrand competition in a differentiated product market and how this possibility gives rise to an option to create capacity in stages. This gives the first-follower an 'option to revert to the competitive equilibrium'. Our focus on collusion in price competition leads us to the interesting insight that for a certain degree of collusion (ratio by which NE payoff is improved for both the players), there are two collusive price points with corresponding capacity requirements. That is, the first-follower can install even lesser capacity at high collusive price point as compared to the capacity corresponding to low collusive price point. If the incumbent reciprocates, the first-follower can continue to play the cooperative price strategy. If the incumbent follows a purely competitive pricing strategy, then depending on how the demand uncertainty has been resolved, the first-follower can enhance capacity and follow a purely competitive pricing strategy thence. Retaining this option to play the competitive price in the first stage, allows the first-follower, FSM, to stage investment. We find that for a wide variety of scenarios in the market volatility, first-follower's price-elasticity, collusion price points and degree of collusion; investing in lesser capacity is the optimal investment strategy for the first-follower.

The incumbent has a very large capacity, and the investment problem is faced by only the first-follower. Option games literature till date only focuses on symmetrical decision problems, for example (Smets, 1993; Grenadier, R., 1996; Trigeorgis, 1996). Product market competitive dynamic gives rise to an option like feature in the investment problem. Staging investment dominates a one-shot capacity creation strategy under a wide variety of scenarios. This insight can help companies such as FSM to ensure successful R&D programs are seen through to the market; even if their pure-competitive NPVs are below 0. Variable cost implication of lower scales as well as the follower becoming capacity constrained in certain cases are endogenous to our analysis; and are the significant costs of flexibility.

Literature Review

The focus of Real Options models on (partially) irreversible investment under uncertainty has lead to claims in the literature (Dixit & Pindyck, 1994) of its utility in 'strategic' investment decision analysis. Optimizing ones behavior in the face of competition and uncertainty is studied by Option Game models. The Option Game models address the competitive effect by a combined game-theoretic and option-theoretic approach, which strengthens the claim to 'strategic' decision analysis (Trigeorgis, 1996). The degree to which the competitive effect is endogenous to the analysis is a key differentiator of option-game papers. The least endogenous manner in which 'competitive' effect is captured is by adjusting the 'dividend' upwards when an opportunity to invest is modeled as an American call option (Dixit & Pindyck, 1994). Early real options papers which included the competitive aspect, modeled the underlying asset to be subject to a Poisson arrival process and on arrival the investment opportunity is lost (Trigeorgis, 1991; Ankum & Smit, 1993). Note that these earlier attempts do not use game-theoretic approach to dealing with the competitive effects.

The game-theoretic treatment of the competitive effect (endogenous) is a rapidly growing area, with text books appearing in the fast growing area of Option Games (Huisman, 2001a; Grenadier, R., 2000; Trigeorgis, 1996). In the typical endogenous treatment, firms compete to invest in capacities under demand uncertainty. Real option papers typically view the value of the project (which does not include the contingent/ discretionary investment – the exercise price) to follow GBM (in continuous time analysis) or a binomial process (in discrete time analysis). In option game papers, the parameters of the demand (or inverse demand) functions – intercept term or elasticity – follow a GBM or a binomial process (Huisman, 2001a; Grenadier, 2000; Trigeorgis, 1996). Competition to invest is modeled as a Cournot game to begin with – where the strategic variable is quantity and the firms set their quantities (create capacities) simultaneously (Cournot, 1897; Romp, 1997). The insight from these models is that under competition, firms invest earlier than in the monopolistic case, under uncertainty. In a more generalized approach (Huisman, 2001b; Huisman & Kort, 1999; Joaquin & Butler, 2000), the threshold value levels for investment are derived for the first-follower (by assuming that the other player has already invested and approaching it as a Stackelberg follower's decision problem), the leader (approaching it as a Stackelberg leader's decision problem) and for simultaneous exercise.



Leader and Follower Values and Entry Thresholds (Dias & Teixeira, 2003)

When the simultaneous entry payoff dominates the sequential payoffs of Stackelberg competition (Romp, 1997), then Cournot type game emerges. Similar insights emerge in the discrete time models (for example, Trigeorgis, 1996), which are accessible to a wider audience due to the relative simplicity in the math.

Game-theoretic concepts: Game theory being a well developed field by itself, a number of game-theoretic concepts has been included in various option game papers. Indeed, this is a significant growth area for option game literature. Whereas the initial option games papers focused basic game-theoretic settings of complete information and non-cooperative players ((Romp, 1997) gives a simple explanation for the basic game-theory concepts); subsequent papers began to focus on more advanced game-theoretic concepts. For instance, in (Grenadier, 1996) two building owners have an option to upgrade their buildings. Upgrading a building improves its own rentals and has a negative externality – its impact on the other building's rent. With demand shocks in each of the periods, (Grenadier, 1996) gives a rational option game explanation for the seemingly irrational real estate buildup in times of declining demand. The building owners in this paper do not collude and the game is set in complete and perfect information. Later option games papers focus on tacit collusion (Huisman & Kort, 1999; Joaquin & Butler, 2000; Boyer, Gravel & Lasserre, 2004), information spillovers (Trigeorgis, 1996), war of attrition (Dias, 1997), bargaining (Dias & Teixeira, 2004) and move from duopoly setting to oligopoly setting(Murto, Nasakkala & Keppo, 2004).

Collusion: (Boyer, Gravel & Lasserre, 2004) as well as (Huisman & Kort, 1999) (Huisman & Kort, 2003) investigate the effect of magnitude and irreversibility of capacity outlays (with respect to the market size) on the development of the industry. They find that the early phase of such an industry is characterized by strong preemptive competition which implies riskier entry, lower expected returns, and more bankruptcies. This outcome occurs irrespective of the volatility or the speed of market development. At later stages of development, when both firms hold capacity, competition may be weaker in the sense that tacit-collusion equilibrium points may exist. ***Tacit collusion to restrict production takes the form of postponed simultaneous investment by both firms***. (Huisman & Kort, 1999) as well as (Joaquin & Butler, 2000) show that when the demand level is set high enough (by adjusting the parameters of the demand function upward – for instance, the intercept term), then this tacit collusive equilibrium is no longer stable.

Asymmetry: The effect of firm asymmetry is an important direction of development in the real options field. (Joaquin & Butler, 2000) investigate the effect of asymmetry in variable costs on leader, follower and simultaneous exercise thresholds. In multi-stage games, firms can carry out R&D in the initial stages which bestows on them cost advantage which can be propriety or shared (Trigeorgis, 1996; Smit & Trigeorgis, 2004; Smit & Trigeorgis, 1997). However, the decisions facing the players are the same. That is, the literature focuses on competition among equally positioned firms.

Price competition in Differentiated product markets: In an early paper, (Kreps & Scheinkman, 1983) analyze the equilibrium of a two stage duopoly game. Firms first compete on capacity to be installed and in the next time period on price. Kreps and Scheinkman (1983) show that this Cournot-Bertrand game has the same equilibrium as a Cournot game. This point has been emphasized in (Varian, 1992) as well as in (Dias & Teixeira, 2004). This has perhaps contributed to the focus on quantity as a strategic variable, which is more suited to commodity type product markets.

We model a situation in which the investment decision is faced only by the first-follower. Further, unlike investment timing games and research and development races, the first-follower here has an option to revert to the competitive price strategy and thereby an opportunity to scale-up accordingly. This is essentially a scaling up option, studied in a option game setting. We focus on the collusive aspect and find that high price point and low price point collusion are both possible – each with a different capacity implication and a different equilibrium outcome. The bringing together of price competition in differentiated products, demand uncertainty, asymmetric decision situation, collusion possibility and the combined impact of the three on initial capacity levels as well as quantum of scaling is the feature unique to our study.

In our study, the first-follower firm has developed a technology and obtained the required regulatory clearances to launch the drug as soon it goes off patent. The market which would result from the first-follower's investment in production capacities is modeled as a price competition between differentiated products – the augmented Bertrand model (Vives, 2001). The investment decision is faced by the first-follower only – therefore, it is asymmetric in the decision of interest. The purely competitive equilibrium in the product market does not support the investment in production capacities. However, the first-follower has a latent opportunity to collude on the prices (Romp, 1997). The prospect of collusion gives the first-follower an opportunity to go in for a smaller capacity in the first period and play the collusive strategy. The risk in this strategy is that of the first-follower becoming capacity constrained – the benefit is from postponing investment until the demand uncertainty gets resolved. The costs incurred by the first-follower to achieve this flexibility and scalability in capacity are in terms of variable cost impact, capacity constrained and incremental capacity addition penalty; the former two being endogenous to our option game analysis. This is a situation faced by a significant number of research oriented Indian (and indeed, developing country) firms targeting the first-follower space.

Model Setting

A small biotechnology based vaccine and drug research and manufacturing firm in India (FSM) has developed the technology and obtained permissions from drug regulators to launch a niche segment (monoclonal antibody) drug as the first-follower, as soon as the innovator's drug goes off-patent. Traditionally, FSM like other Indian firms has chosen to go in for prices which are 1/3 to 1/2 of the innovator's prices. In the case of this particular niche segment drug, the typically low price strategy makes the project a negative NPV project. However, management is of the view that a more 'cooperative' approach to pricing might result in better payoffs. Since the stages of research and development have already been completed, the typical R&D real options models are not applicable in this particular project for FSM.

Market uncertainty gets resolved through the passage of time in option game models. In multi period settings, this allows the decision to defer investment from the first stage of the game. We consider, in addition to demand uncertainty which gets resolved through the passage of time, uncertainty regarding competitive interaction (Romp, 1997). This is an uncertainty which can only be resolved by participating in the market after creating capacities in the case of market entry by a first-follower which we explore. Our attempt shows that there is an option to choose lower capacity levels and enhance this capacity in subsequent stages. The first-follower has a **latent opportunity to try and negotiate a 'collusive' pricing strategy with the incumbent**, prior to deciding on the capacity to be installed, where the demand is uncertain. Such an agreement to collude on the prices is **non-binding** (Dias & Teixeira, 2004) – the incumbent and the first-follower can enter into such an agreement and then deviate from it. That is, either of the players can behave in an opportunistic manner. It is this latent opportunity that we are exploring. Prior to making the capacity investment decision, this collusion opportunity is significant because collusive outcomes in Bertrand duopoly of differentiated products (Singh & Vives, 1984) require lesser quantities as compared to NE quantities – hence lesser capacity needs to be installed – to play.

Our model is a two stage model. At the beginning for the first stage, the first-follower has to decide on the capacity to install which will be required to produce the drug. The cost required to set up this capacity is incurred in one go, at the beginning for the first period; and it takes the entire of first stage (one year) to install the capacity. The second stage of the model is an infinitely repeated (one time unit is one year) Bertrand pricing game in a differentiated duopoly with an opportunity for price collusion (Singh & Vives, 1984). This collusion is on the basis of an agreement entered into prior to the first-follower setting up the capacity. In the first stage of the model, demand is uncertain – the intercept term of the demand functions can take two values – corresponding to the 'up' and 'down' stages of demand. The Bertrand pricing game itself occurs after this demand uncertainty has been resolved by the passage of the first-stage of the model.

For each state of demand (either 'up' or 'down') which materializes in the second stage of the model, the first-follower can negotiate with the incumbent the 'degree of collusion' and following from that, the collusive prices that each should set. This negotiation occurs prior to the first stage of the game, when the first-follower has to make the capacity decision. The degree of collusion is the extent by which the NE payoff of each of the players is enhanced, if they successfully coordinate on the collusive price. We have only investigated scenarios where the degree of collusion is the same for both the players. Further, we have only investigated scenarios where the degree of collusion is the same for both states of demand, at the given level of volatility. The incumbent and the first-follower are more likely to agree to a non-binding collusive agreement under the 'down' state of demand as compared to the 'up' state. Such a non-binding collusive agreement only in the 'down' state can be included in the analysis and is an area for future work in this direction. We can show that for the same degree of collusion, a 'high-price-pair' and 'low-price-pair' are possible. That is, the incumbent and the first-follower can collude on two price pairs of prices – and in both the cases, with the restriction of equal degree of collusion for players and across demand states. The quantities cleared by the market are least for the 'high-price-pair' collusive outcome, more for the 'low-price-pair' collusive outcome and maximum for the NE outcome.

The existence of two collusive price-pairs can be demonstrated by solving the collusive payoff functions of the incumbent and the first-follower simultaneously, which requires solving a

Quartic equation in price (Abramowitz & Stegun, 1972). The maximum degree of collusion possible (β_{Max}) is determined by the price points lying in the region to the right and above both incumbent's and first-follower's NE isoprofit curves (Romp, 1997).

Second stage

The second stage of the two-stage game is an infinitely repeated Bertrand pricing game in a differentiated duopoly (Singh & Vives, 1984) (augmented Bertrand model). Whichever demand state fructifies continues steadily for each succeeding year. Such an evolution for the market demand abstracts a great deal from reality. In multi stage settings, market evolution has been modeled to follow exogenous demand shock at each stage; for example, (Trigeorgis, 1996) (Smit & Trigeorgis, 2004) (Smit & Trigeorgis, 1997). Our objective, in this paper, is to explore the possibility of collusion outcomes and the capacities required by the first-follower to support the same. From a game-theoretic perspective there are five ways in which purely competitive players are able to achieve cooperative (collusive) outcomes in a repeated game setting (Romp, 1997). These are infinitely repeated games, repeated games with multiple Nash equilibrium, finitely repeated games with bounded rational players, uncertainty about when the game will end in finitely repeated games and finitely repeated games where each of the players assigns a small probability to the other being 'irrationally cooperative' in the first instance of a finitely repeated game (Romp, 1997; Rosenthal, 1981; Radner, 1980). While the last of these mechanisms mirrors market development better, the case of infinitely repeated games is simpler and allows us to concentrate on the collusive pricing – lower capacity linkage; the key focus of this paper.

The two firms set prices with full information of their competitors variable costs, demand elasticities, intercepts of demand function and the cross elasticities. Although, in the first stage of the game when the first-follower makes the capacity decision, demand is uncertain; this uncertainty is resolved at the beginning of the second stage, the two players have to set the prices in the second stage. This translates into the first-follower requiring the extent of the first stage – 1 year – in our case to set up the capacity. The intercept term can take two values – representative of demand uncertainty – in the first stage of the game. In the second stage of the game, one of 'up' or 'down' demand equation intercepts has fructified and demand state in the second stage of the model is common knowledge.

The first-follower, as part of the collusive agreement entered into with the incumbent, follows a punishment strategy (Romp, 1997) where the first-follower sets the collusive price in the first year of the second stage. If the incumbent sticks to the collusive agreement, then this collusive outcome continues to infinity. If the incumbent deviates from the collusive agreement, then the first-follower reverts to the NE price. Depending on the capacity created by the first-follower in the first stage of the game, the first-follower may or may not be able to execute the NE pricing strategy. In case the first-follower had set up a lesser capacity anticipating a collusive outcome, then the first-follower will have to invest in the incremental capacity in the first year of the second stage in order to play the NE from the second year onwards. In case, the investment cost does not cover the incremental revenues, then the first-follower will settle with the existing capacity. But, our modeling approach does not explicitly consider the possibility of the incumbent trying to follow a limit pricing strategy with a view to shutting the first-follower out.

The main entry barrier in the biopharmaceutical industry is technological. In our case, the first-follower has already crossed this barrier, and obtained the necessary regulatory clearances to enter the domestic market. The domestic market is miniscule as compared to the world market for the particular monoclonal antibody. In the past, large MNCs have attracted regulatory attention due to significantly lower prices of drugs across countries. Monopolistic practices are monitored closely by regulators, particularly is the drug sector.

By equating the incumbent's collusion and deviation strategies, we can obtain the **indifference discount rate** of the incumbent (Romp, 1997). If the incumbent discounts future revenues at a rate lower than the indifference discount rate, then the incumbent will stick to the collusive price. We derive the expected value to the first-follower from following this 'try collusion' strategy by assigning a probability to incumbent's discount rate being lower than the indifference discount rate. This probability function is increasing in the incumbent's indifference discount rate. That is, higher the indifference discount rate of the incumbent the higher the probability that the incumbent's discount rate is a 'cooperative' one. When the incumbent's discount rate is lower than the indifference discount rate, then the incumbent cooperates and the payoff to the first-follower corresponds to the collusive outcome. When the incumbent's discount rate is higher than the indifference discount rate, then the incumbent does not cooperate. The first-follower's payoff corresponds to incumbent's reaction function outcome for the first year and the NE payoff thereafter. In this particular paper, we use the probability that the incumbent's discount rate is lesser than the indifference discount rate is equal to the indifference discount rate itself, subject to a maximum of 1.

First Stage

This possibility of a collusive outcome in the second stage of the game gives the first-follower a choice to invest in different capacity levels in the first stage of the game. For each demand state, the NE capacity and the Collusive (at the agreed upon degree of collusion) outcome capacity are the capacity choices open to the first-follower; giving rise to four levels of capacity to choose from. The capacity required to play the collusive strategy under 'down' state of demand is the least. The capacity required to play the NE strategy under 'up' state of demand is the maximum. In between these two values are the capacity required to play the NE strategy under 'down' state of demand and the capacity required to play the collusive strategy under 'up' state of demand.

We assume that the incumbent is able to observe the capacity decision made by the first-follower. The incumbent entertains the option of colluding only when the first-follower installs a capacity in line with that required by the cooperative outcome. That is, there is no chance of the incumbent cooperating were the first-follower to install capacity required to play NE in the 'up' state of demand. There is chance of the incumbent cooperating only when the first-follower installs capacity corresponding to collusive quantity of the 'up' state or lower. Note that under certain combinations of demand volatility and degree of collusion, collusive quantity of the 'up' state might be higher or lower than the NE quantity of the 'down' state of the demand.

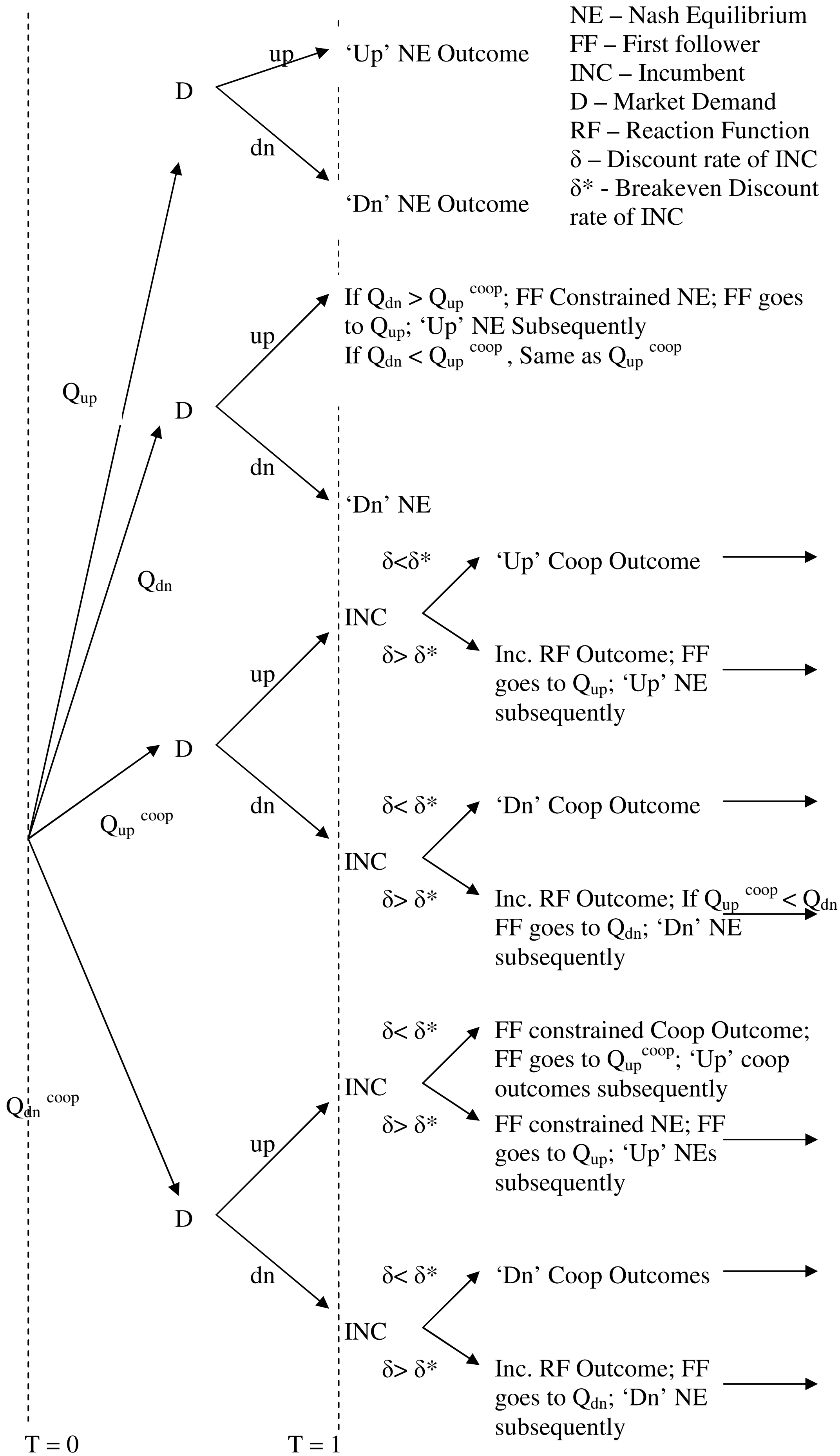
Flexibility Cost

By going in for capacities lower than or equal to the collusive quantity of the ‘up’ state the first-follower benefits from flexibility in the face of the demand uncertainty and from the probability that the incumbent will stick to the collusive pricing strategy. However going in for lower capacity levels has cost impact in three areas. Firstly, going in for lower capacities may make the first-follower **‘capacity constrained’** in realizations of demand and incumbent cooperativeness which require larger capacities than those available with the first-follower. This capacity constraint is addressed by a class of games called **Bertrand-Edgeworth** games (Vives, 2001; (Edgeworth, 1925). When the capacity constraint is binding – that is, the potential quantity to the first-follower is greater than the installed capacity – the first follower would adjust price upward to make full use of the capacity. This is anticipated by the incumbent and so on. The payoffs to the incumbent and the first-follower are calculated following (Froeb, Tschantz & Crooke, 2003).

Secondly, we introduce an ‘incremental capacity addition penalty’. That is, if the first-follower installs a lower capacity in the first stage of the game and is required to enhance capacities in the second stage; then this ‘stepping up’ of capacity is costly. In the biotechnology industry, this corresponds to incurring expenditure on the appropriate technology which will allow such scaling up. The larger the capacity step, the costlier is the technological features which will allow for such capacity step up. Therefore, we set the ‘incremental capacity addition penalty’ to be proportional to the capacity step up involved, in the second stage of the game. Lower the initial capacity installed (in the first stage) and higher the final capacity installed (in the second stage), higher is the incremental capacity addition penalty. Whereas, the first cost (in the previous paragraph) is endogenous to the game-theoretic analysis; this second cost is exogenously supplied to the model.

The third cost of lower capacities is the capacity impact on variable costs. Variable cost is taken to be inversely proportional to the installed capacity and is endogenous to the model; since our model has two players attempting to maximize their payoffs – quantity times difference between price and variable costs – in a game-theoretic setting. The variable costs are derived from the material costs as well as the level of wastage. Typically the wastages are lower, higher the capacity since higher capacities support better process control instrumentation.

Figure 1: Real Option to Revert to Competitive Price Strategy



Model

In the second stage of the game, the incumbent (INC) and the first follower (FF) face the following linear demands, following standard practice – for example, (Smit & Trigeorgis, 2004; Smit & Trigeorgis, 1997; Vives, 2001; Singh & Vives, 1984)

$$q_{INC} = \Phi_t - k_{INC} p_{INC} + \alpha p_{FF} \quad \ldots(1)$$

$$q_{FF} = \Phi_t - k_{FF} p_{FF} + \alpha p_{INC} \quad \ldots(2)$$

Due to superior brand reputation of the incumbent, the incumbent's quantities are less sensitive to the price changes than the first-follower. We express this by keeping $k_{INC} < k_{FF}$. We run our experiments under two sets of values of k_{INC} and k_{FF}; (0.6,1) and (0.6,0.8). The value for the intercept term of the demand functions Φ_t is uncertain at time t = 0. At time t = 1, Φ_t takes two values Φ_{up} and Φ_{dn}. We run our experiments under two sets of values of Φ_{up} and Φ_{dn}; (125,80) and (150,67). We add the condition that the product of the price elasticities is greater than the square of the cross-elasticity; that is

$$k_{INC} k_{FF} \geq \alpha^2 \quad \ldots(3)$$

This ensures that the second order partial derivative condition for the existence of maxima holds (Singh & Vives, 1984)

The variable cost of the first-follower are a function of the installed capacity and tends to fall, the larger is the installed capacity. That is, $v_{FF} = {}^{M}\!/_{Q_{FF}}$. The variable cost of the incumbent, v_{INC}, is a constant. Given the prices of the incumbent and first-follower, p_{INC} and p_{FF}, their payoffs in one period of the game are given by

$$\Pi_{FF} = p_{FF} q_{FF} - M \quad \ldots(4)$$

$$\Pi_{INC} = q_{INC}(p_{INC} - v_{INC}) \quad \ldots(5)$$

Under both realizations of Φ_t the Bertrand-Nash Equilibrium (BN) prices, quantities and payoffs (Sing & Vives, 1984; Vives, 2001) are as follows.

$$p^{N}_{INC} = 2k_{FF}(\Phi_t - v_{INC}) + \alpha\Phi_t / (4k_{INC}k_{FF} - \alpha^2) \quad \ldots(6)$$

$$p^{N}_{FF} = \alpha(\Phi_t - v_{INC}) + 2k_{INC}\Phi_t / (4k_{INC}k_{FF} - \alpha^2) \quad \ldots(7)$$

$$q^{N}_{INC} = 2k_{INC}k_{FF}(\Phi_t + v_{INC}) + \alpha(k_{INC}\Phi_t - \alpha v_{INC}) / (4k_{INC}k_{FF} - \alpha^2) \quad \ldots(8)$$

$$q^{N}_{FF} = k_{FF}[\alpha(\Phi_t - v_{INC}) + 2k_{INC}\Phi_t] / (4k_{INC}k_{FF} - \alpha^2) \quad \ldots(9)$$

Under certain combinations of the first-follower's investment strategies, one of q^{N}_{up}, q^{Coop}_{up}, q^{N}_{dn} or q^{Coop}_{dn}, on one hand and demand state realizations together with cooperativeness of the incumbent on the other, the first-follower is capacity constrained in the first year of the second-stage. That is, the first-follower is not able to play the NE as afforded by the demand state-competitor disposition realization, because the installed capacity is lesser than the equilibrium, or potential, quantities. Equilibriums under capacity constraints were studied by Edgeworth (1925), and this class of games in price competition is called Bertrand-Edgeworth (Vives, 2001). The conditions under which the first-follower will be capacity constrained in the first year of the second stage of the game can be got from the following inequality.

$$q^{N}_{up} > q^{Coop}_{up}, q^{N}_{dn} > q^{Coop}_{dn} \quad \ldots(10)$$

Depending on levels of volatility, elasticity and level of collusion the first-follower quantity under up-state-demand with collusion may be greater or less than down-state-demand with pure competition; $q^{Coop}_{up} <> q^{N}_{dn}$.

Let C be the production capacity of the first follower and let this constraint be binding – that is, the equilibrium quantity (either competitive or cooperative) to the first-follower is greater than the first-follower's installed capacity. Following Froeb et al. (2003), we solve the payoffs in such cases by making sure that the slack variable - the difference between the potential quantity and the capacity, is zero – resulting in the first derivative of the unconstrained profit function of the first-follower to be less than zero. The constrained equilibrium prices are given by the two equations below, from which given the demand functions (equations 1, 2) and profit functions (equations 4, 5); the payoffs to the incumbent as well as the first-follower can be calculated.

$$p^{C}_{INC} = [k_{FF}(k_{INC}v_{INC} + \Phi) + \alpha(\Phi - C)] / (2k_{INC}k_{FF} - \alpha^2) \quad \ldots(11)$$

$$p^{C}_{FF} = (\Phi + \alpha p_{INC} - C) / k_{FF} \quad \ldots(12)$$

Collusion

Let us consider an outcome which pareto-dominates the NE by the factor of β ($\beta > 1$). The payoffs to the incumbent and the first-follower in this case are given by $J^{Coop}_{INC} (= \Pi^{N}_{INC} \beta)$ and $J^{Coop}_{FF} (= \Pi^{N}_{FF} \beta)$. Let p^{Coop}_{INC} and q^{Coop}_{INC} be the corresponding prices and quantities for the incumbent and p^{Coop}_{FF} and q^{Coop}_{FF} be the corresponding prices and quantities for the first-follower, which support this cooperative outcome. The values of p^{Coop}_{INC}, q^{Coop}_{INC}, p^{Coop}_{FF} and q^{Coop}_{FF} can be obtained by solving the following two equations,

$$J^{Coop}_{INC} = (\Phi_t - k_{INC} p^{Coop}_{INC} + \alpha p^{Coop}_{FF}) p^{Coop}_{INC} \quad \ldots(13)$$

$$J^{Coop}_{FF} = (\Phi_t - k_{FF} p^{Coop}_{FF} + \alpha p^{Coop}_{INC}) p^{Coop}_{FF} \quad \ldots(14)$$

The above two equations can be converted into a quartic, an equation with non-zero coefficient of ^4 term and no higher powers, in p^{Coop}_{INC} or p^{Coop}_{FF} terms and as far as there are real solutions (Abramowitz & Stegun, 1972), collusion to the degree β is possible and we get the corresponding prices and quantities. Interestingly, for each degree of collusion there are two possible sets of prices which will result in quantities ultimately achieving the degree of collusion (subject to finding real roots to the quartic equations). We call these two possible sets of points **'high price points'** and **'low price points'**. The capacities required to play the 'high price point' collusive price is typically half or less of the capacities required to play the 'low price point' collusive price at each level of collusion degree, β . Note that the quantities required to follow both the high-price point and low-price point collusive strategies is less than the NE quantities. We run our experiments for low price point and high price point collusive possibilities, separately.

Were the incumbent to deviate from the collusive price point and maximize current-period profits, then the incumbent's price on the reaction function can be found using the following reaction function equations.

$$p^{RF}_{INC} = (\Phi_t + \alpha p^{Coop}_{FF} - v_{INC}) / 2k_{INC} \quad \ldots(15)$$

$$p_{FF}^{RF} = (\Phi_t + \alpha p_{INC}^{Coop}) / 2k_{FF} \quad \ldots(16)$$

When the first-follower establishes a cooperative production capacity, the incumbent may not always respond to the cooperative pricing scheme. The first-follower may price cooperatively, but the incumbent may respond competitively and price at the incumbent's reaction function. In the infinitely repeated Bertrand game that we are considering, we assume that the first-follower responds to such deviation from the agreed upon collusive price by reverting to the realized demand level's NE subsequently. This behavior of the first-follower is also common knowledge. Whether the incumbent will stick to the collusive outcome is a function of how heavily the incumbent discounts future earnings.

When the incumbent deviates from the (agreed upon) pricing strategy, we assume that the first-follower responds by increasing the capacity to the appropriate demand level's NE (if the capacity set up in the first period turns out to be lesser) and then setting the NE price in all subsequent periods of the second stage. The only case when the first-follower does not invest in the second stage of the game in the face of the incumbent following a purely competitive strategy is when the cost capacity enhancement is not covered by the difference between the NE payoffs to infinity and constrained equilibrium payoffs to infinity.

$q_{FF}^{Coop,RF}$ and $q_{INC}^{Coop,RF}$ are the quantities when the first-follower's cooperative price is met with a competitive response from the incumbent (incumbent follows a pricing strategy on the incumbent's reaction function). The resulting prices, quantities and payoffs can be obtained from the equations 15, 16 (price reaction functions); equations 1, 2 (quantities) and equations 4, 5 (payoffs).

$$q_{INC}^{Coop,RF} > q_{INC}^{N}; q_{FF}^{Coop,RF} < q_{FF}^{N} \quad \ldots(17)$$

The above condition ensures that the incumbent has a short-term incentive to deviate from the cooperative pricing strategy and that the first-follower's threat of following up any deviation from the pricing strategy with subsequent NE price is credible. The value of the discount rate where the incumbent is indifferent between cooperating and following a purely competitive pricing strategy is given by δ^* (the indifference discount rate), obtained by equating the payoffs from the two strategies,

$$\delta_{INC}^{*} = (\Pi_{INC}^{Coop} - \Pi_{INC}^{N}) / (\Pi_{INC}^{Coop,RF} - \Pi_{INC}^{N}) \quad \ldots(18)$$

Under each combination of the first-follower investment strategy and demand state realization, the first-follower estimates a probability of δ_{INC} exceeding δ_{INC}^{*}. We specify this probability with the function

$p(\delta_{INC} > \delta^*_{INC}) = \delta^*_{INC}$ … (19)

Under risk-neutrality, the expected value of each combination of first follower investment strategy and demand state realization is found out. When the first-follower sets up competitive capacities, there is no chance of the incumbent playing cooperatively. For each volatility, elasticity and degree of collusion (β) , whether $q^{Coop}_{up} > q^{N}_{dn}$ or $q^{Coop}_{up} < q^{N}_{dn}$; the incumbent is open to collusion as far the first-follower sets up a capacity which is lesser than q^{N}_{up}. If the first-follower sets up capacities larger than greater of q^{Coop}_{up} and q^{N}_{dn}, the incumbent is not open to collusion and the second stage of the game is characterized by NE payoffs summed to infinity.

First Stage

In the first stage of the game, the expected payoffs from each realization of the demand parameter is calculated and the present value of investing in each of the quantity levels; q^{N}_{up}, q^{Coop}_{up}, q^{N}_{dn} or q^{Coop}_{dn} is found. We have computed these payoffs for two volatility levels, two levels of the first-follower's elasticity, high price point versus low price collusion; as well as for two levels of 'incremental capacity addition penalties'. The option-game is evaluated under 2^4 scenarios, arising out of combination of 2 volatility levels, 2 levels of elasticity of the first-follower, high and low price point collusive possibilities and two levels of the 'incremental capacity addition penalty'. For each of the scenarios, the NPVs of the four investment strategies are calculated for 7 degrees of collusion (β) up to the maximum possible degree beyond which real solutions do not exist for price combinations yielding the collusive payoffs.

The risk-neutral probability associated with the 'up' state of demand is given by (Smit & Trigeorgis, 1997; Smit & Trigeorgis, 2004; Trigeorgis, 1996)

$$p(up) = [\ (1 + R_f) - (d + r)\ ]\ /\ (u - d) \quad \ldots (20)$$

$$r = \delta_{FF} / (1 + \delta_{FF}) \quad \ldots (21)$$

δ_{FF} is the first-follower's risk-adjusted rate of return. The cost of investment in the first stage of the game has two components. The first component is a factor 'I' which is a per unit capacity investment cost. In the second stage of the game under certain combinations of first-stage investment decision, demand state realization and incumbent's cooperativeness; it may become necessary for the first-follower to add capacities incrementally. The second component of investment cost penalizes this incremental capacity addition – smaller the increment, greater is the penalty. This mirrors the real life cost implication of incremental capacity additions, which emerged from discussions with R&D and Production personnel at FSM.

Scenario Analysis

Experimental runs were carried out using the following data. Price and cost values are in multiples of Rs.1000/- whereas the quantity figures are in multiples of 10. The complex algebraic form of the existence conditions of collusive price pairs is an impediment to the direct analysis of the partial derivates of the payoffs under different investment scenarios. This leads us to generate some scenarios and test the stability of our findings.

Discussions with the top management of FSM yielded the following values of the parameters of the demand function, variable costs and investment costs. Price Cross Elasticity is taken to be equal for the incumbent and the first-follower ($\alpha = 0.6$). The price-elasticity of demand for the incumbent, $k_{INC} = 0.6$. Since the incumbent has a stronger brand position, the price-elasticity of demand of the first-follower is higher than the incumbent. We have investigated the effect of two levels of price-elasticity of the first follower – first, $k_{FF} = 1.0$ and second, $k_{FF} = 0.8$. The intercept term of the linear demands is the same for both the incumbent and the first-follower; and in the first period of the game, its value is uncertain. In one set of scenarios, the intercept term of the demand function Φ_t takes the values $\Phi_{up} = 125$ and $\Phi_{dn} = 80$, giving the up-state factor, u, of 1.25 and the down-state factor, d, of 0.80. In another set of scenarios, the intercept term of the demand function takes the values $\Phi_{up} = 150$ and $\Phi_{dn} = 67$, giving the up-state factor, u, of 1.5 and the down-state factor, d, of 0.67. The variable cost of the incumbent, $v_{INC} = 50$ units (that is, Rs.50, 000/-). For each volatility-elasticity combination (total of 4), we inspect both the low level collusive price pair and the high level collusive price pair; at different degrees of collusion. In the base case, all 8 scenarios have a per-unit capacity investment cost of 400 units and the ‘incremental capacity addition penalty of 100 units. We rerun all the eight scenarios with higher incremental capacity addition penalty of 400 units.

From the experimental results presented in Appendix (graphs 1 through 8), we see that the ‘one-go’ investment, corresponding to putting up capacity of q_{up}^{N} has a negative NPV, at per-unit capacity investment cost of 400 units. The ‘option to play the competitive strategy’ has significant value at all degrees of collusion, β . The optimal decision is, in most of the cases, to go in for either q_{dn}^{Coop} or the minimum of q_{dn}^{N} and q_{up}^{Coop} . These results are stable in each of the scenarios evaluated, as well as in the 8 scenarios where the incremental capacity addition penalty is 4 times that of the base cases.

The benefits out of going in for a smaller capacity accrue from limited exposure, in case the down-state of the demand fructifies as well as the increased payoffs from the possibility of maintaining collusive price levels. The costs of smaller capacity, apart from the incremental capacity addition penalties, arise from up-state of demand fructifying and from the incumbent being purely competitive. In such a case, the first-follower becomes capacity constrained, thus hurting the payoffs in the initial year of the second stage.

As is intuitive, the range of capacities to be considered is larger under high-price point collusion and the range of capacities to be considered is smaller under low-price point collusion. At low degrees of collusion (where β is low), the NPV of establishing q_{dn}^{Coop} or the minimum of q_{dn}^{N} and q_{up}^{Coop}, through collusion on the high-price point are lower than the payoffs through collusion on the low-price point. Perhaps, collusion at the high-price point exposes the first-follower to being heavily capacity constrained should the incumbent turn out to be purely competitive, or the demand-state turns out to be 'up' or both. However, at higher degrees of collusion (where β is high), this difference between the NPVs of low-price point and high-price point collusion are much less pronounced.

Under high-price point collusion, the difference between NPV of q_{dn}^{Coop} and NPV of minimum of q_{dn}^{N} and q_{up}^{Coop} is large under smaller degree of collusion and as the degree of collusion increases, this gap in the NPV between these two strategies decreases. Under low-price point collusion, the difference between NPV of q_{dn}^{Coop} and NPV of minimum of q_{dn}^{N} and q_{up}^{Coop}. Unlike the high-price collusion case, NPV is maximum for capacity corresponding to minimum of q_{dn}^{N} and q_{up}^{Coop}, and not corresponding to q_{dn}^{Coop}. However, in the case of low-price point collusion at a larger degree, the maximum NPV is the one associated with q_{dn}^{Coop}. In the cases with high volatility, the maximum NPV is for the investment in the capacity corresponding to minimum of q_{dn}^{N} and q_{up}^{Coop} and no reversal in this result occurs even at larger degrees of collusion.

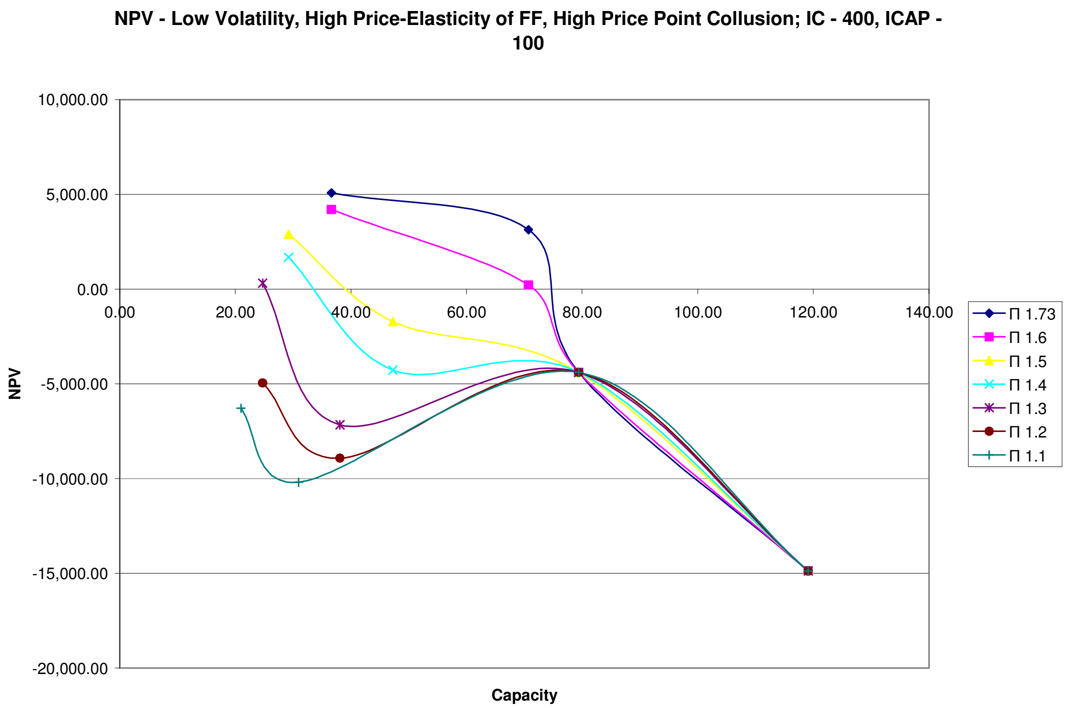
Limitations, Extensions, Contributions

The first order derivatives of collusion payoffs with respect to key model variables have a complicated structure (Abramowitz & Stegun, 1972), due to the quartic equation solutions underlying identification of the possible collusion prices. Generation of scenarios and their analysis is a way around this problem, but the same level of confidence cannot be had. Addressing this issue is an important planned research work. The second stage of game is modeled as having only on demand shock, and then payoffs computed to infinite periods. A much more realistic approach and filled with better insights is to consider 3-5 years in the second stage of the game, with a demand shock at each of the years; and then analysis of the game-theoretic Equilibria and collusion opportunities (Rosenthal, 1981; Trigeorgis, 1996; Grenadier, R., 1996). Such an extension could provide valuable insights into the industry structure evolution, as well. In this work, the main focus has been to emphasis the real option to revert to the competitive strategy, arising due to collusion possibilities also requiring lesser capacities; and therefore a more realistic approach to modeling the development of the duopoly has been sidestepped. There is a chance that the incumbent engages in a pricing strategy which heavily discourages the first-follower from entering the market. In the drugs sector, while such behaviour is unlikely to be allowed affect market participants by the regulator, inclusion of a 'blocking out' pricing by the incumbent would enrich the analysis greatly. The analysis in each of the scenarios assumes complete and perfect information available to both players. Lack of complete and perfect is an area for extending this work.

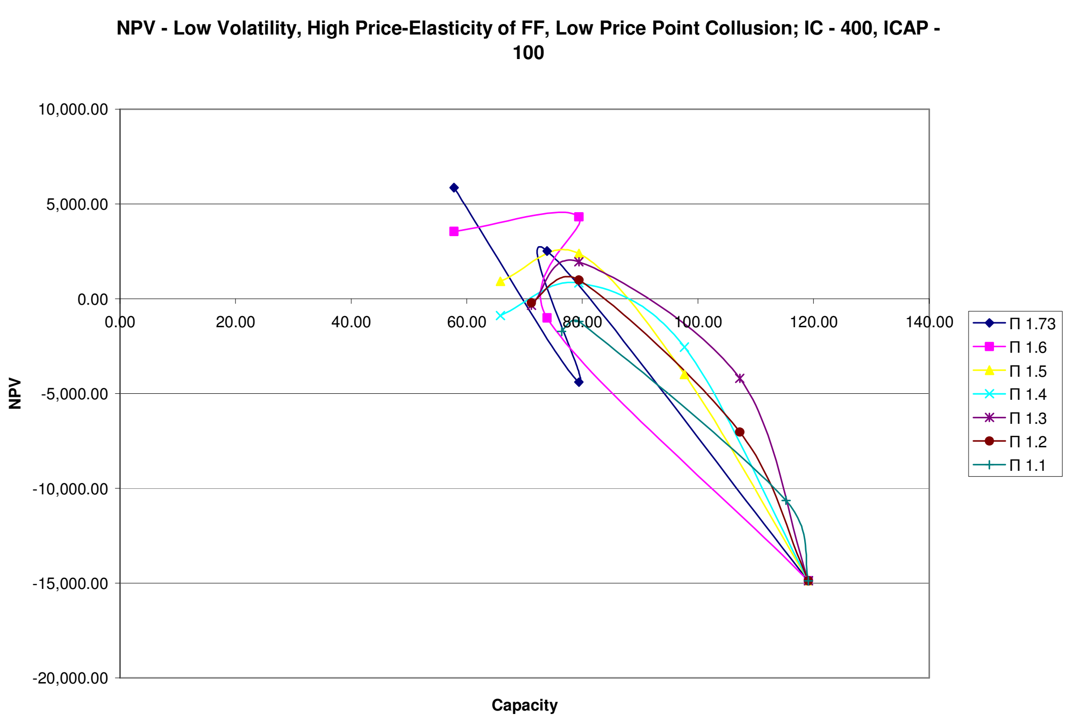
Option-games literature is surprisingly biased towards the examination of investments where both players are in a race to develop cutting edge technology, investing in process improvements, etc. Almost no attention is paid to the problems of first-followers, which is very important from the point of view of Indian industry as well as companies originating in other parts of the third-world. The price collusion – lesser capacity requirement – hence option to scale up capacities contingent on market demand and competitor type is a hitherto unexplored linkage in option-games literature. The current work addresses this gap in the literature and is line with the manner in which the investment problem is perceived in practice. It also gives rise to problems of a technical nature like solving for potential collusion price-pairs which leads us to the solution of quartic equations, the conditions for existence of real price points and corresponding reaction function options. Though the idea of collusion is widely discussed in game-theoretic literature, this idea has to my knowledge not been incorporated in option-game and dealt with in Cournot game setting, our work brings out the possibility of two collusion points in price competition between differentiated products. Focus on the collusion aspects also reveals the algebraic complexity involved in finding out potential collusive price points.

This work is a first step in bringing to bear on the first-follower capital investment problems of firms, the idea of option-games in general and the possibility of the 'real option to revert to the competitive strategy' in particular. Firms in capital intensive industries could find that this analysis approach enriches their decision analysis process.

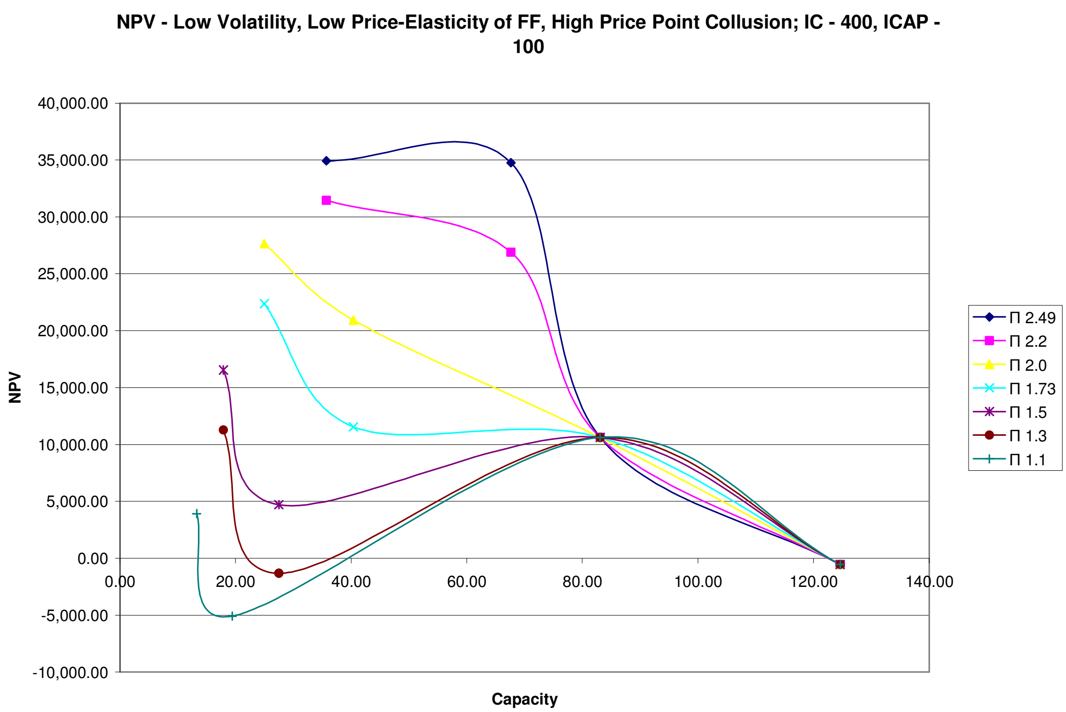
Graph 1



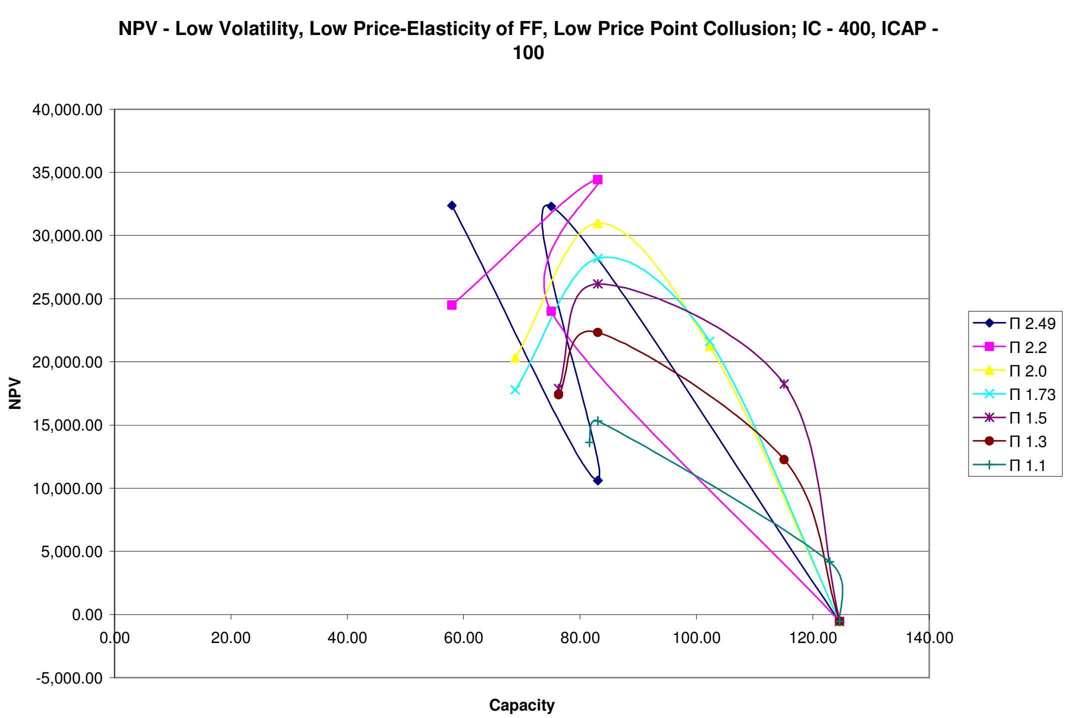
Graph 2



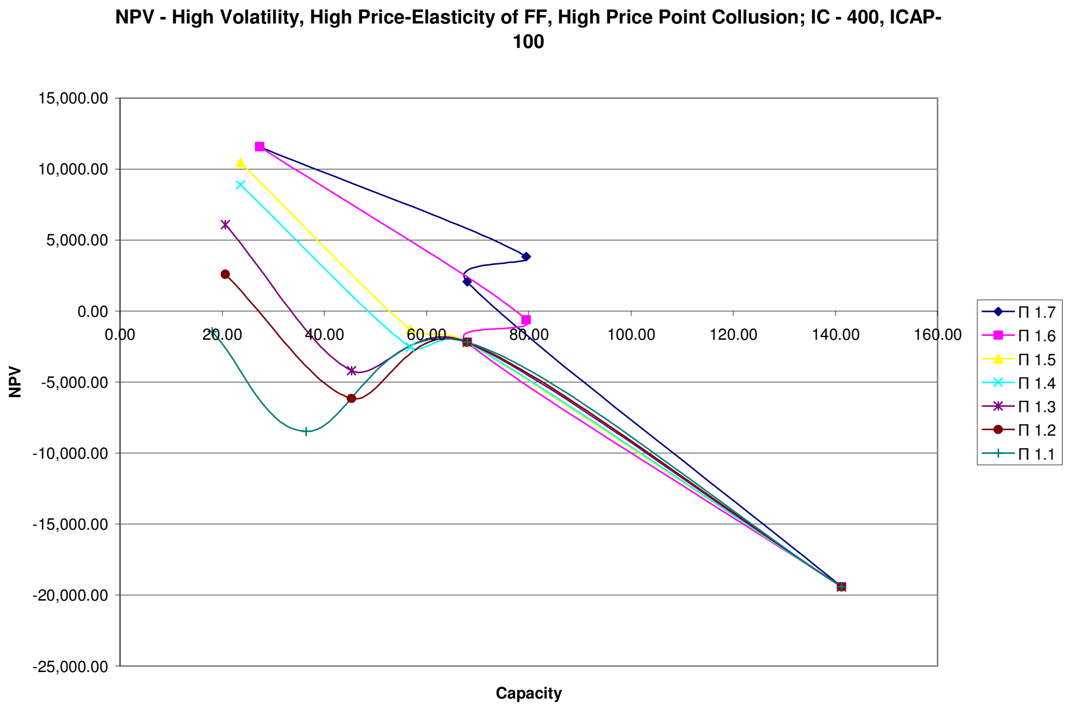
Graph 3



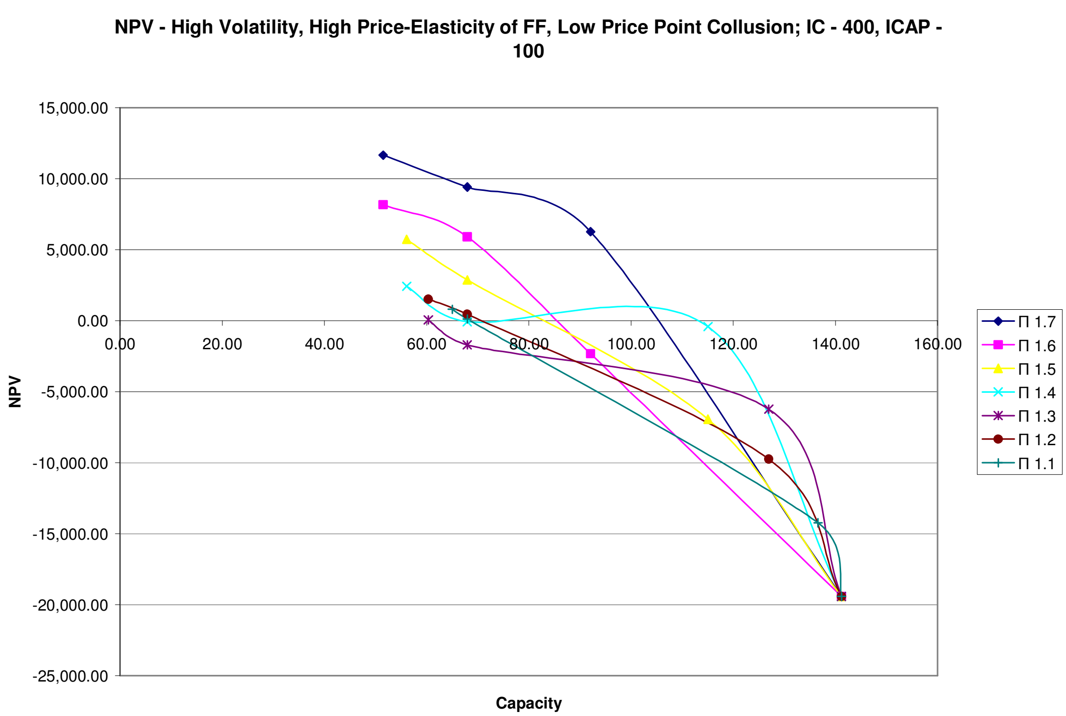
Graph 4



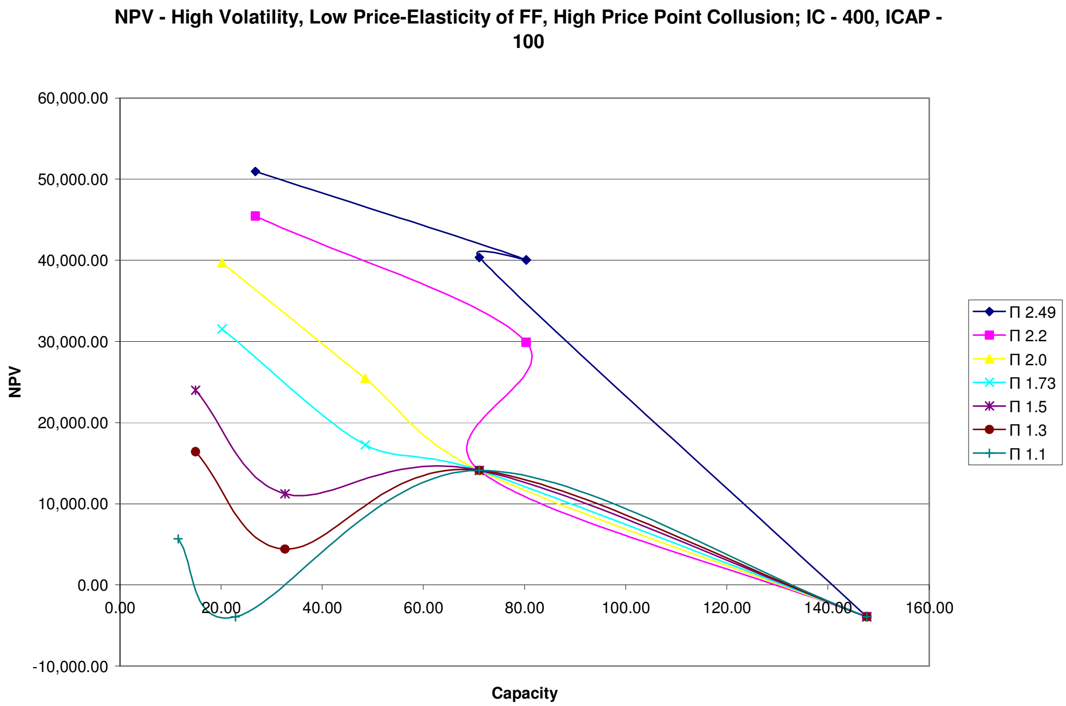
Graph 5



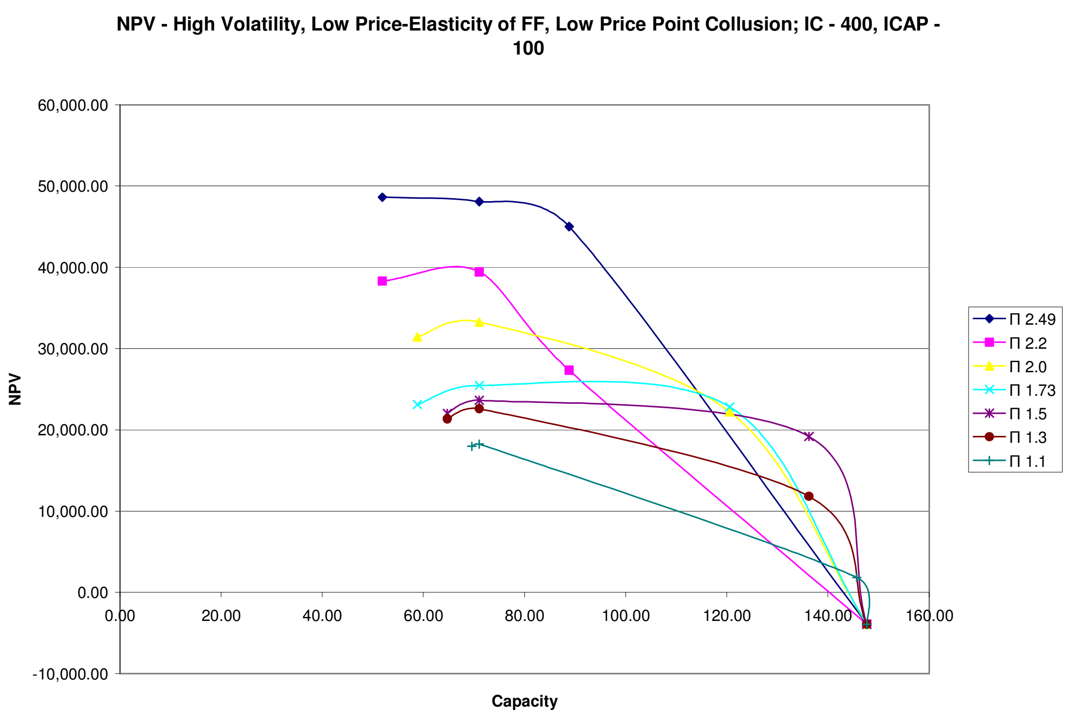
Graph 6



Graph 7



Graph 8



References:

Abramowitz, M. & Stegun, I.A. (Eds.). 1972. Solutions of quartic equations. (Vol. 9). New York: Dover.

Ankum, L.-A. & Smit, H.-T. . 1993. A real options and game-theoretic approach to corporate investment strategy under competition. Financial Management, 22(3): 241-250.

Berger, P., G., Ofek, E. & Swary, I. 1996. Investor valuation of the abandonment option. Journal of Financial Economics, 42(2): 257-287.

Bowman, E.H. & Hurry, D. 1993. Strategy through the option lens: An integrated view of resource investments and the incremental-choice process. Academy of Management Review, 18(4): 760-782.

Boyer, M., Gravel, E. & Lasserre, P. 2004. Real options and strategic competition: A survey. Paper presented at the Real Options: Theory meets Practice.

Cournot, A. (Ed.). 1897. Researches into the Mathematical Principles of the Theory of Wealth. New York: Macmillan.

Dias, M.A.G. & Teixeira, J.P. 2003. Continuous-time option games: Review of models and extensions; Part-I. Paper presented at the Real Options: Theory meets Practice, Washington D.C.

Dias, M.A.G. & Teixeira, J.P. 2004. Continuous-time option games: Oligopoly, war of attrition and bargaining under uncertainty. Paper presented at the Real Options: Theory meets Practice, Montreal, Canada.

Dias, M.A.G. 1997. The timing of investment in E&P: Uncertainty, irreversibility, learning and strategic consideration. Paper presented at the SPE Hydracarbon Economics and Evaluation Symposium.

Dixit, A., K. & Pindyck, R., S. 1994. Investment under uncertainty. New Jersey: Princeton University Press.

Edgeworth, F. 1925. The pure theory of monopoly. Papers Relating to Political Economy, 32(1): 111-142.

Froeb, L., Tschantz, S. & Crooke, P. 2003. Bertrand competition with capacity constraints: mergers among parking lots. Journal of Econometrics, 113(1): 49-67.

Garner, J., L., Nam, J. & Ottoo, R., E. 2002. Determinants of corporate growth opportunities of emerging firms. Journal of Economics and Business, 54(1): 73-93.

Grenadier, S., R. 1996. The strategic exercise of options: Development cascades and overbuilding in real estate markets. Journal of Finance, 51(5): 1653-1679.

Grenadier, S., R. 2000. Game Choices: The Intersection of Real Options and Game Theory: Risk Publications.

Huisman, K.J.M. 2001a. Technology Investment: A Game Theoretic Real Options Approach. Boston, MA: Kluwer Academic Publishers.

Huisman, K.J.M. 2001b. Technology investment: a game theoretic real options approach. Boston, MA: Kluwer Academic Pub.

Huisman, K.J.M. & Kort, P.M. 1999. Effects of strategic interactions on the option value of waiting.: Tilburg University.

Huisman, K.J.M. & Kort, P.M. 2003. Strategic investment in technological innovation. European Journal of Operational Research, 144(1): 209-223.

Joaquin, D.C. & Butler, K.C. 2000. Competitive investment decisions: a synthesis. In M. J. Brennan & L. Trigeorgis (Eds.), Project Flexibility, Agency and Competition: 324-339: Oxford University Press.

Kreps, D.M. & Scheinkman, J.A. 1983. Quantity precommitment and Bertrand competition yield Cournot outcomes. Bell Journal of Economics, 14: 326-338.

McGrath, R., Gunther. 1997. A real options logic for initiating technology positioning investments. Academy of Management Review, 22(4): 974-996.

Murto, P., Nasakkala, E. & Keppo, J. 2004. Timing of investments in oligopoly under uncertainty: A framework for numerical analysis. European Journal of Operational Research, 157(2): 486-500.

Quigg, L. 1993. Empirical testing of real option-pricing models. Journal of Finance, 48(4): 621-640.

Radner, R. 1980. Collusive behavior in oligopolies with long but finite lives. Journal of Economic Theory, 22(1): 136-156.

Romp, G. 1997. Game theory: Introduction and applications. New York: Oxford University Press.

Rosenthal, R. 1981. Games of perfect information, predatory pricing, and the chain-store paradox. Journal of Mathematical Psychology, 25(1): 92-100.

Singh, N. & Vives, X. 1984. Price and quantity competition in a differentiated duopoly. Rand Journal of Economics, 15(4): 546-554.

Smets, H.R. 1993. Essays on foreign direct investment. , Yale University.

Smit, H.-T. & Trigeorgis, L. 1997. R&D option strategies.

Smit, H.-T. & Trigeorgis, L. 2004. Quantifying the strategic option value of technology investments.

Trigeorgis, L. 1991. Anticipated competitive entry and early preemptive investment in deferrable projects. Journal of Ecoconomics and Business, 2(5): 143-156.

Trigeorgis, L. 1996. Real options: Managerial flexibility and strategy in resource allocation. Cambridge, MA: MIT Press.

Varian, H.R. 1992. Microeconomic Analysis (3rd Edition ed.): W. W. Norton & Co. Inc.

Vives, X. 2001. Oligopoly pricing: old ideas and new tools. Massachusetts: MIT Press.