Dynamic Investment Strategies with Demand-Side and Cost-Side Risks

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Abstract

Investments in cost reductions are critical for the long run success of companies that operate in dynamic and stochastic market environments. This paper studies optimal investment in cost reductions as a real option under the assumption that a single firm faces two different sources of risk, stochastic demand and input prices. We derive optimal investment strategies for a monopoly as well as a firm in a perfectly competitive market and show that in case of high marginal costs, cost reductions take place earlier in competitive than in monopoly markets. While the existence of an option to invest in cost reductions increases firm value it also increases a firm's systematic risk. Risk can be smaller in a monopolistic than in a competitive industry.

Key Words: Dynamic Investment Strategies, Real Options and Firm Value, Demand-Side and Cost-Side Risks, Market Structure and Investment Policies.

Running Title: Cost Reducing Investments

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1 Introduction

The long run success of a company critically depends on its investment strategy to stay competitive. Increased competitiveness both at the single firm and at the industry level results from investments into cost reductions. The theory of industrial economics has studied the problem of cost reducing investment in detail (see, for example, Flaherty [10], Spence [20], Fudenberg and Tirole [9], Piccione and Tan [19]) and explored the strategic interactions resulting from competitive advantages. Many of these papers study investment decision as the outcome of a two stage optimization problem. In the first stage firms do the investment and decide on their optimal cost levels, in the second stage firms choose their optimal output for given production technologies (see Brander and Spencer [3]). While this class of models provides very valuable insights, it suffers from two main shortcomings: investment choices are static and firms choose their output and investments in a deterministic environment.

Real option investment theory as pioneered by Brennan and Schwartz [4], McDonald and Siegel [16], [17], and Dixit and Pindyck [8], overcomes these shortcomings and studies optimal investment strategies under the assumption that the individual company faces a stochastic environment and the firm chooses an optimal threshold level of the exogenous shock at which it invests, i.e. exercises the option to switch from one level of unit costs to another one. In such a set-up the optimal investment corresponds to choosing the optimal stopping time at which a stochastic process is regulated in such a way that the expected discounted profits of the company are maximized.

In this paper we study optimal cost reducing investments under the assumption that a single firm faces two distinct sources of risks, demand side shocks and stochastic changes in input prices. Under these assumptions we derive the optimal investment strategies for two alternative market structures, monopoly and perfect competition. Our way of modeling the demand side of the market allows us to distinguish these two types of market structures on the basis of constant demand elasticity in the market. The monopoly model corresponds to the case of a finite but constant elasticity while in an industry with perfect competition demand elasticity is assumed to be infinite. The single firm in our setting chooses optimal output decisions in the short run and optimal cost reductions in the long run. In this sense our model reflects the two stage approach employed in the traditional industrial organization literature, but investment decisions are based on an inter-temporal trade off between optimal output choices in each period and the long run impact of demand and cost uncertainties.

The assumptions in our model allow us to derive the optimal investment decision in cost reductions analytically. We find that investment in lower unit costs is driven by changes in relative demand and cost levels and are triggered by a constant threshold level at which the firm pays the investment costs and reduces unit production costs from the initial level to a more productive new level. The mathematical structure of our model allows us to fully characterize the dynamic drivers of the investment decision for both the monopoly and the competitive firm. It turns out that the option to reduce production costs has a strictly positive value that is higher for the competitive firm than for monopolist. While the value implications of optimal investments are unambiguous the optimal stopping time when to do cost reductions depends on the cost and demand elasticities prevailing in the industry. When the cost elasticity of short run production costs are high (marginal costs are high and output levels are small) and demand elasticity is low the competitive firm will always invest earlier than the monopolist. If on the contrary, demand is highly elastic and the cost elasticity is low the competitive will exercise later than the monopolist. Hence, the timing of investment strongly depends on prevailing demand and cost conditions.

Choosing investments in cost reductions endogenously allows us to evaluate the risk implications of firm growth under different market structures. Recent research in asset pricing theory has intensively explored dynamic betas and corresponding asset returns. Gomes, Kogan and Zhang [11], Carlson, Fisher and Giammarino [5], [6], and Cooper [7] demonstrate that the existence of growth options increases the risk of a company prior to investments. Once the option is exercised, risk is reduced and converges to the level of the revenue beta of the individual firm. We calculate dynamic betas for our two different types of firms and find that the value of the investment option is smaller for the monopolist than for the competitive firm, and that the risk of the competitive firm can be larger than that of the monopolist. Hence, risk of an individual company in case of a more concentrated industry is smaller than that of a competitive firm. This last result is in line with empirical findings of Hou and Robinson [12] who find that average stock returns of firms in concentrated industries are significantly lower than those in more competitive environments (see also the paper by Aguerrevere [1], [2]).

Our paper is organized as follows. In Section 2 we present the model and discuss its assumptions. Section 3 presents the main results and characterizes the optimal cost reducing investment strategy. Finally Section 4 concludes the paper.

2 Model

We consider a single firm that operates either in a monopolistic or competitive industry and faces the following inverse demand curve

$$P_t = \alpha_t Q_t^{-\gamma} \tag{1}$$

where P_t is the current price of the product, Q_t the output and α_t an exogenous stochastic shift in consumer demand. γ is related to the price elasticity of demand which is given by $-1/\gamma$. Hence, under the assumption $0 \leq \gamma \leq 1$ the price elasticity varies from -1 to $-\infty$. This implies that the demand specification (1) covers two alternative industry structures, monopoly and perfect competition. In case of perfect competition, $\gamma = 0$, is the product price exogenous to the firm and entirely determined by the process α_t.

The firm operates with a decreasing returns to scale technology that is summarized by a convex cost function,

$$C(Q_t) = k_t Q_t^{\kappa}, \tag{2}$$

where $k_t = C_0 c_t$ measures the cost for the first unit of production and $\kappa > 1$ denotes the constant cost elasticity. The costs of the single firm are determined by the current state of the production technology summarized by the constant C_0 as well as the current input prices c_t. While the input prices c_t are exogenous to the firm and governed by a stochastic process, the technology employed (summarized by C_0) is the outcome of the firm's investment strategy. Unit costs C_0 can be reduced by an irreversible investment strategy. In particular, the cost level C_0 can be reduced to $C_1 < C_0$ if the firm invests an amount equal to $IC > 0$.

Using the specification of the demand (1) together with that of the cost function (2) results in the firm's instantenous profit function

$$\pi_t = \alpha_t Q_t^{1-\gamma} - k_t Q_t^{\kappa}. \tag{3}$$

In the short run the firm maximizes profits (3) by choosing an optimal output level Q_t^* in each period t. In the long run it chooses an optimal investment strategy to reduce unit costs from level C_0 to C_1. Since Inada-type conditions hold for the revenue function, first order conditions fully characterize the profit maximizing output choice,

$$\frac{\partial \pi_t}{\partial Q_t} = 0.$$

Optimal output is given by

$$Q_t^* = \left(\frac{(1-\gamma)\alpha_t}{\kappa k_t} \right)^{\frac{1}{\kappa+\gamma-1}}. \tag{4}$$

For $\gamma > 0$ the profit maximizing output level in (4) corresponds to that of a monopoly firm $Q_t^* =: Q_t^M$. For $\gamma = 0$ we obtain the output of a competitive firm, given by

$$Q_t^c = \left(\frac{\alpha_t}{\kappa k_t} \right)^{\frac{1}{\kappa-1}}. \tag{5}$$

Output for a monopoly is smaller than in a competitive industry, $Q_t^M < Q_t^c$. Using short run profit maximizing output levels results in the reduced form profit function

$$\Pi(C_0, c_t, \alpha_t) = \left(1 - \frac{1-\gamma}{\kappa}\right) \left(\frac{1-\gamma}{\kappa}\right)^{\frac{1-\gamma}{\kappa+\gamma-1}} (C_0 c_t)^{\frac{\gamma-1}{\kappa+\gamma-1}} \alpha_t^{\frac{\kappa}{\kappa+\gamma-1}}, \tag{6}$$

which we can express in a simplified way as

$$\Pi(C_0, c_t, \alpha_t) = A (C_0 c_t)^{\frac{\gamma-1}{\kappa+\gamma-1}} \alpha_t^{\frac{\kappa}{\kappa+\gamma-1}},$$

where

$$A = \left(1 - \frac{1-\gamma}{\kappa}\right)\left(\frac{1-\gamma}{\kappa}\right)^{\frac{1-\gamma}{\kappa+\gamma-1}}.$$

Reduced form profits vary with exogenous levels of demand α_t, input prices c_t and the constant cost level C_0. While α_t and c_t are governed by exogenous stochastic processes the level C_0 is under the control of the company and can be varied with a cost reducing investment policy.

The exogenous stochastic demand and input price changes are assumed to follow two correlated geometric Brownian motions, i.e.,

$$d\alpha_t = \mu_\alpha \alpha_t \, dt + \sigma_\alpha \alpha_t \, dW_{\alpha,t} \tag{7}$$

$$dc_t = \mu_c c_t \, dt + \sigma_c c_t \, dW_{c,t} \tag{8}$$

where μ_α and μ_c are constant positive drift rates, σ_α, σ_c are the corresponding constant volatilities, and $dW_{\alpha,t}$ and $dW_{c,t}$ denote two correlated increments of Wiener processes. We assume that $\mathbf{E}(dW_{\alpha,t}\, dW_{c,t}) = \rho \, dt$ with $-1 < \rho < 1$ as their constant correlation.

The long run objective of the firm is to choose a cost reducing investment policy such that the expected discounted value of future profits is maximized, i.e.,

$$V(\alpha_t, c_t; C_0) := \max \mathbf{E}\left\{\int_t^\infty e^{-r(\tau-t)} A(C_0 C_\tau)^{\frac{\gamma-1}{\kappa+\gamma-1}} \alpha_\tau^{\frac{\kappa}{\kappa+\gamma-1}} \, d\tau\right\}, \tag{9}$$

with $r \geq 0$ as the constant discount rate. The firm's investment problem corresponds to a binary optimization problem in which management needs to choose a trigger level of profits $\hat{\alpha}^{\frac{\kappa}{\kappa+\gamma-1}} \hat{c}^{\frac{\gamma-1}{\kappa+\gamma-1}}$ at which the investment costs IC are spent and the new technology with a cost level equal to C_1 is introduced.

Since the reduced form profit function is multiplicatively separable in α_t and c_t we can introduce a state variable transformation,

$$Y_t := \alpha_t^\delta c_t^{1-\delta} = \alpha_t^{\frac{\kappa}{\kappa+\gamma-1}} c_t^{\frac{\gamma-1}{\kappa+\gamma-1}}.$$

together with the definition $\delta := \frac{\kappa}{\kappa+\gamma-1} \geq 1$. Applying Ito's Lemma it is easy to show that Y_t follows a geometric Brownian Motion, too, with state dynamics given by

$$dY_t = \mu_Y Y_t \, dt + \sigma_Y Y_t \, dW_{Y,t}, \tag{10}$$

where

$$\begin{aligned}
\mu_Y &= \delta\mu_\alpha + (1-\delta)\mu_c + \frac{1}{2}\delta(\delta-1)(\sigma_\alpha^2 + \sigma_c^2) + \delta(1-\delta)\rho\sigma_\alpha\sigma_c \\
\sigma_Y^2 &= \delta^2\sigma_\alpha^2 + (1-\delta)^2\sigma_c^2 + 2\delta(1-\delta)\rho\sigma_\alpha\sigma_c > 0 \\
dW_{Y,t} &= \frac{1}{\sigma}\left(\delta\sigma_\alpha dW_{\alpha,t} + (1-\delta)\sigma_c dW_{c,t}\right)
\end{aligned}$$

and thus $dW_{Y,t}$ being the increment of a Wiener process.

With this change of variables the reduced form profit function becomes linear in Y_t and is given by

$$\Pi_t = AC_0^{1-\delta} Y_t. \tag{11}$$

In the next section we use this reduced form profit function and derive the optimal investment policy and the corresponding optimal firm value for the monopolist and the competitive firm.

3 Optimal cost reducing investment

The long run investment decision of the firm corresponds to a real option where management identifies the barrier $\hat{Y}$ at which the option is exercised and costs reduced from C_0 to C_1. Let t^* denote the first time the process Y_t hits the threshold $\hat{Y}$, then the investment problem of the company can be summarized as

$$V(Y) = \max \mathbf{E} \left\{ \int_t^{t^*} e^{-r(\tau-t)} AC_0^{1-\delta} Y_\tau d\tau - ICe^{-r(t^*-t)} + \int_{t^*}^{\infty} e^{-r(\tau-t)} AC_1^{1-\delta} Y_\tau \, d\tau \right\}, \tag{12}$$

with the optimal threshold $\hat{Y}$ as the decision variable. We apply dynamic programming to derive the optimal value function $V(Y)$ (see Leitmann [14]). The linear structure in Y_t allows us to derive an analytical solution. In the following we set $\mu := \mu_Y$, $\sigma := \sigma_Y$ and assume that $r > \mu$.[1]

Theorem 1 *The optimal threshold for the firm to invest in cost reductions is given by*

$$\hat{Y} = \frac{\lambda}{\lambda - 1} \cdot \frac{r - \mu}{A(C_1^{1-\delta} - C_0^{1-\delta})} IC, \tag{13}$$

where

$$\lambda = \frac{1}{2} - \frac{\mu}{\sigma^2} + \sqrt{\left(\frac{1}{2} - \frac{\mu}{\sigma^2}\right)^2 + \frac{2r}{\sigma^2}} > 1. \tag{14}$$

The firm invests in cost reductions when the process Y_t hits this threshold level for the first time (optimal stopping time). The corresponding optimal firm value is given by

$$V(Y) = \begin{cases} \frac{AC_0^{1-\delta}}{r-\mu} Y + \frac{IC}{\lambda-1} \left(\frac{Y}{\hat{Y}}\right)^\lambda & \text{if } Y < \hat{Y} \\ \frac{AC_1^{1-\delta}}{r-\mu} Y & \text{else.} \end{cases} \tag{15}$$

[1] A justification for this assumption follows immediately from risk-neutral valuation (cf. Carlson, Fisher and Giammarino [5]).

Proof: To derive the optimal value function $V(Y)$ and the threshold level, $\hat{Y}$, we apply the general no-arbitrage condition

$$rV(Y) = AC_0^{1-\delta}Y + \mathbf{E}(dV(Y)).$$

This condition states that the total return of an investment in the company is equal to the current dividend (profit) plus the expected capital gain. Applying Ito's Lemma, this no-arbitrage condition becomes a standard Bellman equation:

$$-rV(Y) + AC_0^{1-\delta}Y + \mu YV'(Y) + \frac{1}{2}\sigma^2 Y^2 V''(Y) = 0. \tag{16}$$

Performing the variable transformation $Y = e^X$ equation (16) transforms in a second order differential equation wih constant coefficients. The characteristic equation of the homogenous part is given by

$$-r + \lambda\left(\mu - \frac{1}{2}\sigma^2\right) + \frac{1}{2}\sigma^2\lambda^2 = 0$$

with a positive and a negative root. The negative root can be ruled out using a no-bubbles condition for the optimal firm value. The positive root of this quadratic equation is given by (14). Since the reduced form profit function is linear in the state variable Y, the linear function

$$\frac{AC_0^{1-\delta}}{r-\mu}Y$$

is a particular solution of the Bellman equation (16). Using this particular solution together with the general solution of the homogenous part of (16) results in the general solution of the Bellman equation

$$V(Y) = \frac{AC_0^{1-\delta}}{r-\mu}Y + DY^{\lambda}$$

where D is a constant of integration. D and the optimal threshold $\hat{Y}$ have to be determined by the value matching and smooth pasting conditions. Value matching requires that at the trigger level $\hat{Y}$ fulfills

$$V(\hat{Y}) = \frac{AC_1^{1-\delta}}{r-\mu}\hat{Y} - IC.$$

This determines the constant of integration D, while the smooth pasting condition

$$V'(\hat{Y}) = \frac{AC_1^{1-\delta}}{r-\mu}$$

determines the optimal threshold $\hat{Y}$. Multiplying both sides of the smooth pasting condition with $\hat{Y}$ and subtracting the value matching condition determines the constant of integration

$$D = \frac{IC}{\lambda - 1}\hat{Y}^{-\lambda}.$$

Substituting the constant of integration D into the smooth pasting condition results in the investment trigger,

$$\hat{Y} = \frac{\lambda}{\lambda - 1} \cdot \frac{r - \mu}{A(C_1^{1-\delta} - C_0^{1-\delta})} IC.$$

This implies that for any level of the state variable $Y < \hat{Y}$, the optimal firm value is given by

$$V(Y) = \frac{AC_0^{1-\delta}}{r - \mu} Y + \frac{IC}{\lambda - 1} \left(\frac{Y}{\hat{Y}} \right)^{\lambda},$$

while for $Y \geq \hat{Y}$ it is

$$V(Y) = \frac{AC_1^{1-\delta}}{r - \mu} Y.$$

qed

Prior to cost reducing investments the optimal firm value consists of the sum of the present value of the assets in place and the value of the option to reduce unit costs. The value of the assets in place is given by

$$V_A(Y) = \frac{AC_0^{1-\delta}}{r - \mu} Y,$$

and the option value is

$$V_O(Y) = \frac{IC}{\lambda - 1} \left(\frac{Y}{\hat{Y}} \right)^{\lambda} > 0.$$

The convex option value offers interesting insights into the valuation of the cost reducing investment.

Lemma 1 *The firm's option value is strictly positive and*

1. *decreasing in the level of irreversible investment costs IC,*
2. *increasing in the level of cost reductions C_1.*

Proof: The arguments follow immediately from the value function (15). **qed**

Figure 1 plots the option values for different levels of γ in the interval $[0, 1)$, for two levels of market risk $Y = 1$ and $Y = 8$, and three different values of the cost parameter κ. The two values of market risk are smaller than the investment triggers, implying that in both cases the American investment options are still alive. The base set of the parameters is given by $\sigma_\alpha = 0.2$; $\sigma_c = 0.15$; $\mu_\alpha = 0.03$; $\mu_c = 0.03$; $\rho = 0$; $r = 0.1$; $C_0 = 10$; $C_1 = 5$; $IC = 3$. The figure depicts the surprising result that the option value is monotonic and decreasing in γ implying that it is larger in the competitive case ($\gamma = 0$) than in the monopoly ($\gamma > 0$).

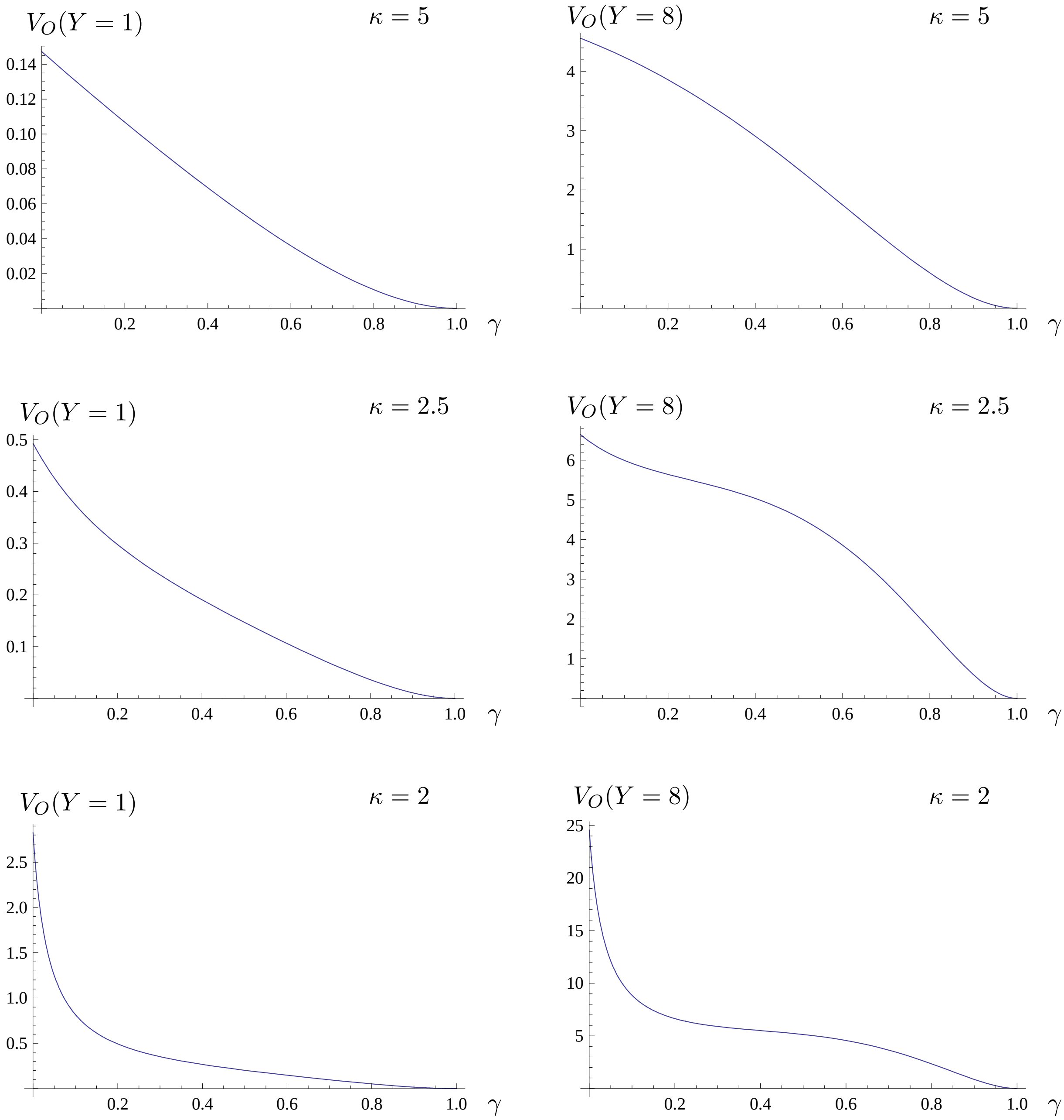


Figure 1: Option values for different values of the demand elasticity, γ, the cost parameter κ, and two values of market risk $Y = 1$ and $Y = 8$.

The results of Lemma 1 can intuitively be explained as follows. If investment costs increase two effects are triggered (cf. McDonald and Siegel [16], [17]). Firms exercise their options on average later since a higher level of profits is required to render them economical (the moneyness of the option is decreased) and profits net of investment costs decrease. Both effects reinforce each other and result in a smaller option value. On the contrary, with a smaller level of C_1 and therefore a larger cost reduction, exercise of the investment option is earlier and net profits are larger. Naturally, this implies a larger option value. The (numeric) result that the option value is larger for the competitive firm than for the monopoly, is surprising but is driven by the levels of demand elasticity. The larger γ becomes the less price sensitive is market demand. This increases market power of the monopolist and decreases the incentive to exercise a cost reducing investment. Competition in a competitive market, on the contrary, drives down rents and hence firms use any opportunity to increase their competitiveness. This provides a strong incentive for cost reductions and makes the investment options more valuable. It should be pointed out that monopoly and perfect competition in this model are distinguished on the basis of different demand elasticities only and not by the level of competition. Papers that do analyze investment options with competitive (strategic) interactions are Pawlina and Kort [18], Mason and Weeds [15], and Huisman and Kort [13]. In addition the main result in Theorem 1 provides insights into the timing of the investment in different industries.

Lemma 2 *In a monopolistic industry* $(1 > \gamma > 0)$ *the option trigger* $\hat{Y}$ *is*

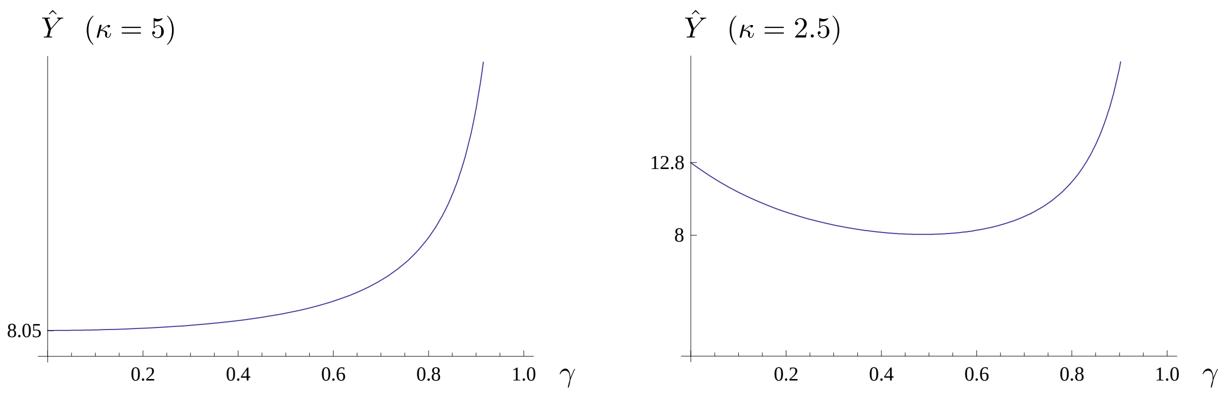
1. *always higher than that for the competitive firm* $(\gamma = 0)$ *if* κ *is large;*
2. *smaller than that of the competitive firm if* γ *is close to 0 and* κ *close to 1.*

Proof: From the definition of the constant $\delta = \frac{\kappa}{\kappa+\gamma-1}$ it is obvious that

$$\lim_{\kappa \to \infty} \frac{\kappa}{\kappa + \gamma - 1} = 1$$

holds and hence $1 - \delta \to 0$. This effect is reinforced as γ increases from 0 to 1. Hence, for κ large enough both $C_0^{1-\delta}$ and $C_1^{1-\delta}$ approach 0 and $\hat{Y}$ increases without bounds. The opposite is the case if κ is small and γ is close to zero. **qed**

The results of Lemma 2 are depicted in Figure 2 for different values of κ.



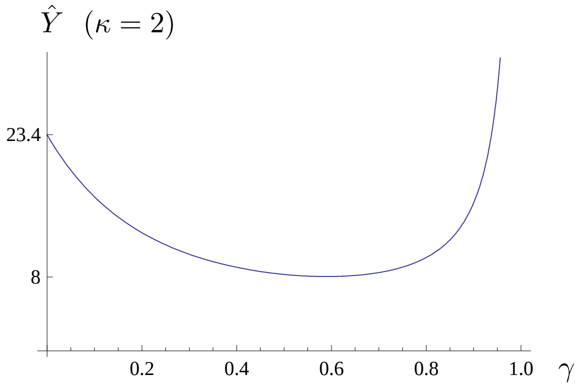


Figure 2: Option triggers as a function of demand elasticity for three different values of the cost parameter κ. $\gamma = 0$ corresponds to the competitive case.

The three graphs of Figure 2 demonstrate that for small values of the cost parameter κ will the monopoly firm exercise the option faster than the competitive firm, while for κ large will a competitive industry experience a faster cost reduction than any monopoly.

The explicit functional form of the optimal value function (15) can be used to derive the firm's systematic (beta) risk. The firm's beta is defined as the percentage change of the optimal firm value over the percent change in the underlying risk factor Y (see Carlson, Fisher and Giammarino [5])

$$\beta(Y) = \frac{V'(Y)Y}{V(Y)}. \tag{17}$$

In our model the combined demand and input price risk as expressed by $Y_t = \alpha_t^{\delta} c_t^{1-\delta}$ is the underlying risk factor that is responsible for value changes and hence determines the systematic risk of the company.

Theorem 2 *Beta (systematic) risk of the firm is given by*

$$\beta(Y) = \begin{cases} 1 + (\lambda - 1)\frac{V_O(Y)}{V(Y)} & \textit{if } \; Y < \hat{Y}, \\ \\ 1 & \textit{else.} \end{cases} \tag{18}$$

Proof: Differentiating the firm value with respect to Y and applying definition (17) implies for $Y < \hat{Y}$,

$$\beta(Y) = \frac{V_A(Y) + \lambda V_O(Y)}{V(Y)} = 1 + (\lambda - 1)\frac{V_O(Y)}{V(Y)}.$$

For $Y \geq \hat{Y}$ the result follows from linearity of the optimal value function. **qed**

As in Carlson, Fisher, and Giammarino [5] the firm's risk is given by the revenue beta, which is equal to 1, and the option risk. Hence, the existence of the option to reduce costs increases systematic firm risk. This risk increases with the volatility of the underlying risk factor Y and the moneyness of the option. It also depends on other fundamentals of the model, including the constant price elasticity of demand. This dependence can be exploited to compare the risks of a competitive and a monopolistic firm.

Lemma 3 *Prior to the exercise of the cost reduction option, $Y < \hat{Y}$, risk for the competitive firm is ambigous. It can be smaller or larger than that of a monopolist. After option exercise, $Y \geq \hat{Y}$, risk for both firms is identical to the constant revenue beta.*

Proof: The result follows immediately from the optimal firm value for $\gamma = 0$ and $0 < \gamma < 1$ and is demonstrated numerically in Figure 3. **qed**

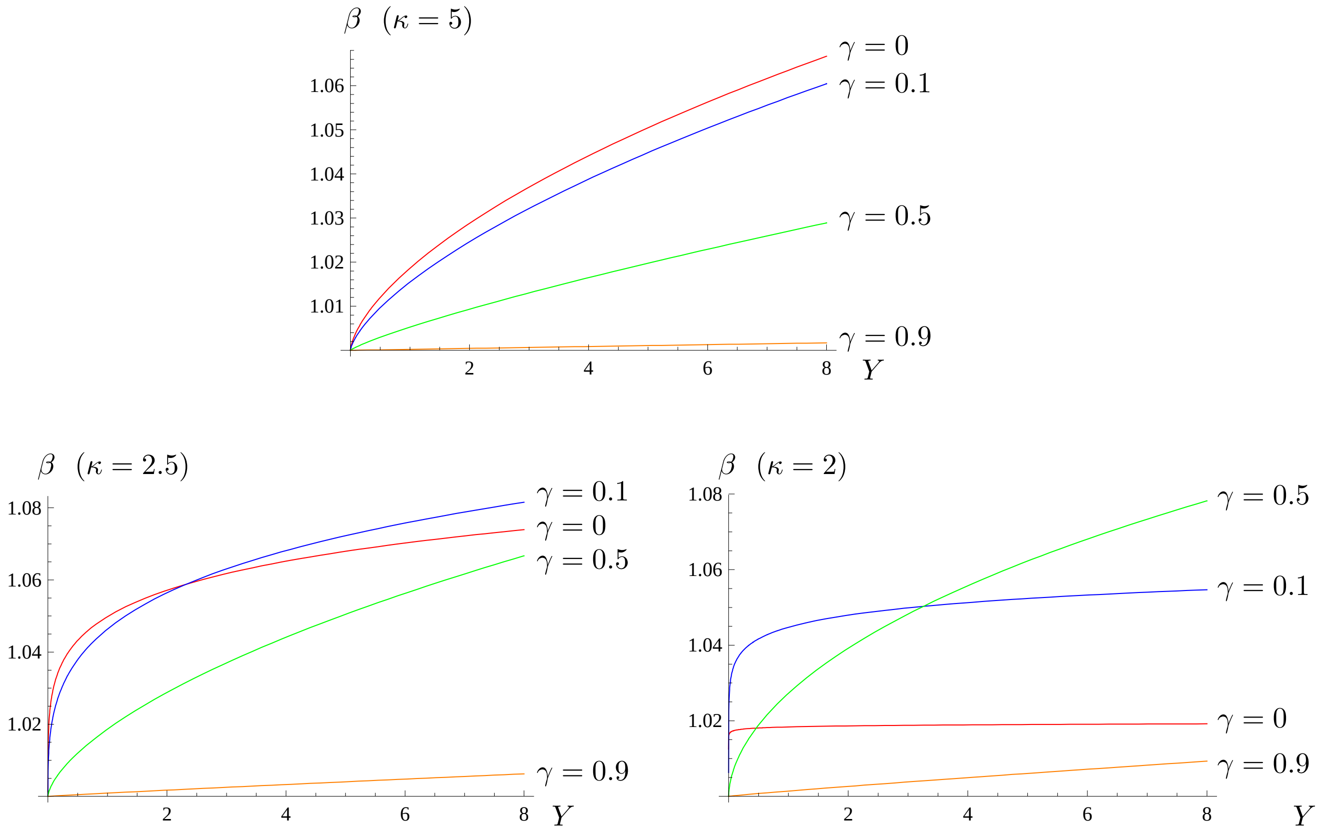


Figure 3: Firm betas for different values of demand elasticity and the cost parameter κ. Risk in the competitive industry $\gamma = 0$ can be smaller or larger than risk in a monopoly $\gamma > 0$.

Figure 3 shows that risk of any firm increases in Y. This is an immediate consequence of the investment option. As Y gets closer to option exercise, risk of any firm runs up and jumps to revenue beta afterwards. In case of a high cost parameter κ, risk of any monopolistic firm is smaller than that of a competitive firm. The intuition for this result is closely related to the shock absorbtion capacity of the two firms. In case of a monopolistic industry the single firm can fully concentrate on shock absorbtion when it is hit by an adverse price change and need not take into account any industry response to the shock. In case of a competitive industry the firm not only needs to react to a shock by restructuring its resources but also needs to take into account the industry's response to the shock. Hence, its shock absorbtion capacity is limited which implies that the monopolistic firm has lower risk than the competitive one. The last result is consistent with empirical evidence. As documented in the paper by Hou and Robinson [12], average returns of companies in more concentrated industries are smaller than in less concentrated ones.

There is no monotonic ranking of firm risk for different demand elasticities in case of low values for κ. Depending on how price elastic demand is, will firm risk in the monopoly be either higher or lower than in the competitive case. If demand elasticity approaches -1, and monopoly rents increase will corresponding beta values be very small.

4 Conclusions

This paper studies optimal investment strategies in cost reductions for a single firm that can either be a monopolist or a competitive firm facing two sources of fundamental risks, demand side and cost side risks. These sources of risks are modeled as correlated geometric Brownian motions. The single firm chooses optimal output in every period for given levels of demand and input prices and selects a value maximizing investment strategy in the long-run. The investment strategy corresponds to a perpetual American call option that is exercised when the underlying risk process hits a threshold level for the first time. Dynamic investments of the company imply that the optimal firm value is the sum of the present value of the assets in place and the value of the investment option. The explicit derivation of the optimal value function provides novel insights into the analysis of cost reducing investments when the company is either a monopolist or a competitive firm. We find that the value of the investment option is larger in a competitive market than in a monopoly. Option exercise, however, cannot uniquely be ranked. In case of a high cost elasticity the competitive firm will exercise the option earlier than the monopolist, while in case of very elastic demand and small cost elasticity the monopolist will exercise earlier than the competitive firm. Finally, we explore the risk implications arising from optimal investment choice. Dynamic beta is given by a constant revenue beta equal to one plus a risk adjustment associated with the investment option risk. While this risk structure applies to both the monopolist and the competitive firm, it turns out that prior to option exercise beta for the competitive firm can be larger than for the monopolist.

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