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Imperfect Market or Imperfect Theory
A Unified Analytical Theory of Production and Capital Structure of Firms

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Abstract

We present a unified analytical theory of production and capital structure of firms. It is extended from an analytical theory of production, whose main result is an analytical formula of variable cost of production as a function of fixed cost and uncertainty. Problems on capital structure can be naturally incorporated into the theory on production from a simple observation. Debt is fixed income for investors and hence fixed cost for issuing firms. The decision on capital structure is part of the decision process that determines the level of the fixed cost and variable cost of firms to achieve a high rate of return based on the understanding of current and future market conditions. The new theory offers a simple and parsimonious understanding to a broad range of empirical patterns documented in the literature. It reinforces the impression from other recent studies that puzzles in corporate finance often result not from “imperfect market” but rather from “imperfect theory”.

1. Introduction

It has been about fifty years since Modigliani and Miller (1958) proposed that capital structure of a firm is irrelevant in a perfect market. Since then, researchers have searched for various imperfections in the capital market. If an imperfection is identified, this type of imperfection would be gradually reduced over time from competition or regulation. So we might expect capital structures of firms will be less and less relevant and financial decision making becomes simpler and simpler over time. When Modigliani and Miller first published their paper on the irrelevance of financial structure in a perfect market about fifty years ago, theories and practices in finance were relatively simple. Since then, problems in corporate finance, instead of getting simpler and simpler, have become more and more complicated. In the process, many complex financial instruments have been created in the financial markets. Number of finance professionals also increase tremendously in the last fifty years. Do all these mean that the financial markets get less perfect over time?

Empirical tests find that capital structure of firms often deviate systematically from optimal levels. These are often attributed to market imperfection. However, further investigation generally reveals that the designs of these tests are flawed (Molina, 2005). This means that the inconstancy between theory and market reality is often due to imperfection of theory instead of imperfection of market. However, many theories on capital structure are still built on the assumption of imperfection in capital market or product market (Istaitieh and Rodrigues-Fernandez, 2005).

A brief review of the concept of "imperfection" in old astronomy will shed some light to our discussion. Ancient people had long observed that stars moved in perfect harmony in the sky. Several planets, however, moved in irregular trajectories. It was thought that this was caused by the imperfectness of the planets. There were many elaborate theories why the planets were imperfect. However, after Copernicus proposed the theory of the sun centered universe, the movements of planets appeared much less imperfect. Since then, the imperfect match between the theory and observation of planetary movements is more and more attributed to the imperfection of theory instead of the imperfection of the reality. The process of improving the theory, through the efforts of Kepler, Newton and many others, turned out to be the driving force in the establishment of modern science.

When Modigliani and Miller (1958) first developed an analytical theory of capital structure, they assumed that production of a firm is independent from financing decisions. Although later works recognized the cost of financial distress to firms, the absence of a structure model about various factors of a firm's operation make it difficult to handle endogeneity problems in empirical testing (Zingales, 1998; Molina, 2005). Empirical evidences also indicate that firm's financial decisions are closely related to the operational side of the firm and market environment (Istaitieh and Rodrigues-Fernandez, 2005; Khanna and Tice, 2005). Therefore, it will be very helpful to develop a unified theory of production and financing of firms in which market environment is an integral part.

In this work we present a unified analytical theory of production and capital structure of firms. It is a natural extension from an analytical theory of production, whose main result is an analytical formula of variable cost of production as a function of fixed cost and uncertainty. From the theory, it can be derived that high fixed cost systems are much more sensitive to uncertainty than low fixed cost systems. When uncertainty increases, the variable cost of high fixed cost systems increase much faster than that of low fixed cost systems. In general, higher fixed cost systems need higher output volume to breakeven. At the same time, they have lower variable costs in production and earn higher rates of return in large markets. Therefore high fixed cost systems are more competitive in large and stable markets while low fixed cost systems are more flexible in small and dynamic markets.

Problems on capital structure can be naturally incorporated into the theory on production from a simple observation. Debt is fixed income for investors and hence fixed cost for issuing firms. The increase of debt increases the fixed cost of firms. The decision on capital structure is part of the decision process that determines the level of the fixed cost and variable cost of firms to achieve a high rate of return based on the understanding of current and future market conditions. The new theory, by integrating financial decisions into the general firm decision processes, offers a simple and parsimonious understanding to a broad range of empirical patterns documented in the literature. This shows that "market imperfection" is not needed in understanding empirical patterns. It reinforces the impression from other recent studies that puzzles in corporate finance often result not from "imperfect market" but rather from "imperfect theory" (Molina, 2005).

Capital structure of firms is one of the most active research areas in finance. Many recent works have offered excellent literature review about the subject, which we will not repeat here. The theory presented here is an update from part of Chen (2005). The paper is structured as follows. Section 2 presents an analytical theory of production and competition. Section 3 extends the analytical results to the problem of capital structure from a simple observation that debt adds to fixed cost of a firm. We then show how this theory provides a simple and unified understanding of a broad stream of empirical results. Section 4 concludes.

2. An analytical theory of production and competition.

Suppose S represents economic value of a commodity, r, the expected rate of change of value and σ, the rate of uncertainty. Then the process of S can be represented by the lognormal process

$$\frac{dS}{S} = rdt + \sigma dz \,. \qquad (1)$$

The production of the commodity involves fixed cost, *K*, and variable cost, *C*, which is a function of *S*, the value of the commodity. If the discount rate of a firm is *q*, from the Feymann-Kac formula, (Øksendal, 1998, p. 135) the variable cost, *C*, as a function of *S*, satisfies the following equation

$$\frac{\partial C}{\partial t} = rS\frac{\partial C}{\partial S} + \frac{1}{2}\sigma^2 S^2 \frac{\partial^2 C}{\partial S^2} - qC \tag{2}$$

with the initial condition

$$C(S,0) = f(S) \tag{3}$$

To determine *f(S)*, we perform a thought experiment about a project with a duration that is infinitesimally small. When the duration of a project is sufficiently small, it has only enough time to produce one unit of product. In this situation, if the fixed cost is lower than the value of the product, the variable cost should be the difference between the value of the product and the fixed cost to avoid arbitrage opportunity. If the fixed cost is higher than the value of the product, there should be no extra variable cost needed for this product. Mathematically, the initial condition for the variable cost is the following:

$$C(S,0) = \max(S - K, 0) \tag{4}$$

where *S* is the value of the commodity and *K* is the fixed cost of a project. When the duration of a project is *T*, solving equation (2) with the initial condition (4) yields the following solution

$$C = Se^{(r-q)T} N(d_1) - Ke^{-qT} N(d_2) \tag{5}$$

where

$$d_1 = \frac{\ln(S/K) + (r + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = \frac{\ln(S/K) + (r - \sigma^2/2)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

The function *N(x)* is the cumulative probability distribution function for a standardized normal random variable. When the discount rate of the firm is equal to *r*, the rate of change of the commodity value, formula (5) takes the same form as the well-known Black-Scholes (1973) formula for European call options

$$C = SN(d_1) - Ke^{-rT} N(d_2) \tag{6}$$

It should be noted that the interpretations of uncertainty, σ differ between option model and project investment model. In an option model, the uncertainty is purely about the underlying assets. In a project, uncertainty is about the whole production system, of which the uncertainty of the underlying asset is only a part. For example, suppose both

Microsoft and a small software company plan to develop same type of application software based on the Windows operating system. The uncertainty of demand for this type of software affects both companies. At the same time, the small software company also faces uncertainty about the upgrading of the Windows operating system, which affects the developers in Microsoft less as they are better informed.

Suppose the volume of output during the project life is Q, which is bound by production capacity or market size. We assume the present value of the product to be S and variable cost to be C during the project life. Then the total present value of the product and the total cost of production are

$$SQ \text{ and } CQ + K \tag{7}$$

respectively. The return of this project can be represented by

$$\ln\left(\frac{SQ}{CQ + K}\right) \tag{8}$$

and the net present value of the project is

$$QS - (QC + K) = Q(S - C) - K \tag{9}$$

Unlike a conceptual framework, this analytical theory enables us to make quantitative calculation of returns of different projects under different kinds of environments. First, we examine the relation between fixed cost and variable cost at different levels of uncertainty. For example, a product can be manufactured with two different technologies. One needs ten million dollars of fixed cost and the other needs one hundred million fixed cost. Assume the other parameters are unit value of the product, to be one million, discount rate, to be 10% and duration of the project, to be twenty-five years. When uncertainty of the environment is 30% per year, variable cost for the low fixed cost project is 0.59 million and variable cost for the high fixed cost project is 0.14 million, calculated from (6). When uncertainty of the environment is 90% per year, variable cost for the low fixed cost project is 0.98 million and variable cost for the high fixed cost project is 0.94 million. In general, as fixed costs are increased, variable costs decrease rapidly in a low uncertainty environment and decreases slowly in a high uncertainty environment. This is illustrated in Figure 1.

Next we discuss the returns of investment on different projects with respect to the volume of output. Continuing the example on two technologies with different fixed costs, we now discuss how the expected market sizes affect rates of return. Suppose the level of uncertainty is 30% per year and other parameters are the same. If the market size is 100, the return of the low fixed cost project, calculated from (8), is 37% and the return of the high fixed cost project is -12%. When the market size is 400, the return of the low fixed cost project is 48% and the return of the high fixed cost project is 97%. Figure 2 is the graphic representation of (8) for different levels of fixed costs. In general, higher fixed cost projects need higher output volume to breakeven. At the same time, higher fixed cost projects, which have lower variable costs in production, earn higher rates of return in large markets.

From the above discussion the level of fixed investment in a project depends on the expectation of the level of uncertainty of production technology and the size of the market. When the outlook is stable and market size is large, projects with high fixed investment earn higher rates of return. When the outlook is uncertain or market size is small, projects with low fixed cost breakeven easier.

Projects are undertaken by firms, which often utilize existing assets to help reduce costs in producing or marketing new products. For example, Microsoft often bundles its application software together with its Windows operating system. This effectively reduces the cost of marketing. In general, new products from large firms often enjoy the benefit of brand recognition, which reduces variable cost in marketing. At the same time, costs of projects are often affected by the characteristics of firms. In general, ownership and management are less integrated in large firms than in small firms. Therefore, large firms adopt more rigorous check and balance systems for corporate control than small firms. This added cost of monitoring often increases the cost of projects. Therefore, higher fixed cost large firms generally concentrate on large and stable markets while lower fixed cost small firms thrive in uncertain niche markets. Firms of different sizes will choose different types of markets. For example, large banks, as high fixed cost systems with large network of branches, concentrate on standard financial products with high volumes, such as the credit card business, or lending based on hard information that can be easily obtained from standard accounting measures. Small community banks, as low fixed cost systems, concentrate on small business loans based on soft information, which is specialized information with small market size. DeYoung et al. (2003) and Berger et al. (2005) provide organizational theories to explain the differences in lending practices of large and small banks. But it can also be understood clearly from return patterns of firms of different sizes as shown in Figure 2.

Firms of different sizes often adopt different competition strategies in the market. In the retail gasoline market, the existence of small independent firms in local markets is often associated with high level of price volatility while markets served only by major brands exhibit price stability (Eckert, 2003). In the following we will work out an example to explain the pricing strategies of different firms. Suppose there are two gas stations, one from a small independent firm and the other from a large branded firm. Each gas station sells 30 unit of gasoline daily and gasoline price is 1 per unit. The gas station from the large firm, which needs to pay license fee to the headquarter, has a fixed cost of 5 and the gas station from the small firm has a fixed cost of 2. We further assume the discount rate is 12% per year and the duration of the fixed assets of both gas stations are 15 years. If the usual uncertainty rate is 35%, the marginal cost for two gas stations are 0.749 and

0.549 respectively, calculated from (6). If each gas station decided to start and aggressive price competition to increase daily volume to 50, the uncertainty rate will increase to 55%. From (6), marginal cost for both gas stations will become 0.847 and 0.740 respectively. The profit difference of the gas stations from the small independent firm will be

$$50(1-0.847) - 30(1-0.749) = 0.132$$

While the profit difference of the gas station from the large firm will be

$$50(1-0.740) - 30(1-0.549) = -0.516$$

From the computation, we can see that gas station from small independent firms will benefit from aggressive pricing competition while large firms will not. This is why large firms often engage in price collusion while small firms are more aggressive in price competition.

3. A theory of capital structure

The capital structure theory presented here is a direct generalization of production theory from a simple observation. Since debts are fixed income instruments for investors, they are fixed costs for issuing firms. Therefore, cost of debt forms part of fixed cost in firm's operation. The decision on capital structure is part of the decision process that determines the level of the fixed cost of firms. While debt can be swapped into equity, rebalancing capital structure is costly, especially during financial distresses when the need to rebalance is at their greatest. For example, when a firm is doing well, its stock price is high and debt ratio is low. There is little need to rebalance. When a firm is in trouble, the burden of debt service is heavy. But its stock price is low and issuing new shares at low price may be a very costly way to rebalance capital structure.

From discussion in the last section, fixed cost in operation, or operating leverage, matters to the performance of a company. For the same reason, capital structure, or financial leverage, matters to the performance of a company. From Figure 1 and 2, firms will choose a proper combination of fixed cost and variable cost to achieve high rate of profit based on the estimation of current market condition and probable future market condition. High fixed cost systems perform well in an environment of low uncertainty and large market size. They perform badly in an environment of high uncertainty or small market size. The performance of low fixed cost systems is the opposite. Besides the tax advantage of debt, from our theory, firms adopt financial policy to reach desired level of fixed cost and variable cost. In the trade-off theory, the cost of debt is essentially the cost of bankruptcy. In this theory, variable cost of operation is a function of fixed cost and uncertainty, which are affected by the debt level. So the level of debt, by affecting fixed cost and variable cost of operation, has much broader impact on firms than the cost of bankruptcy. For example, employees in high debt firms, even with low probability of bankruptcy, may be less willing to invest in firm specific skills, for there is higher chance of layoff to reduce cost in the future.

Istaitieh and Rodrigues-Fernandez (2005) classified studies on factor-product markets and firm's capital structure into three strands of literature. The first is the stakeholder theory of capital structure. The second is market structure literature. The third is the firm's competitive strategy literature. Each strand of literature contains diverse and complex methodologies and ideas. In the following, we will show that the new theory provides a unified understanding of the empirical evidences.

Researches on stakeholder theory find that firms producing specialized products, purchasing a high proportion of their inputs from dependent suppliers, depending on relatively few customers for a major proportion of their sales, engaging high level of innovative activities or having highly specialized employees generally maintain low debt levels (Titman, 1984; Barton, Hill and Sundaram, 1989; Cavanaugh and Garen, 1997; Sarig, 1998; Banerjee, Dasgupta and Kim, 2004). This is because these firms face high level of uncertainty in their business. Since high level of uncertainty affects high fixed cost systems more, these firms will maintain low level of debt to reduce the level of fixed cost. Skilled employees of highly leveraged firms can negotiate better contract terms than can employees of similar but less leveraged firms, because more leveraged firms, as higher fixed cost systems, are more susceptible to uncertainty from employee movement (Sarig, 1998). On the other hand, firms with high reputation, which are of lower uncertainty, can increase their debt capacity for high fixed cost systems perform well in low uncertainty environment.

Literature on market structure shows that during downturns, more highly leveraged firms tend to lose market share and experience lower operating profits than do less leveraged competitors and highly leveraged firms that engages in R&D suffer the most (Opler and Titamn, 1994). This is because both leverage and R&D add to fixed cost. From Figure 2, higher fixed cost systems suffer more than lower fixed cost systems when market size shrinks in economic downturns. When firms radically increase their leverage through an LBO, they greatly increase their fixed cost, which make them vulnerable to rival's aggressive competition (Chevalier, 1995).

The firm's capital structure also affects its competitive strategy in the product market. First, leveraged firms have incentives to move aggressively to gain a strategic advantage. (Brander and Lewis, 1986; Maksimovic, 1988) "As firms take on more debt, they become motivated to pursue output strategies that raise returns in good states and lower returns in bad states. … firms will produce more than the … output level without debt" (Istaitieh and Rodrigues-Fernandez, 2005) . A firm that increases its debt level increases its fixed cost. From Figure 2, a firm with higher fixed cost earns higher rate of return when revenue is high, that is, in good states, and earns lower rates of return when revenue is low, that is, in bad states than lower fixed cost firms. Firms with higher fixed cost also have greater incentive to produce more because return curve is steeper for higher fixed cost firms. Financial instruments are often applied to reduce marginal cost by the increase of fixed cost, as described in the following passage:

> A firm that has access to resources at a lower marginal cost than its competitors has a strategic advantage that can exploit to gain a larger market share and profits. Maksimoviv (1990) shows that a firm that does not have such a strategic advantage can create it, for a fixed initial fee, by purchasing an option to acquire a factor of production, such as financing, at favorable terms. By initially negotiating a future bank-loan commitment, the firm can finance an expansion of output to meet a strategic contingency at more favorable terms than would be possible if the expansion had to be financed in the spot market. The ability to exercise the commitment enables the firm to threaten its rivals strategically… Firms can obtain low-interest rate loan commitments from banks and thereby create incentives for more aggressive product market competition (e.g., by increasing quantity.) (Istaitieh and Rodrigues-Fernandez, 2005)

Second, unleveraged rival firms have strong incentive to react aggressively to exhaust the leveraged firms. From Figure 2, firms with high fixed costs need high level of output to breakeven, and, from Figure 1, are very sensitive to the increase of market uncertainty. If possible, rival firms will adopt aggressive production and marketing strategies to squeeze the highly leveraged firms and increase market uncertainty, which hurts leveraged firms more than unleveraged ones. Whether leveraged firms will increase output or decrease output depends on competitive strength of different firms in those particular environments.

Khanna and Tice (2005) provide a detailed analysis on the role of debt and operating efficiency to the competitive strategies of firms. They define operating efficiency as chain-wide sales-per-square foot. Higher operating efficiency may be achieved in several ways. Some chains put more money on advertising, which is fixed cost, to increase sales. Other chains may systematically select prime location as their store sites, which generally have higher business volume but also higher purchasing or rental cost. Still others may provide better training to their employees with extra cost. Therefore, high efficiency chains can be more precisely understood as low marginal cost chains that are often achieved through higher level of fixed cost. High debt firms, as we have discussed, are also high fixed cost firms. So the exit of high debt- high efficiency store during recession can be more intuitively understood as the exit of high fixed cost, low variable cost store during recession, when market size shrinks.

To further illustrate the competitive dynamics of firms, we will apply the theory to compute the profit figures of two firms with identical production factors serving a common market under different competitive environments. We assume each firm has a fixed cost of 5, the discount rate is 12% per year and the duration of the fixed assets of both firms are 15 years. If the uncertainty rate is 35% and the value of each unit of product is 1, the marginal cost for each firm is 0.549, calculated from (6). Suppose the market size is 60 and each firm take 50% of the market share. From (9), the profit for each firm is

$$\frac{1}{2}60(1-0.549)-5=8.53$$

The level of fixed cost of a firm can be adjusted through a change of debt level. If other parameters are the same, we can calculate from (9) that the optimal level of fixed cost is 7.5, which can be achieved through higher debt level. At that level of fixed cost, the variable cost, according to (6), is 0.448 and the profit of the high debt firm is

$$\frac{1}{2}60(1-0.448)-7.5=9.05$$

Since the high debt firm has lower variable cost than the low debt firm, it has strong incentive to expand its market share. At the same time, the low debt firm, fearful about the possible expansion by the high debt firm, may start an aggressive marketing war, which increases uncertainty level to 55%. We can compute the new profit figures of high debt and low debt firms. Assume each firm takes 50% of the market share. For the low debt firm, the profit figure, from (9), is

$$\frac{1}{2}60(1-0.740)-5=2.806$$

While the profit for the high debt firm becomes

$$\frac{1}{2}60(1-0.682)-7.5=2.055$$

Therefore, under intensified competition, both firms earn less and the high debt firm's earning is even lower than the low debt one. The computation shows that the change of capital structure changes the dynamics of competition. The level of intensity of competition is partly determined by rival firms' capital structures. It is consistent with Khanna and Tice's (2005) observation that competition is more intensive in cities with stores of different levels of debt level than cities with stores of homogenous debt levels.

Now suppose a recession hits, the market size shrinks to 40. Assume each firm takes 50% of the market share. For the low debt firm, the profit figure, from (9), is

$$\frac{1}{2}40(1-0.740)-5=0.204$$

While the profit for the high debt firm becomes

$$\frac{1}{2}40(1-0.682)-7.5=-1.130$$

The profit for the high debt firm becomes negative. This will make it easier for the low debt firm to drive out high debt firm. The above computation shows that high debt firms are more vulnerable to intensified competition, especially during economic downturn, when the market size shrinks. This is another reason why the actual debt levels taken by firms are lower than optimal debt levels calculated from many works (Molina, 2005). It also explains that low debt firms, the “fat” firms, will do well in an industry downturn, for fatness is an important factor of fitness in lean time (Zingales, 1998). In general, there does not exist a universally applicable measure of fitness (Simpson, 1944; Stearns, 1992). The concept of fitness is conditioned on environmental constraints, which may change over time (Dawkins, 1999).

This theory of capital structure of firms can be extended to understand the relation between the “capital structure” of countries and the characteristics of their industries. If a country’s economic activities are heavily financed by bank loans, as in Germany, they are of high fixed cost. The country will be more closely associated with mature industries whose level of uncertainty is low. If a country’s economic activities are heavily financed by equity markets, as in the US, they are of low fixed cost. The country will be more closely associated with new industries whose level of uncertainty is high. This is indeed what Carlin and Mayer (2003) observed in their study.

Since Modigliani and Miller (1958) first proposed the corporate finance theory about fifty years ago, the fixed costs of most economic activities have increased tremendously. A large portion of labor force goes through college education before starting to work, at great cost. Many projects cost billions of dollars to build and maintain. As high fixed cost systems are very sensitive to uncertainty, financial decisions, by affecting both the levels of fixed cost and uncertainty, become more and more important over the years. This helps answer the question raised at the beginning of the paper: It is not the imperfectness of market but rather the increase of the fixed cost of economic activities that make the financial decisions more relevant over time.

4. Concluding remarks

Current capital structure theories may be classified as the trade-off theory, the pecking order theory and the market timing theory (Hovakimian et al., 2004). Pecking order and market timing are both due to information asymmetry. The cost of financial distress discussed in the trade-off theory is also largely due to information asymmetry. Therefore these theories are not mutually exclusive. Factors discussed in these theories all play a part in determining financial structure. But the absence of a structure model in these theories makes it difficult to determine the relation between these factors and market conditions.

The theory presented here is derived from simple and universal assumptions and the parameters in this theory have clear meaning. The analytical results derived from the theory about the relation among many factors in production, financing and market environment are consistent with a broad spectrum of empirical results. This shall mitigate the problem of endogeneity in modeling, which is central in understanding many puzzles in corporate finance (Molina, 2005).

While the simplicity and universality of the theory makes it less likely to overfit empirical patterns, great amount of details need to be worked out for each individual problem. For example, qualitatively, it is easy to identify debt with fixed cost. But for each firm, it can be challenging to quantify the relation between the level of debt and the level of fixed cost in each case for different firms have different levels of financial flexibility under different kinds of market conditions. These difficult works will be left to the future.

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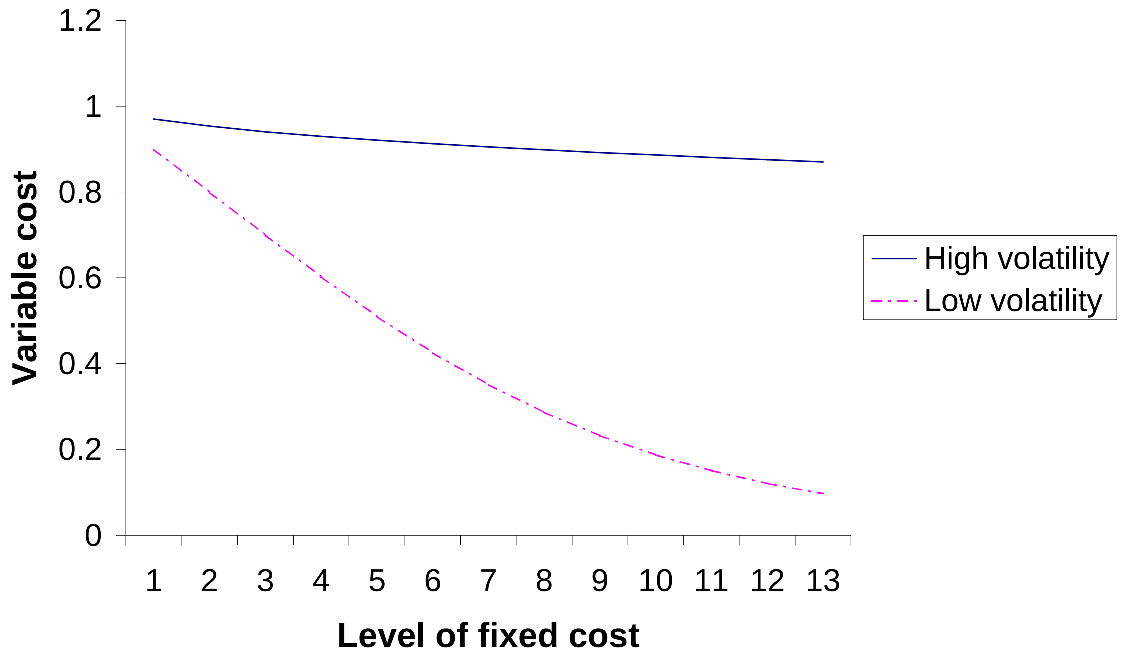
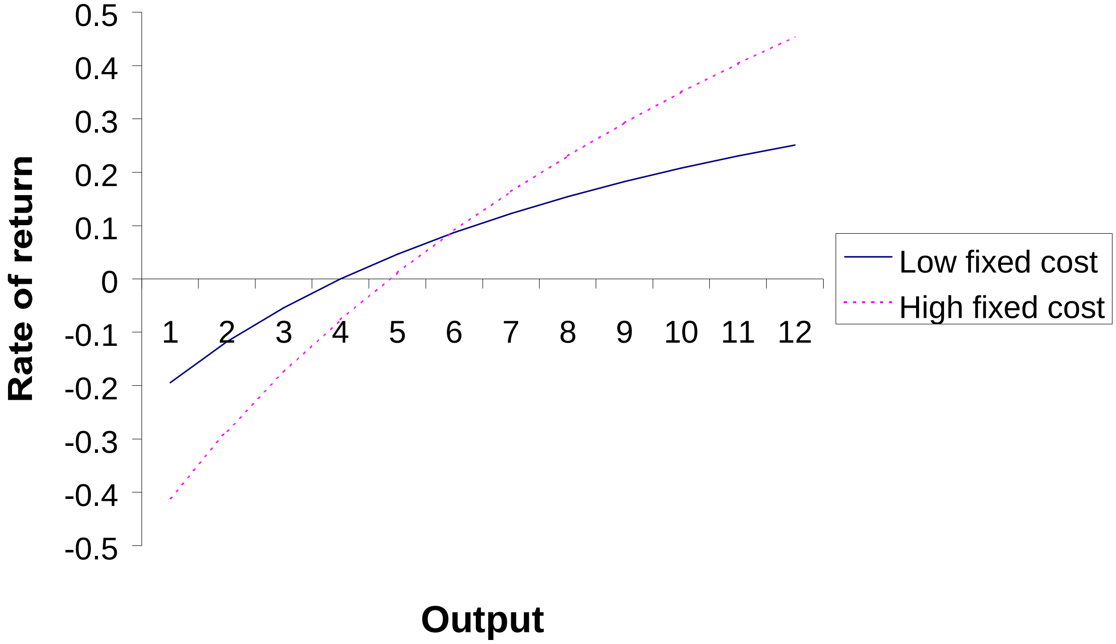
Figure captions

Figure 1. Level of uncertainty and variable cost: In a low uncertainty environment, variable cost drops sharply as fixed costs are increased. In a high uncertainty environment, variable costs change little with the level of fixed cost.

Figure 2. Output and return with different levels of fixed costs: For a large fixed cost investment, the breakeven market size is higher and the return curve is steeper. The opposite is true for a small fixed cost investment.



1.2
1
0.8
0.6
0.4
0.2
0
Variable cost
1 2 3 4 5 6 7 8 9 10 11 12 13
Level of fixed cost
High volatility
Low volatility


0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Rate of return
1 2 3 4 5 6 7 8 9 10 11 12
Output
Low fixed cost
High fixed cost