Convertibles and Milestones in Staged Financing

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Abstract: This paper investigates a popular phenomenon in which the manager of a firm uses convertibles in staged financing. Staged financing is particularly popular in corporate finance, even although it has potential incentive and risk problems. This paper finds many interesting properties of convertibles in staged financing, including the fact that staged financing using convertibles can almost achieve the first best. We also find that risks can reduce agency costs by putting pressure on the manager to perform. These results may explain why convertibles are a popular instrument in staged financing in reality.

Keywords: Convertibles, Staged Financing, Milestones

JEL Classification: G32, G31

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1. Introduction

Staged financing has been widely used as a financing strategy in corporate finance. In venture capital financing, in particular, staged financing applies basically to every firm and this has been increasingly true in recent years. Interestingly, staged financing is almost always carried out by convertibles. Why should staged financing be carried out by convertibles? Is there an advantage to use convertibles in staged financing?

In venture capital, entrepreneurs (ENs) seek funding from venture capitalists (VCs) for their ideas. An entrepreneur (he) has no capital and the firm is typically new or very young. There may be great potential for the firm, but success is rare and the risks for investors are high. If a venture capitalist (she) decides to invest, she typically invests in stages in order to reduce her risk exposure in the early stages. However, staged financing may cause some problems, depending on the type of financial instruments used to carry out the financing strategy. First, since later installments may not come, the entrepreneur may not have enough incentives to invest effort in making his idea a success. Second, an inadequate initial investment may put the project at risk and the project may fail prematurely. Third, the entrepreneur may try to boost his early performance in order to impress the VC for a further investment (Cornelli–Yosha 2003). Finally, to induce further installments, the entrepreneur may make a very "sweet" deal with the VC, which may cause the firm to go bankrupt when market conditions fluctuate.

Since convertibles tend to go hand in hand with staged financing in reality, we naturally suspect that convertibles with their special features may be able to resolve many of the associated problems with staged financing. But, it is not clear why convertibles can do this. Based on the incomplete-contract approach, this paper investigates and analyzes staged financing using convertibles. Indeed, we find that staged financing using convertibles can almost achieve the first best.

Our model emphasizes three popular features in real-world corporate finance: staged financing, convertibles, and decision events. Decision events result from various ex-post options, including default, conversion and bankruptcy. In venture capital, investors typically have no interest in interfering with daily management of the firm if the firm is doing well (Gorman–Sahlman 1989). Yet, the investors would like to have the option of taking control of the firm under certain circumstances. One likely purpose is to deal with decision events. If the firm is not doing well, to save her investment, the VC may take control of the firm and decide to replace the top manager or to sell off the firm; if the firm is just surviving, the VC may maintain the loan to earn interest; if the firm is doing very well, the VC may use the conversion option to own a share of equity at a low cost to benefit from the growth of the firm. This aspect of our model follows the line of Aghion–Bolton (1992) and Hellmann (2001).

Our emphasis on decision events is due to the widely observed phenomenon of performance targets and milestones in real-world venture capital financing. As observed by Kaplan–Strömberg (2003, Table 3), about 73% of fundings explicitly includes some type of contingency. That is, future installments in staged financing are generally conditional upon the firm achieving certain business or financial objectives, referred to as milestones. Most contracts in venture capital contain specific milestone-contingent clauses. In our model, milestones are not imposed per se in the model setup, but they appear in the equilibrium strategies. That is, the VC will take certain planned actions based on specific milestones in equilibrium. These milestones can either be explicitly written into the contract or be implicit in the available choices provided by convertibles and staged financing.

The conversion option plays a very different role in our model from its traditional role in the existing literature. In the literature, the two parties in a joint venture invest in turns. The conversion option allows a switch of ownership in the middle so that each player becomes the full owner when it is time for him/her to invest. By this, both parties invest efficiently. In contrast, we investigate the option in a model in which an ownership switch does not play the traditional role. A conversion may or may not happen in equilibrium in our model; the conversion option serves as an incentive instrument only. Instead, we focus on other issues such as staged financing and decision events.

Even though staged financing is typically carried by convertibles, researchers rarely provide an explanation for the phenomenon. The paper by Cornelli–Yosha (2003) is an exception. They emphasize the role of convertibles in dealing with window dressing in staged financing, while we emphasize the role of convertibles in dealing with various decision events in staged financing. Our model includes the case in Cornelli–Yosha (2003) as a special case.

This paper proceeds as follows. Section 2 contains a literature review. Section 3 defines the model for venture capital financing in an environment with uncertainty and moral hazards. We allow staged financing as an optimal strategy in our model. To carry out staged financing, we allow convertibles as a vehicle of investment. Section 4 analyzes the solution in relation to various underlying factors. Section 5 concludes the paper with a few concluding remarks.

2. Literature Review

Popularity of Convertibles

Convertibles are a major instrument in corporate finance (Trester 1998). According to VentureXpert, convertibles are the dominant instrument in venture capital and they have been becoming more and more popular in recent years. In 2005, 93% of investments in all stages were done by convertibles. The second most popular financing instrument was debt. But, debt financing accounts for only a small percentage and it has been decreasing in popularity in recent years. In 2005, debt financing accounted for only 2.14% of financing in all stages.

There are many studies that seek to explain preferences of financial instruments in corporate finance. They are based broadly on two approaches: the asymmetric-information approach and the incomplete-contract approach. There is also a recent literature on real options that explains the use of convertibles in staged financing. We here give a short review of the three literatures in relation to our model.

The Asymmetric-Information Approach

The main message from the asymmetric-information approach is that convertibles give the firm a backdoor to equity and give investors an opportunity to wait and see if the project is worth investing.

Myers–Majluf (1984) consider a firm that knows more about its own value than investors. Due to this asymmetric information, investors tend to undervalue a good firm's stock. This may explain several aspects of corporate financing behaviors, including the tendency for firms to rely on internal sources of funds and a preference for debt over equity. Under this situation, one good way to sell equity is through convertibles.

Stein (1992) considers three types of firms and the type is a firm's private information. A separating equilibrium is found, in which a bad firm chooses equity financing, a medium firm chooses convertible financing, and a good firm chooses debt financing. This result follows from a large cost of financing distress from debt. The bad firm will not choose convertible financing since in a bad situation it is not able either to pay back the debt or to force conversion in order to eliminate the debt. The potential cost of financial distress induces the bad firm to avoid any form of debt financing. Similar arguments apply to the other two types of firms.

In contrast, our model is based on incentive inducement. In our model, any firm can employ convertibles in staged financing. In particular, we do not require the firm to be of a medium type to issue convertibles, which is consistent with the popularity of convertibles in venture capital. Our result is quite different from Stein (1992). For example, if the firm performs well (a good type ex post), the investor in our model will convert her investment into equity, otherwise she will keep debt to the end (Figure 4). Our conclusion is based on bankruptcy risk, which reduces the investor's incentive to invest early. Only when the firm looks very promising, the investor chooses to convert. Also, Stein (1992) looks at corporate finance purely from the firm's point of view — it is about commitment and signaling. We look at it from both the firm's and the investors' points of view, and the design of the convertible is a bargaining outcome or a balance of incentives and risks of the two parties.

Bagella–Becchetti (1998) provide a refinement of Stein's (1992) asymmetric information model. They show that a bond-plus-warrant issue is the optimal financing strategy in a separating equilibrium.[3] They also provide empirical evidence in support of their findings.

However, the classification of firms into three types (bad, medium and good) is problematic. Two things come to mind when we classify firms: risks and expected returns. If we divide each of the two aspects (risks and returns) into three possibilities: low, medium and high, then there are total nine types of firms and most of the types cannot be ranked. Also, the manager and investor have two things to decide in their investment decision: a choice of financial instrument and a choice of investment strategy. In other words, when facing a specific combination of risks and expected returns, the manager and investor need to decide a combination of financial instrument and investment strategy. For example, new startups in high-tech industries tend to be very risky and those that are able to find fundings are expected to have very high returns. It turns out that these firms have usually been financed by convertibles using a staged financing strategy. In other words, in corporate finance, the choice of financial instrument and the choice of investment strategy may be tied together. This is actually the focal point of our model. Given that the staged investment strategy is chosen for various reasons, our point is that convertibles can be an effective instrument to carry out a staged investment strategy,. This point applies to any firm, regardless of a firm's type.

The asymmetric-information approach tends to emphasize the motivation of the supply side of convertibles. In particular, firms are supposed to use financial instruments as signals of their types. Indeed, surveys indicate that two-thirds of managers claim that convertibles are used ultimately to obtain equity financing. However, this phenomenon can also be explained by motivations from the demand side for convertibles. Convertibles have an advantage in copying with many possible decision events under staged financing and uncertainty. This is a key point in our model. In reality, convertible holders will never convert early unless they really have to (when facing a decision event or at maturity). Since the firm's type is only determined and revealed ex post, it is natural that investors use convertibles to implement a wait-and-see strategy (i.e., the staged financing strategy). Convertibles provide investors with the option to determine their positions ex post. This argument is consistent with Essig's (1991) observation that small firms, and hence risky firms, tend to have a high proportion of convertibles in their total debt. However, the asymmetric-information approach generally suggests that only the medium firm chooses convertible financing.

In order to compare an agency model with an asymmetric information model, for an agency model, we call a firm a good firm if it has a high output ex post in equilibrium and call a firm a bad firm if it has a low output ex post. By this, in an agency model the firm has an en-

[3] Our class of convertibles includes this bond-plus-warrant issue.

dogenous type (determined in equilibrium by choices), while in an asymmetric information model the firm has an exogenous type (assigned by nature).[4] In an agency model the type is observable, while in an asymmetric information model the type is not directly observable. However, an asymmetric information model typically discusses a separating equilibrium (or a pooling equilibrium with a sufficiently reliable signal). If so, the two classes of models can indeed be compared in equilibria.

In our model, instead of dividing firms into a few types upfront at $t = 0$, the firm's type is determined ex post at $t = 1$. The ex-post type of the firm is determined by incentives and a luck factor. Specifically, when output y (expected output if there is uncertainty in the second period) is less than y_1, as shown in Figure 4, the firm is bad; when output is between y_1 and y_2, the firm is a living dead; when output is between y_2 and y_3, the firm is medium; and when output is larger than y_3, the firm is good. These output values are used as performance targets or milestones in equilibrium, based on which the investor takes pre-determined actions.

The Incomplete-Contract Approach

Our model is based on the incomplete-contract approach. This approach emphasizes information revelation during a production process and allows various ex-post options and renegotiation possibilities. In addition to a revenue-sharing agreement, this approach allows various mechanisms to deal with various problems such as information revelation, renegotiation, incentives, ex-post options, and holdups. In particular, this approach treats real-world financial instruments, staged financing and equity sharing as mechanisms deployed by economic agents to deal with various corporate financing problems.

This approach pays particular attention to two major issues in a joint project: risk sharing and moral hazard. First, there is a need for proper risk sharing between investors and managers. The risks include various decision events, particularly default and bankruptcy, and various possible shocks to the system. Second, there is also a need to deal with various incentive problems, including the manager's incentive to invest, the investor's incentive to invest, the manager's incentive to keep the project going even if it is better to shut it down, and the investor's incentive to commit early. Third, the risk and incentive issues can be entangled. For example, staged financing can be used to control risks, but staged financing can itself create certain agency problems. How should the various mechanisms be properly combined?

A dominant view in the existing literature on convertibles and incentives is the ownership-for-investment view. The two parties are supposed to invest in sequence. A convertible

[4] A signal in an asymmetric information model can be endogenous. This is completely different from endogenous types. In fact, the endogeneity of signal does not play a role in a pooling equilibrium.

allows a switch of ownership in the middle so that each investing party becomes the sole owner when it is his/her turn to invest. Efficiency can be achieved under double moral hazard since the sole owner has the incentive to invest efficiently. In such a model, a conversion to equity will definitely happen in equilibrium. The pioneer of this view is Demski–Sappington (1991), followed by Nöldeke–Schmidt (1995, 1998), Che–Hausch (1999), Edlin–Hermalin (2000), Schmidt (2003), and many others.[5]

The ownership-for-investment view predicts an increase in capital expenditure following conversion. However, as pointed out by Alderson–Betker–Stock (2002), only Mayers' (1998) finding is consistent with this. Mayers (1998) presents an empirical study on the real options theory. For a firm that often faces investment opportunities, in comparison with debt, convertibles allow the firm to obtain cash flows through conversion. However, a more careful empirical study by Alderson–Betker–Stock (2002) does not find that a conversion leads to greater investments and financing activities. In fact, the only thing that changes after a conversion is the capital structure.

Baker–Wurgler (2002) find that capital structure is less influenced by corporate governance considerations than was previously thought. This makes sense, since in reality investors have little interest in assuming control of the firm. For example, in the venture capital industry, investors are typically venture capital firms, which invest in a portfolio of small companies across industries. They have neither the technical expertise nor the managerial personnel to run a number of companies in diverse industries. They prefer to leave operating control to the existing management. The investors do, however, want to participate in strategic decisions that might change the basic product/market character of the company and in major investment decisions that might divert or deplete the financial resources of the firm. For this purpose, they will generally ensure some representation in the board of directors of the firm. Only if severe financial, operating, or marketing problems develop, the investors may want to be able to assume control and attempt to rescue their investments. For this purpose, some protective provisions in their financing agreements will be sufficient. In our model, the manager has full control of the project during the whole course. Only at an exit point may the conversion option be exercised, depending on the firm's performance and the rights defined in the financial instrument.

Further, Baker–Wurgler's (2002) empirical study shows that 'market timing' has large and persistent effects on capital structure. Their main finding is that low leverage firms are those that raised funds when their market valuations were high, and vice versa. That is, the manager of the firm acts like a fund manager who manages the firm's financial assets like an investment portfolio. Baker and Wurgler's contribution is to show that such an interpretation

[5] In Schmidt (2003), the optimal conversion ratio is less than 100%. This is due to the fact that there are only three possible states in his model and the investor has only three possible actions by his Assumption 1.

to the firm's capital structure is consistent with data. In our model, conversion to equity is not based on the need for the investor to become the owner of the firm; instead, an ex-post decision on conversion is based on the comparison of the market value of the firm with the conversion value of the convertible. As shown in our Figures 6–10, conversion to equity tends to happen when the firm's market value is high and the firm tends to keep debt when its market value is low. This is consistent with Baker–Wurgler's (2002) empirical findings, even though our theory is completely different from their own interpretation of their empirical findings.

Kaplan–Strömberg (2003) provide an empirical study that supports the view of incomplete contracts in venture capital financing. They find that VC financings allow VCs to separately allocate cash flow rights, board rights, voting rights, liquidation rights and other control rights. They also study the interrelation and the evolution across financing rounds of the different rights.

Finally, Schmidt (2003) shows that convertible financing is efficient in a three-state model. There are two key differences between Schmidt (2003) and our model. First, in Schmidt (2003), uncertainty happens before investments; in our model, uncertainty happens after investments. If uncertainty happens before investments, the uncertainty is really a type of the firm and this type is publicly observable. Given each type, the two parties decide how much to invest. The investors do not face uncertainty when they make investment decisions; instead, investments are made conditional on uncertainty/type. If uncertainty happens after investments, the investors face risk when they make investment decisions and investments are independent of uncertainty. An incentive problem is difficult to resolve in an agency model if risks are mixed with incentives. If there is no risk, the first best can be easily achieved. This is why Schmidt (2003) can achieve efficiency. Second, our model emphasizes staged financing. In both models, the investor invests twice and the manager invests once in the middle of the VC's two investments. However, in Schmidt (2003), the initial investment I is a given constant; it is not a choice variable and it does not affect expected output, output uncertainty or incentives. In our model, the initial investment k is a choice variable and it affects expected output, output uncertainty and incentives. The key in staged financing is that the parties use staged financing as a mechanism to control incentives and risks; it works by dividing the required funding into several installments, by which the investors can see how the project is doing, keep pressure on the manager, and strike a balance in risk sharing between the two parties. One interesting case is when the optimal initial investment happens to be the full amount of the required funding, which is called upfront financing. With upfront financing being an optimal solution in our model under certain conditions, our model allows us to make an interesting comparison between upfront financing and staged financing.

Staged Financing

Staged financing is a well adopted corporate strategy. For example, in venture capital, almost all investment is through staged financing instead of upfront financing (Sahlman 1990). According to the real options literature, when a company with many real investment options raises funds for a project today, it must take into account a second fund raising in the near future. It could raise funds today for both projects to save issue costs or raise them when needed. Hence, the financing horizon of such a company is over multiple periods. In other words, as determined by the business environment, the financing strategy of a company with real options is inherently sequential.

Gompers (1995) views staged financing as a mechanism that the VC monitors the EN's incentive. Gompers finds empirical evidence that potential agency costs increase as assets become less tangible, growth options increase, and asset specificity rises and that the VC monitors the EN more frequently as potential agency costs rise.

As Mayers (2000, p.20) observes, 31% more companies raise new capital around the time of conversion than a typical company and most of them issue debt only. Hence, a firm may have an optimal debt-equity ratio in the long run so that fund raising for investment opportunities needs to take into account capital structure in a multi-period setting. For this purpose, the firm may need to choose a proper financial instrument and an effective financing strategy. As we show, a properly structured convertible coupled with a properly designed staged investment strategy is an effective approach. Indeed, there are many surveys and empirical studies (Mayers 1998, 2000), but only one theoretical study by Cornelli–Yosha (2003), that tie convertibles with staged financing.

Asquith (1992) shows that about two-thirds of all convertibles are eventually converted, which supports the view that convertibles are used in an anticipated/planned financing sequence. Jen–Choi–Lee (1997) further show that the stock market responds more favorably to announcements of convertible issues by companies with high post-issue capital expenditures and high market-to-book ratios (both are plausible proxies for growth potential), but low credit ratings and high (post-offering) debt-equity ratios. These findings support Mayers' (1998) view that convertibles are suitable for companies with many real investment options.

However, many other forms of financial instruments can also be consistent with the survey results and empirical evidence. For example, as noted by Brennan–Her (1993) and Mayers (1998), there is ambiguity with interpretations of existing evidence on the use of convertibles. Much of the existing evidence that supports the argument of cost-saving in staged financing (Mayers 1998) also supports other known arguments, including after-issue risk shifting (Jensen–Meckling 1976; Green 1984), risk estimation (Brennan–Kraus 1987; Brennan–Schwartz 1988), and asymmetric information (Constantinides–Grundy 1989; Stein 1992). These problems call for theoretical analysis and a good understanding of convertibles.

In the existing literature, only Cornelli–Yosha (2003) offer a theoretical explanation for a need to use convertibles in staged financing. They argue that, with staged financing, the manager has the incentive to do window dressing in order to attract further investments from investors. However, with convertibles, if the manager overstates the company's value, the investor will convert to equity and sell her shares in the market (or equivalently sell her convertibles directly to the market). In other words, they emphasize the role of convertibles in dealing with window dressing resulting from staged financing. We, on the other hand, emphasize the role of convertibles in dealing with various decision events in staged financing, including the problem of window dressing as a special case.

Wang–Zhou (2004) have a similar model as ours. They deal with straight equity in staged financing, while we discuss convertibles in staged financing. They show that straight equity is inefficient and it is approximately efficient for "cost-efficient" firms. However, straight equity is rare in venture capital and VC-backed firms may not be cost efficient. We show that a convertible to be approximately efficient for any firm. We argue that, by raising funds in stages, our solution gives investors an opportunity to see how the project goes, keep pressure on the manager to perform, and strikes a balance in risk sharing between the two parties. In particular, we argue that the conversion option in a convertible seems fit to handle various possible decision events in staged financing.

Finally, one puzzling popular phenomenon in real-world venture capital is the milestone financing strategy. That is, investors set performance targets or milestones to take certain specified actions (Sahlman 1990). The existing literature lacks theoretical and empirical studies on this phenomenon. Interestingly, our solutions are consistent with this phenomenon. In fact, the variables y_1, y_2, and y_3 in our model (Figure 4) are precisely the milestones in equilibrium, based on which certain actions are taken. The manager and investors can actually specify these items in their agreement to implement explicitly a milestone strategy. For example, although conversion can happen at an investor's selection, automatic conversion can happen conditional on certain milestones in reality (when a company goes IPO); this corresponds to the case with $y \geq y_3$ in our model. Our model does not impose a milestone strategy per se; instead, a milestone strategy appears naturally in equilibrium, given the options in a convertible under staged financing.

3. The Model

3.1. The Project

For the convenience of presentation, we will refer to a venture capital-backed firm, although much of the conclusion is applicable to many types of firms. Specifically, consider a firm that relies on a venture capitalist (VC) for investment in a project. The project lasts two periods. The firm is initially owned and managed by a single entrepreneur. The entrepreneur (EN) provides an investment x, called effort, and the VC provides a necessary funding of total amount K. The EN provides his effort x after accepting the contract, with cost $c(x)$, and this effort is applied throughout the two periods. The VC provides the funding K in two stages with an initial installment k in the first period and a planned second installment $K-k$ in the second period. Given effort x from the EN and the initial investment k from the VC, an output y is produced at the end of the second period. This y is random at the beginning of the first period (ex ante).

Staged financing is used to allocate the total amount K between the two installments. Specifically, the VC offers to provide a total of k in funds at the beginning of the first period. After the uncertainty is realized and input x is observed at the end of the first period, the VC considers providing the rest $K-k$ in funds. The VC has the option of not providing the second installment without any penalty.

The production process takes two periods to finish. Both the EN and VC are indispensable to the project. If the project is abandoned in the middle by either party, the firm is liquidated for a fraction θk of the initial capital investment, where $\theta \in [0,\ 1)$. The EN and VC share the revenue at the end of the project based on the existing contract.

3.2. Timing of Events

There is an information revelation process. The uncertainty of output is realized and publicly revealed at the end of the first period (ex post). The EN's effort is observable at time $t=1$ but not verifiable. The VC's investments k and $K-k$ are verifiable, but her option on whether or not to continue her investment at $t=1$ is not ex-ante contractable. This means that the VC's decision on the option will be conditional on the observation of the EN's input x and on the knowledge of the random shock. As some information becomes available ex post, the two parties are allowed to renegotiate the contract.

The timing of events is illustrated in Figure 1.[6] At each time point, the sequence of events is from the top of the list to the bottom.

[6] We can make the model more realistic by allowing a second random shock to the output in the second period. However, there is no need for this complication for the current purposes.

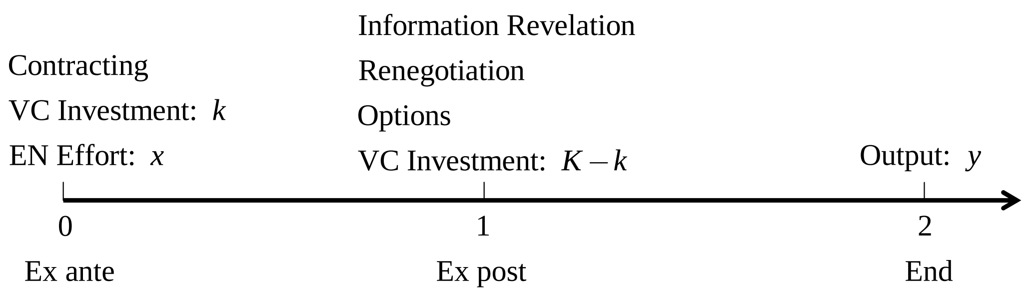

Figure 1. The Two-Period Model

Specifically, at $t=0$, the two parties negotiate a contract. If the contract is accepted by the two parties, the VC invests k and the entrepreneur applies effort x and incurs cost $c(x)$. At $t=1$, uncertainty is resolved. The VC considers the options to quit and to renegotiate. If the project is bad, the VC abandons the project without investing $K-k$; if the project is mediocre, she may demand negotiation of a new contract; if the project is good, she continues to invest. At $t=2$, the project is finished and the two parties divide the output based on the existing contract.

3.3. Convertibles

A convertible allows an investor to invest in the form of debt that pays a guaranteed rate of return r, and this security provides an option for the investor to convert her investment into equity at any time (either at $t=1$ or $t=2$) at a guaranteed conversion ratio τ or equivalently at a given striking price.

Our convertibles include many forms of assets with the key feature that the investor has an option of converting her investment into equity at a later stage. The most popular convertibles in venture capital are convertible preferred stock, which is a class of capital stock that may pay dividends at a specified rate and that has priority over common stock in the payment of dividends and the liquidation of assets. Convertibles can also be a package that includes both pure debt and warrants with a discount on the purchasing price of warrants. A warrant does not involve an upfront investment but allows the investor to purchase stock at a guaranteed price at a later stage (Kaplan–Strömberg 2003).

3.4. Assumptions

A few assumptions are needed for a tractable model. First, output y is random ex ante, defined by

$$y=\mu f(x,k),$$

where $f(x,k)$ is a typical production function and μ is random ex ante with distribution function $\Phi(\mu)$. This particular form is unnecessary; it is for the convenience of interpretation.

Naturally, we assume that the output process follows the law of first-order stochastic dominance (FOSD), which means that $f(x,k)$ is increasing in (x,k).

We take the interest rate (or dividend rate) r as given. We expect it to be heavily influenced by the prevailing safe return in the market. Often, the interests/dividends are accrued and paid with the principal at maturity (Kaplan–Strömberg 2003, p.10).

The total required investment K is not a choice variable; it is a given fixed number. We may consider this fund as a necessary amount to develop a product. We may also consider K as optimally determined by an early stage problem and our current problem is to decide how to allocate this total investment in multiple stages.

The VC has the option to abandon the project ex post by not providing the planned second installment. The VC may benefit from the resolution of uncertainty by investing ex post. But, this affects the EN's incentive to work. Hence, the VC needs to choose the allocation of investments across stages properly in order to balance the EN's incentive to expend effort and her own benefit.

Finally, assume that both parties are risk neutral in income. For simplicity, also assume no discount for time preferences and no interest payment at time $t=1$. The interest is paid at the end of the project with the proceeds if the VC keeps debt.

3.5. Model Setup

Both parties in our model have certain bargaining power both ex ante and ex post. The two parties negotiate and bargain over the terms of a contract ex ante and possibly ex post. This means that, with the possibility of renegotiation, the two parties will negotiate an agreement that ensures social welfare maximization ex ante as well as ex post, subject to incentive conditions.

Specifically, let Π_{VC} and Π_{EN} be the ex-ante payoffs to the VC and the EN, respectively. The contract is an outcome of negotiation. There are three variables to decide: initial investment k, effort x, and conversion ratio τ. In our model, the conversion ratio is the proportion of the firm's equity that a convertible can be converted into. We denote the conversion ratio as τ, where $\tau \in [0, 1]$. Given that the VC's initial investment k is contractable but her decision on whether or not to provide the second installation is not contractable ex ante, and given that the EN's effort x is not verifiable, with the assumption of an efficient bargaining outcome, the ex-ante problem is

$$
\begin{aligned}
V = \max_{x,k,\tau} \ & \Pi_{EN} + \Pi_{VC} \\
\text{s.t.} \ & \text{IC}_1: \ \frac{\partial \Pi_{EN}}{\partial x} = 0, \\
& \text{IC}_2: \ \frac{\partial^2 \Pi_{EN}}{\partial x^2} < 0, \\
& \text{IR:} \ \Pi_{VC} + \Pi_{EN} > 0.
\end{aligned}
\tag{1}
$$

Here, we have two incentive compatibility (IC) conditions IC_1 and IC_2 to ensure right incentives from the EN. We also have a joint individual rationality (IR) condition. As long as the project is socially viable (the IR condition is satisfied in equilibrium), the two parties can make a monetary transfer to ensure their individual IR conditions. The size of this transfer depends on their relative bargaining power ex ante and it will not affect their investment incentives. Hence, we have a joint IR condition instead of two separate IR conditions. Our task is to analyze the solution of (1) under convertible financing.

Remark 1. We do not restrict ourselves to a principal-agent setup, in which one of the parties is given the full bargaining power ex ante. Our model is not a standard contract model either, in which admissible contracts are output-sharing contracts only. Our model has an incomplete contract, which allows ex-post options. This is consistent with Kaplan–Strömberg's (2003) observation that contracts in the venture capital industry are inherently incomplete.

Remark 2. There are two sets of bargaining power for the two parties: the bargaining power for ex-ante negotiation and the bargaining power for ex-post renegotiation. We do not need to specify the ex-ante bargaining power explicitly, since it involves a fixed monetary transfer between the two parties and this transfer will not affect their investment decisions. On the other hand, ex-post bargaining power is defined within a convertible. With an ex-post option for conversion, a convertible provides the holder certain ex-post bargaining power. In a traditional model, conversion is guaranteed in equilibrium. However, in our model, conversion is conditional. An important component of convertibles is its special rights in certain decision events. These special rights have implications on risks and incentives.

Remark 3. The risk and incentive problems in our model are distinctly different from that in the literature. Although our model certainly allows traditional risks, such as demand and technology shocks, we focus on the risks from the three possible decision events: default, bankruptcy, and conversion.

Remark 4. There are several incentive problems. First, there is the traditional incentive problem, resulting from a unverifiable input from the EN. Second, the VC has an incentive problem since her second investment decision comes after the EN's investment. However, although the VC can take over ownership before her decision on the second installment in our model, she will not do so under normal circumstances (if the expected value of the firm is positive). Finally, the possibility of no second installment affects the EN's incentives. This can work in two ways: the EN may be discouraged by the risk; or the EN may alternatively work harder to boost performance in order to secure the second installment (Cornelli–Yosha 2003).

3.6. The Solutions

The First-Best Solution

As a benchmark, consider the first-best problem first. The first-best problem is a staged financing problem in which there are no agency problems. Specifically, the EN's investment x is contractable and the second installment is provided if and only if it is ex-post efficient to do so. Hence, at time $t=1$, if and only if

$$y-(K-k)\geq \theta k \quad \text{or} \quad y\geq y_1 \equiv K-(1-\theta)k \quad \text{or} \quad \mu \geq \mu_1 \equiv \frac{y_1}{f(x,k)}, \tag{2}$$

it is ex-post efficient to continue the operation; otherwise, the firm defaults at $t=1$.

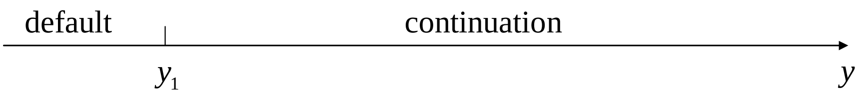

Figure 2. The Milestone of the First-Best Problem

Therefore, with probability $\Phi(\mu_1)$ the firm defaults at $t=1$, otherwise it continues with a second installment $K-k$. If the firm defaults, the total payoff is θk; if it continues, the total payoff is $\mu f(x,k)$. Taking into account the initial investment k and the cost $c(x)$ of effort x, the first-best problem is:

$$\max_{x,\,k\geq 0} \ \theta k \Phi(\mu_1) + \int_{\mu_1}^{\infty} \left[\mu f(x,k) - (K-k)\right] d\Phi(\mu) - k - c(x). \tag{3}$$

The Second-Best Solution

Suppose now that the VC deploys convertibles in her financing strategy. Denote a convertible as (K, r, τ) with principal K, interest rate r, conversion ratio τ, convertible at and after $t=1$, and maturity at $t=2$. Assume that the interests are cumulated and paid at $t=2$.[7]

Although convertible holders receive a guaranteed fixed rate of return like a straight debt holder before conversion, some liquidity protection measures for straight debt holders do not apply to convertible holders. There are two key differences in a holder's rights. First, a convertible holder has no foreclosure rights. Second, in the case of default, a convertible holder is

[7] In reality, due to the cash constraint in early stages, interests and dividends are typically cumulative and become part of the liquidation preference upon a sale or liquidation of the company.

not treated as a debt holder. These mean that whether or not the firm should default is subject to negotiation and that, in the case of default, the VC is not entitled to the firm's worth up to her investment. Specifically, if renegotiation leads to default, a convertible holder shares the proceeds with the EN according to their share holdings $(\tau, 1-\tau)$. A contract is renegotiable at any time; but, in equilibrium, renegotiation never needs to happen.

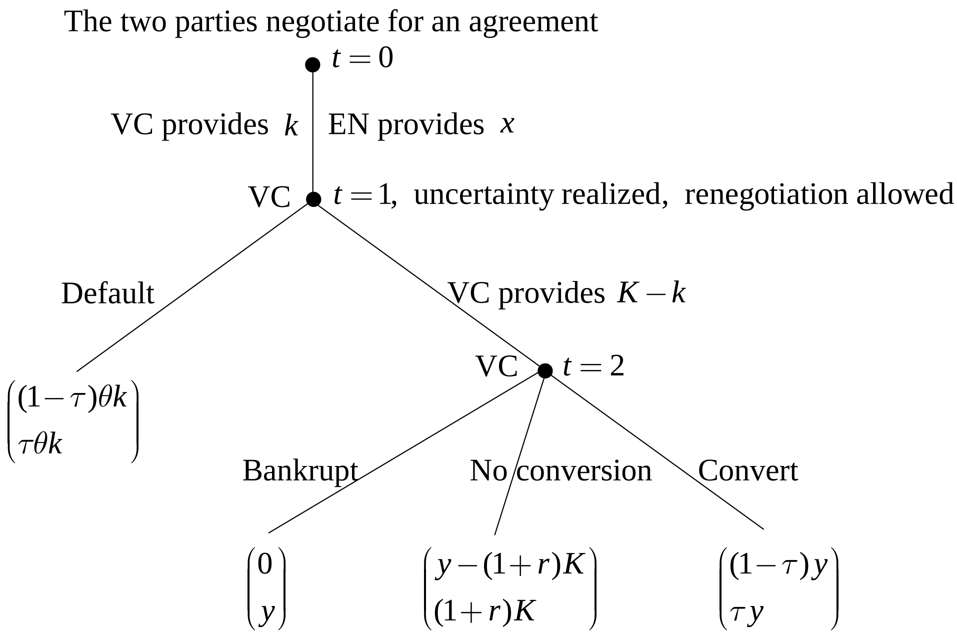

Figure 3. The Game Tree for Convertible Financing

As stated in Proposition 1, it turns out that the solution is determined by a few milestones, where the milestones are defined as

$$y_1 \equiv K-(1-\theta)k, \qquad y_2 \equiv (1+r)K, \qquad y_3 \equiv \frac{(1+r)K}{\tau}.$$

Here, in terms of output levels, y_1 is the threshold for default, y_2 is the threshold for bankruptcy, and y_3 is the threshold for conversion, as shown in Figure 4. These output levels are the milestones by which certain decisions are taken. We hence call them the milestone of default, the milestone of bankruptcy and the milestone of conversion, respectively.

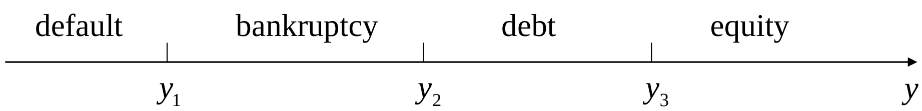

Figure 4. The Milestones in Convertible Financing

Proposition 1 (Milestones). The second-best solution can be described by a milestone strategy, which states that:

- if $y < y_1$, the firm defaults at $t=1$;

- if $y_1 \le y < y_2$, the VC provides the second installment $t=1$ and keeps debt, and the project continues, but the firm goes bankrupt at $t=2$ and the VC receives y at $t=2$;
- if $y_2 \le y < y_3$, the VC provides the second installment at $t=1$, keeps debt to the end, and receive income $(1+r)K$ at $t=2$;
- if $y \ge y_3$, the VC provides the second installment, converts to equity at $t=2$, and receives income τy at $t=2$.

Although our model does not impose milestones per se, milestones appear naturally in equilibrium. In fact, the optimal contract can explicitly contain clauses like the statements in Proposition 1. This is consistent with what we often observe in reality (Sahlman 1990).

Let $\mu_i \equiv y_i / f(x,k)$ for $i=1,2,3$. By Proposition 1, taking into account the initial costs k and $c(x)$ and the fact that, if $y<y_1$, the firm defaults and the VC's and the EN's incomes are $\tau\theta k$ and $(1-\tau)\theta k$ at $t=1$, respectively, we find the ex-ante payoff functions:

$$\Pi_{EN} \equiv (1-\tau)\theta k\Phi(\mu_1) + \int_{\mu_2}^{\mu_3} [y-(1+r)K]\, d\Phi(\mu) + \int_{\mu_3}^{\infty} (1-\tau) y\, d\Phi(\mu) - c(x),$$

$$\Pi_{VC} \equiv \tau\theta k\Phi(\mu_1) + \int_{\mu_1}^{\mu_2} [y-(K-k)]\, d\Phi(\mu)$$

$$+\int_{\mu_2}^{\mu_3} [(1+r)k-(K-k)]\, d\Phi(\mu) + \int_{\mu_3}^{\infty} [\tau y-(K-k)]\, d\Phi(\mu) - k.$$

The ex-ante contractual problem is problem (1) with choice variables x, k and τ.

3.7. A Numerical Solution

We will look at the numerical solution, which allows us to look at many aspects without being hindered by technical difficulties. We use a computer program, called Mathcad, to analyze the solution. To do this, we choose a set of parametric functions:[8]

$$f(x,k) = \alpha\sqrt{x}k^{\beta}, \qquad c(x) = cx^2, \qquad \mu \sim N(1,\sigma^2),$$

where $\alpha>0$, $\beta>0$, $c>0$, and $N(1,\sigma^2)$ denotes the normal distribution with mean 1 and variance σ^2. Here, we may consider $\sqrt{x}$ as a traditional production function, k^{β} as reflecting easy of liquidity constraints in early stages. μ as a technology shock, α as productivity, c as the cost coefficient, and σ as the risk factor. We also have the liquidation value θ. As shown in Figure 6, the cost parameter c is highly correlated with the agency cost (the loss of efficiency due to agency problems). Hence, we can simply treat c as a measure of agency costs.

For the following set of parameter values:

[8] In the production function $f(x,k)$, the power parameter of x is chosen as ½. We have tried various numbers in $(0, 1)$ and the results are generally the same.

$$\alpha = 0.5, \quad \beta = 0.05, \quad c = 1, \quad \theta = 0.2, \quad K = 1, \quad r = 10\%, \quad \sigma = 1,$$

the first-best solution (x_{FB}, k_{FB}) with social welfare SW_{FB} and the second-best solution $(x_{SB}, k_{SB}, \tau_{SB})$ with social welfare SW_{SB} are respectively:

$$\begin{pmatrix} x_{FB} \\ k_{FB} \\ SW_{FB} \end{pmatrix} = \begin{pmatrix} 0.623 \\ 0.314 \\ 0.398 \end{pmatrix}, \qquad \begin{pmatrix} x_{SB} \\ k_{SB} \\ \tau_{SB} \\ SW_{SB} \end{pmatrix} = \begin{pmatrix} 0.597 \\ 0.309 \\ 0.158 \\ 0.397 \end{pmatrix}.$$

Here, since $K = 1$, k is the proportion of the initial investment in the total investment.

4. Analysis

In this section, we analyze the second-best solution of problem (1). In the following subsections, we analyze the second-best solution with respect to cost coefficient c, risk factor σ, liquidation value θ, and productivity α. Whenever possible, in the figures, we use a red curve to represent the first-best solution and a blue curve to represent the second-best solution.

4.1. Agency Cost

We first consider the effect of cost on the second-best solution. Here, the cost parameter c is treated as a measure of agency costs.

First, Figure 5 indicates that when the incentive problem is negligible (when c is very small), the VC chooses upfront financing with $k = 1$. As shown in Figure 5, upfront financing occurs roughly before $c = 0.3$. As c increases, the incentive problem becomes severe and hence the VC chooses staged financing in order to put pressure on the EN. It indicates that the initial investment is indeed used to control agency costs. At the same time, with a higher cost, the project is less profitable and it is more risky for the VC to invest early. This negative relationship is also found by Gompers' (1995) empirical study. Specifically, Gompers finds that a lower agency cost leads to a higher duration of each funding, a higher amount of capital per round, and a fewer number of capital infusions.

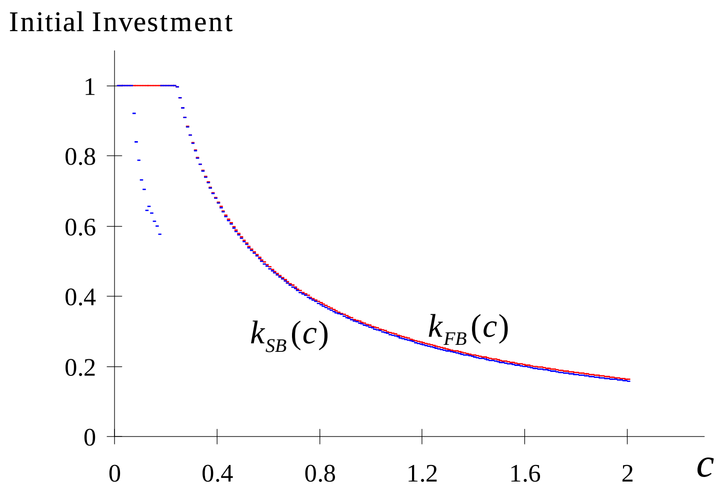

Figure 5. The Initial Investment and Cost[9]

Second, Figure 6 indicates that, when cost goes up, the EN's effort is reduced. Intuition suggests that, with a higher cost, the project is less profitable, implying less incentive for the EN to work. However, this reduction becomes smaller when the VC uses staged financing to control incentives, which is shown by the convexity of the curves in Figure 6.

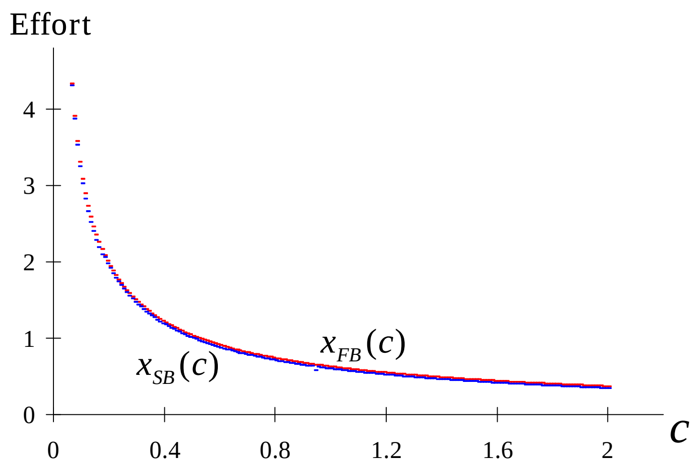

Figure 6. The EN's Effort and Cost

Third, Figure 7 shows the relationship between cost and the milestone of default. The project will be terminated at time $t = 1$ if and only if output is less than the milestone of default, $y < y_1$. As shown in Figure 5, when cost c is sufficiently small, the VC chooses upfront financing, which reduces the likelihood of default. As cost increases, the milestone of default increases and hence the likelihood of default increases, which is due to the EN's reduction in effort and the VC's reduction in the initial investment (as shown in Figures 5 and 6).

[9] There are some isolated points in the figure, which are computing errors by the computer program. Such errors also appear in other figures.

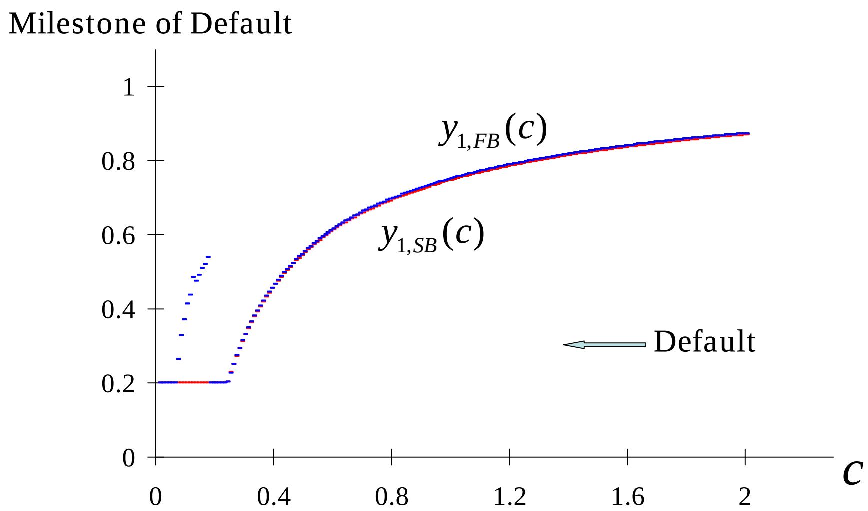

Figure 7. Cost and the Milestone of Default

Fourth, existing theories (Aghion–Bolton 1992) and empirical findings (Kaplan–Strömberg 2003, p.22) show that VCs should/will have more control rights/voting power if a firm has more severe agency problems. Indeed, our Figure 8 indicates that a higher agency cost is associated with a higher controlling share of VCs. This indicates that the conversion ratio can be used to control agency costs. The intuition is that, as cost increases, the EN will invest less and hence the VC demands a higher conversion ratio as compensation.

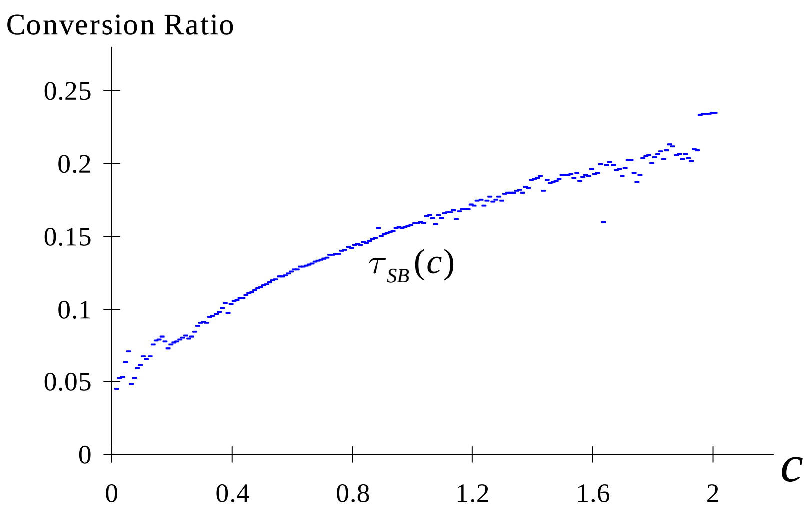

Figure 8. Cost and the Conversion Ratio

Finally, output levels y_1, y_2 and y_3 serve as milestones for specific actions. Figure 9 lists three curves for the three milestones, which divide the whole area into four regions: the region in which the VC will convert to equity, the region in which the VC will keep debt, the region in which the firm goes bankrupt at $t=2$, and the region in which the firm defaults at $t=1$. In particular, Figure 9 indicates that the milestone of conversion (the blue curve) decreases with cost. The intuition is that, when cost increases, since the conversion ratio increases (Figure 8), the VC tends to prefer equity to debt.

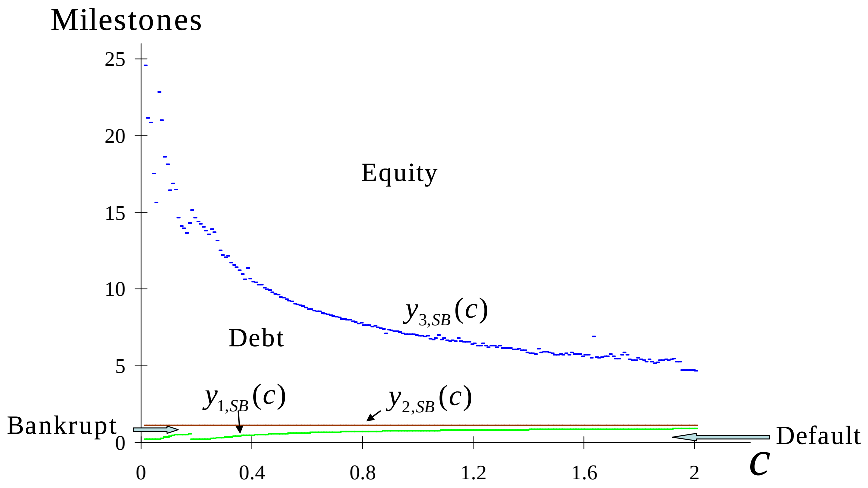

Figure 9. Cost and the Milestones

Proposition 2. As cost increases, social welfare, the initial investment, the EN's effort and the milestone of conversion decrease, while the conversion ratio and the milestone of default increase.

4.2. Risk

We now analyze the role of risk. First, as shown in Figure 10, social welfare increases with risk. The intuition is clear. Since both the EN and VC are risk neutral in income, risk has no welfare cost. However, risk may have a positive effect on incentives (shown in Figure 12). Due to risk and staged financing, to avoid default, the EN may work hard. That is, risk may induce the EN's incentive to work and hence reduce agency costs.

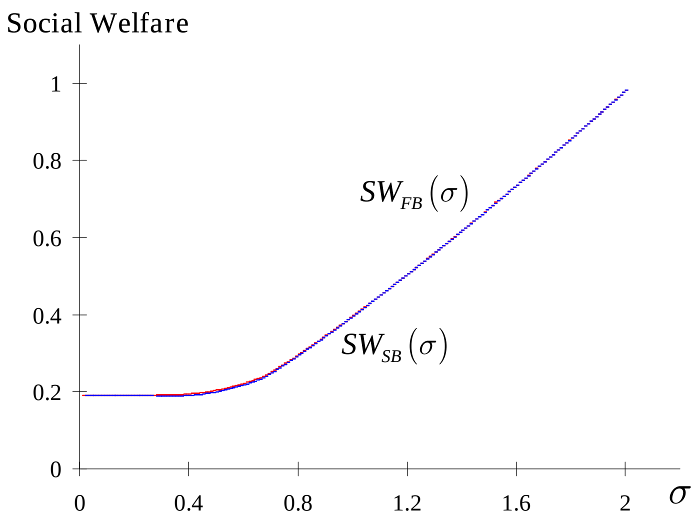

Figure 10. Risk and Social Welfare

Second, Figure 11 indicates that, when risk is low, the VC chooses upfront financing. When risk is high enough, the VC switches to staged financing. As the risk increases further, the initial investment initially decreases; after the risk becomes large enough, due to its positive effect on incentives (Figure 12), the initial investment increases. This clearly indicates that staged financing plays two roles: it is used to control both incentives (Figure 5) and risks (Figure 11). This is consistent with the exiting literature. See, for example, Sahlman (1990), Gompers (1995), Kockesen–Ozerturk (2002), Schmidt (2003) and Wang–Zhou (2004). Interestingly, when the VC switches from upfront financing to staged financing, there is a dramatic effect on the initial investment, which causes a large jump downward. This jump is a reflection of the importance of staged financing on investment behaviors.

Kaplan–Strömberg (2003, p.22) find that, as uncertainty decreases over time, VCs invest more. This empirical evidence may be consistent with our Figure 11. First, since upfront financing is rare in reality, the part of the curve for $\sigma < 0.7$ is generally not observed in reality. Also, the *linear trend* of the curve in the interval of $\sigma > 0.7$ is actually downward. Hence, data may very well show a negative relationship between initial investment and risk.

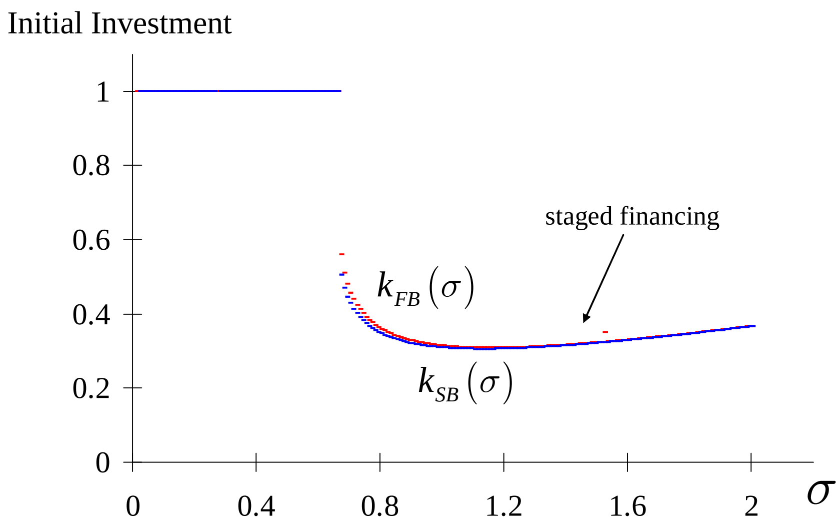

Figure 11. Risk and the Initial Investment

Third, intuitively, staged financing can have both positive and negative effects on the EN's incentives. On the one hand, staged financing discourages the EN due to the risk of the VC's option to quit in the middle of the project. On the other hand, staged financing imposes pressure on the EN, which induces the EN to work hard in order to attract further investments from the VC. These effects seem to be shown in Figure 12. In the case of upfront financing when $\sigma < 0.7$, for the curve representing the EN's effort $x_{SB}(\sigma)$ in Figure 12, $x_{SB}(\sigma)$ initially goes down and later comes up. This indicates that, as the risk increases, the EN invests less due to risk aversion; but when the risk is a large enough, even with upfront financing, the EN begins to worry about the possibility of default, which induces him to increase his effort. In the case of staged financing when $\sigma > 0.7$, as the VC switches from upfront financing to staged financing at around $\sigma = 0.7$, the EN's effort drops substantially. This is the negative effect of staged financing on incentives. As the risk increases further, staged financing begins to have a positive effect on the incentives. When the risk is large enough, the EN's effort can even surpass the level under upfront financing.

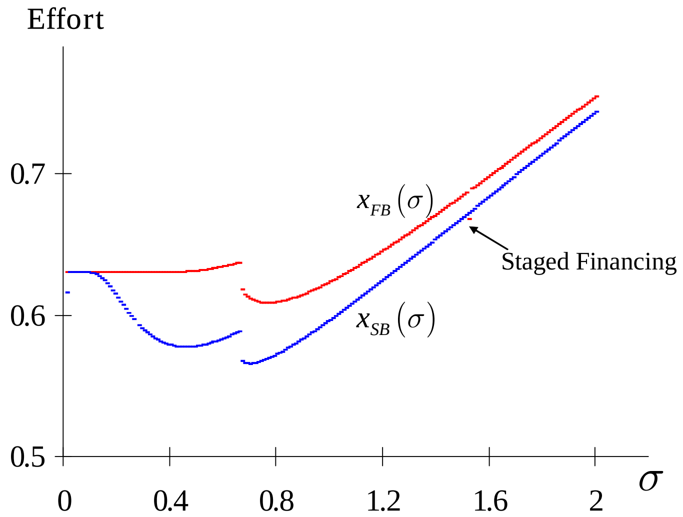

Figure 12. Risk and the EN's Effort

Fourth, Figure 13 is very much the opposite of Figure 11. It indicates that, when the risk is small enough, since the VC chooses upfront financing (Figure 11), the milestone of default is small (less chance for default). As the risk increases further, the VC begins to choose staged financing (Figure 11) and the milestone of default increases quickly, indicating the adverse effect of staged financing on default. After the risk becomes sufficiently large, due to the positive effect of risk on incentives (Figure 12), the milestone of default begins to decrease. Therefore, staged financing generally increases the chance of default; but, in a very risky environment, staged financing can help reduce the chance of default.

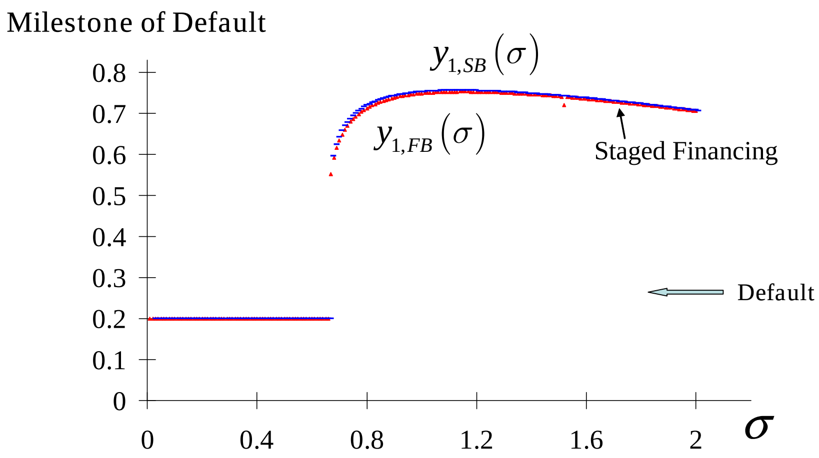

Figure 13. Risk and the Milestone of Default

Fifth, Figure 14 indicates that, as risk increases, the conversion ratio decreases. This is consistent with Kaplan–Strömberg's (2003, p.22) empirical finding that, as uncertainty decreases over time, the VC invests more and the VC's equity share increases. The intuition is as follows. When the risk increases, to avoid default and to attract further investments, the EN is forced to apply more effort. More effort means higher output, by which the VC is willing to accept a lower conversion ratio.

There is an interesting observation here. Cornelli–Yosha (2003) show that, to deal with the EN's window dressing behavior, the VC uses a relatively high conversion ratio in staged financing as compared with upfront financing. This effect is shown in Figure 14 at the jump point around $\sigma = 0.7$ when the VC switches from upfront financing to staged financing. Our model includes Cornelli–Yosha's window dressing effect as a special case.

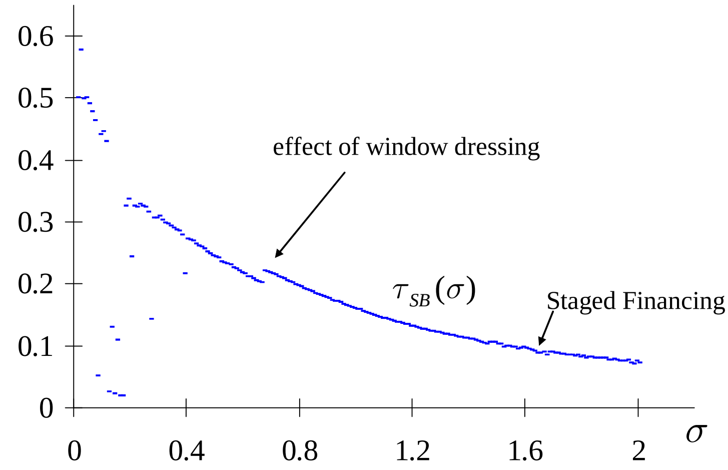

Figure 14. Risk and the Conversion Ratio

Finally, similar to Figure 9, the three curves in Figure 15 divide the whole area into four regions: the region in which the VC converts to equity, the region in which the VC holds debt to the end, the region in which the firm goes bankrupt at $t = 2$, and the region in which the firm defaults at $t = 1$. We find that the milestone of conversion (the blue curve) increases with risk. That is, as the conversion ratio decreases with risk (Figure 14), the VC is less likely to convert her investment into equity.

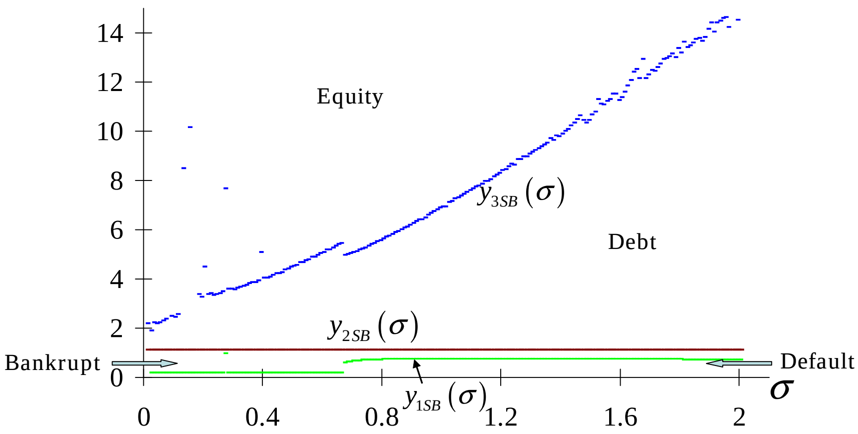

Figure 15. Risk and the Milestone of Conversion

Proposition 3. As risk increases, social welfare and the milestone of conversion increase, the initial investment decreases initially and later increases, the milestone of default increases initially and later decreases, and the conversion ratio decreases.

4.3. Liquidation Value

The literature has paid great attention to liquidation value. The focus has been on its relationship with capital structure. Williamson (1988) argues that leverage should be positively related to the liquidation value of the firm. In empirical studies on capital structure, Titman–Wessels (1988), Friend–Lang (1988) and Rajan–Zingales (1995) all find that the use of debt increases with asset tangibility, where asset tangibility is expected to be positively related to the liquidation value. Gompers (1995), on the other hand, emphasizes the effect of the liquidation value on risks and incentives.

From our model, we first find that, by Figure 16, the initial investment increases with the liquidation value and, when the liquidation value is large enough, the VC switches to upfront financing. This result is easy to understand. If a large part of the initial investment can be recovered when the project turns sour, the VC is naturally willing to invest more at the beginning.

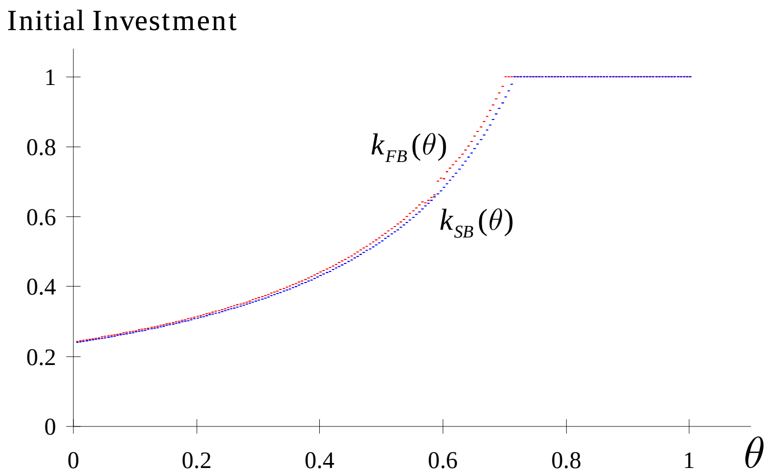

Figure 16. The Initial Investment and the Liquidation Value

Second, Figure 17 indicates that, when the liquidation value is not very large, the EN's effort increases with the liquidation value; however, when the liquidation value is large enough, the EN's effort decreases with the liquidation value. The intuition is clear. When the liquidation value is not large, the VC invests more when the liquidation value is larger (less risky), which encourages the EN to work hard. But, when the liquidation value is large enough, the VC switches to upfront financing, by which the pressure on the EN is off. In this case, since the EN and VC can get a substantial payment from the recovery when the project fails, the EN's effort decreases (Figure 17) and the VC imposes less pressure on the EN. This is consistent with Gompers' (1995) empirical finding that an increase in asset tangibility (hence the liquidation value) reduces the VC's monitoring intensity.

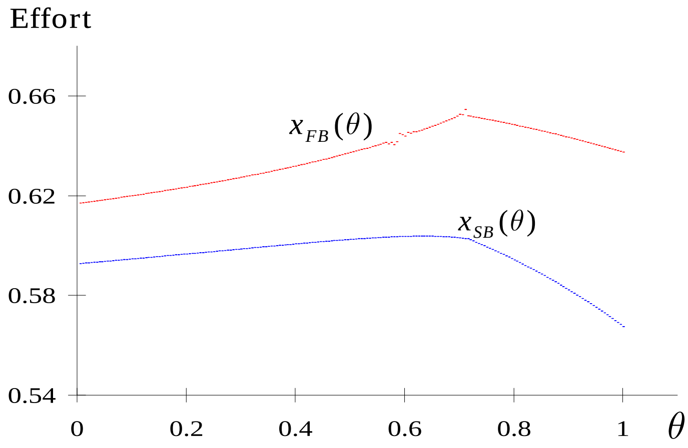

Figure 17. The EN's Effort and the Liquidation Value

Third, Figure 18 indicates that, when the liquidation value is not very large, the milestone of default decreases with the liquidation value; but when the liquidation value is large enough, the milestone of default increases with the liquidation value. The intuition is as follows. When the liquidation value is large enough, the two parties can get substantial payments from the recovery if the project fails. Hence, the incentive for the EN to work and the incentive for the VC to invest further are weak, implying that the two sides are more likely to quit. Only when the liquidation value is relatively small, the two parties have strong incentives to let the project continue. Notice also that the milestones under the first and second best are almost the same.

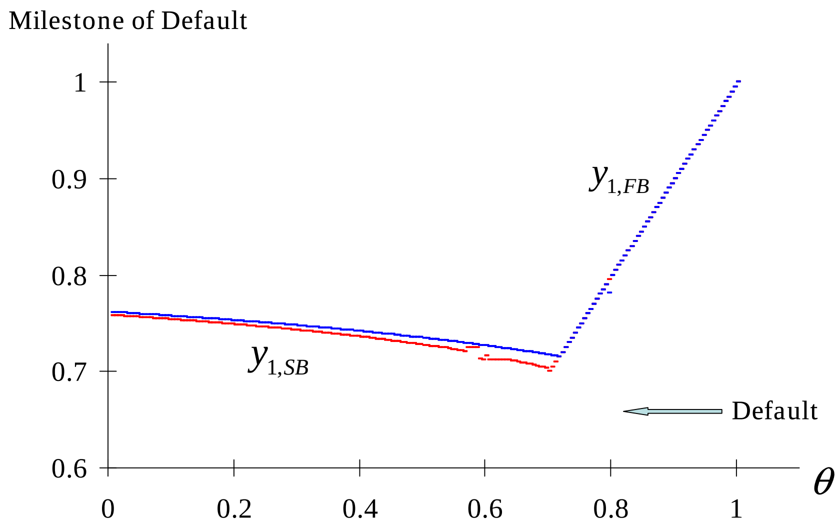

Figure 18. The Milestone of Default and the Liquidation Value

Fourth, Figure 19 indicates that the conversion ratio increases with the liquidation value. When the liquidation value is not very large, the VC needs a large conversion ratio to induce her to invest. When the liquidation value is large enough, the VC switches to upfront financing and the EN's incentive is negatively affected by upfront financing, in which case the VC needs a higher conversion ratio to compensate for the EN's smaller effort.

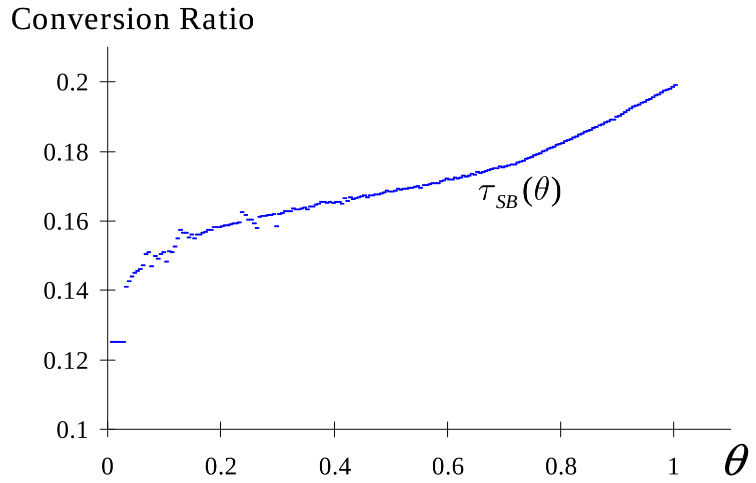

Figure 19. The Conversion Ratio and the Liquidation Value

Finally, Figure 20 indicates that, when the liquidation value increases, the VC is more likely to convert to equity. With a larger liquidation value, the conversion ratio is larger (Figure 19), which induces the VC to convert.

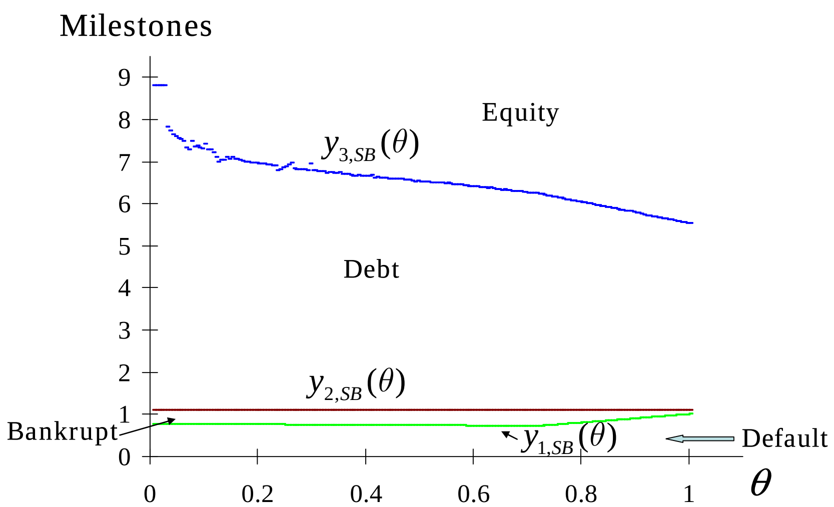

Figure 20. The Milestone of Conversion and the Liquidation Value

Proposition 4. As the liquidation value increases, social welfare, the initial investment and the conversion ratio increase, the milestone of conversion decreases, and the EN's effort increases under staged financing but decreases under upfront financing, while the milestone of default decreases under staged financing but increases under upfront financing.

4.4. Productivity

The role of productivity and R&D in venture capital financing is considered an important issue in the literature (Li–Mahoney 2006 and Dushnitsky–Lenox 2005). Some common questions are: (1) Do venture-backed firms have a preference for R&D, technology and innovation? (2) Will venture capitalists favor R&D intensity? And, (3) is there a preference for VCs to invest in productive firms?

We now analyze the effect of productivity. We use the parameter α to represent productivity and R&D intensity. First, Figure 21 indicates that the initial investment increases with productivity. In particular, the VC chooses staged financing when productivity is not very high. This makes sense since higher productivity means better performance and higher returns, which encourages the VC to invest more initially. This result is consistent with Dushnitsky–Lenox (2005, p.961) and Li–Mahoney (2006, p.29), whose empirical studies find a positive relationship between investment and R&D intensity in venture capital. Here, we assume productivity is perfectly correlated with R&D intensity.

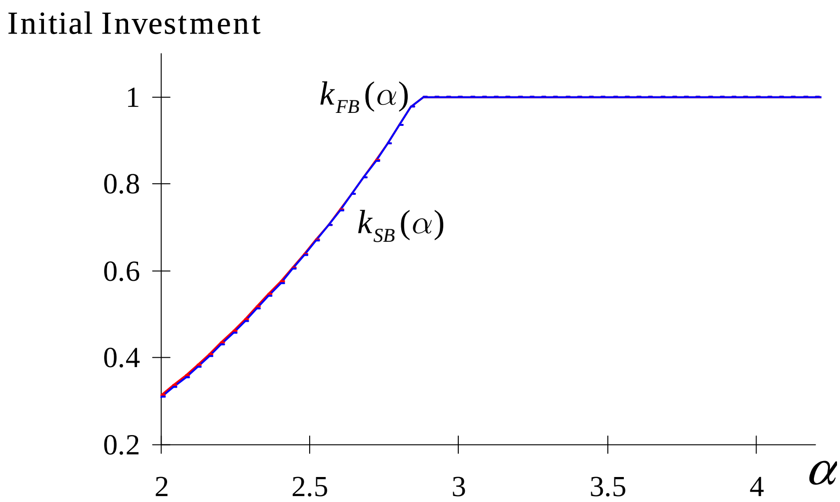

Figure 21. Productivity and the Initial Investment

Second, Figure 22 indicates that, the EN's effort increases with productivity. As in Figure 21, higher productivity means better performance and higher returns, which encourage the EN to work hard.

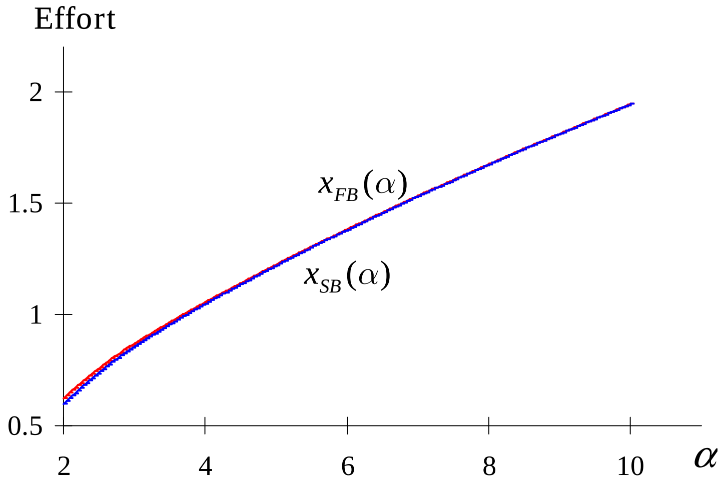

Figure 22. Productivity and the EN's Effort[10]

Third, Figure 23 indicates that the milestone of default decreases with productivity. This is fully expected since higher productivity means a less chance of default. We notice that this milestone is greatly affected by the VC's financing strategy. When the VC uses staged financing if α is not very large, as α increases, the VC invests more initially (Figure 21), which results in a decreasing milestone of default (Figure 23); when the VC uses upfront financing if α is large enough, as α increases, the VC maintains initial investment (Figure 21), which results in a constant milestone of default (Figure 23).

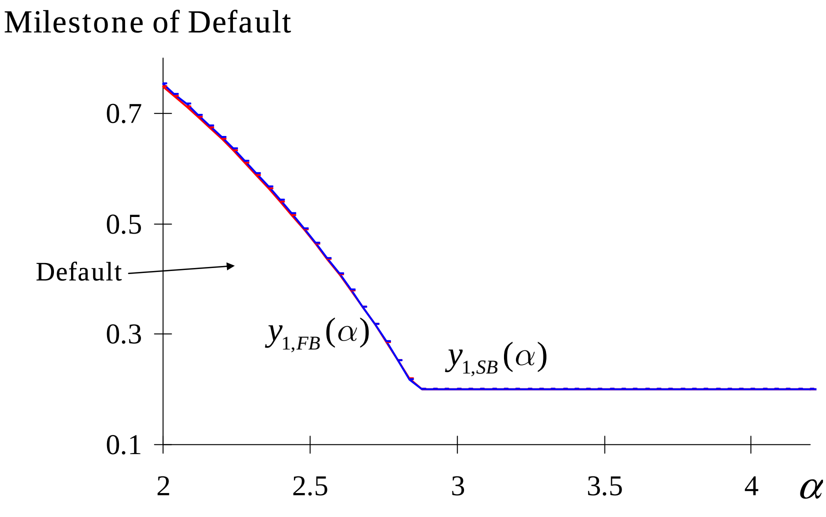

Figure 23. Productivity and the Milestone of Default

Fourth, Figure 24 indicates that the conversion ratio decreases with productivity. With larger profits under higher productivity, the VC is willing to accept a lower conversion ratio. This is consistent with the well-known stylized fact (as mentioned in Kaplan–Strömberg 2003)

[10] Here, α starts from 2 since, when α is less than 2, social welfare may be negative and optimal solutions may not exist.

that, if a firm performs well, investors tend to relinquish income and control rights from the firm.

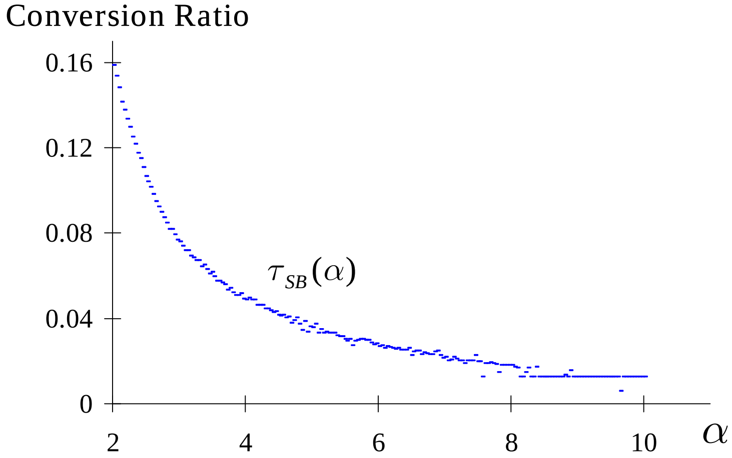

Figure 24. Productivity and the Conversion Ratio

Finally, Figure 25 indicates that the milestone of conversion increases with productivity. This means that the VC is less likely to convert her investment to equity when productivity is high. This can be explained by the fact that the conversion ratio is low when productivity is high (Figure 24). This also implies that the debt interval is widened in Figure 25 when productivity increases, which is consistent with the empirical evidence (e.g., Bagella–Becchetti 1998, Aghion *et al* 2003, and Stern–Chew 2003) and the theoretical conclusion (e.g., Stein 1992 and Bagella–Becchetti 1998) that good firms issue debt more often than bad firms.

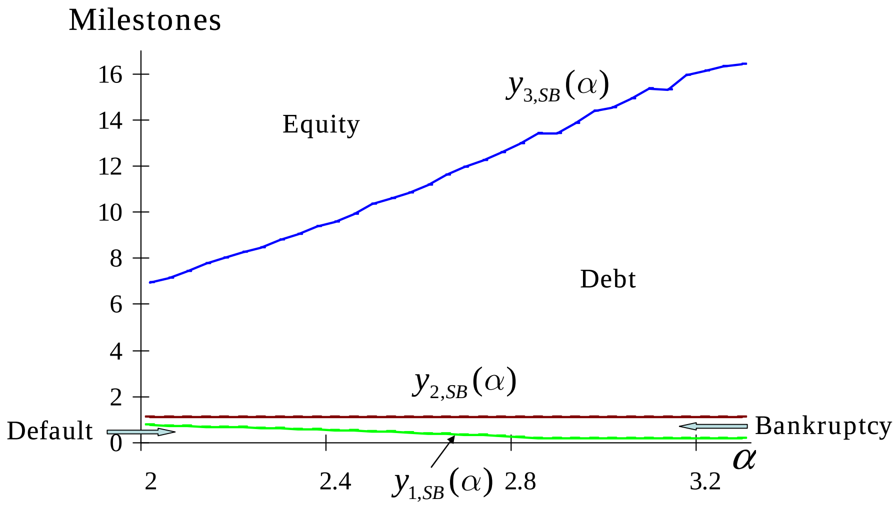

Figure 25. Productivity and the Milestone of Conversion

<u>**Proposition 5.**</u> As productivity increases, social welfare, the initial investment, the EN's effort and the milestone of conversion increase, while the milestone of default and the conversion ratio decrease.

4.5. Efficiency

Staged financing and convertibles are two widely used mechanisms in venture capital financing. Interestingly, Figure 10 shows that the second-best solution (the blue curve) is very close to the first-best solution (the red curve) in terms of social welfare. That is, staged financing using convertibles can almost achieve the first best. This may explain why convertibles and staged financing are used in over 90% of venture capital financing in reality. Furthermore, our figures 5–25 also show many similar characteristics between the first- and second-best solutions (except the effort variables). We hence have the following conclusion.

Proposition 6. Using convertibles, staged financing can almost achieve the first best.

4.6. Empirical Evidence

The above analysis shows some interesting relationships among the key variables in our model. Besides the cited empirical evidence in the above analysis, we now investigate a database of venture capital investments for further evidence.

We use the VentureXpert database, which covers more than 90% of all venture investments around the world. We focus on VC-backed companies that went IPO between 1997 and 2006. We exclude investments by angels and buyout funds. We also exclude data in 1999 and 2000 due to the high-tech bubble. Our data set contains 975 VC-backed companies, to which 2532 VC funds made 3645 investment rounds before IPO. All our regression models are estimated using ordinary least squares. We use *** and ** in the table to denote significance levels of 1% and 5% (two-sided), respectively.

We are interested in five variables: the initial investment k, the EN's effort x, the cost coefficient c, the risk factor σ, and the liquidation value θ. First, the initial investment is measured by the percentage of the initial investment in the total investment from a VC. If this ratio is less than 1, it means staged financing; if it equals 1, it means upfront financing. Second, the EN's effort is measured by the percentage of the EN's equity ownership just before IPO. Here, we implicitly assume that the EN's effort is perfectly correlated with equity ownership. This hypothesis is also taken by Gampers–Lerner (1998, p.2170). Third, the cost coefficient is measured by technology type, taking one for high-tech and zero otherwise. Here, we implicitly assume that a high-tech technology is perfectly correlated with a high cost. Fourth, risk is measured by the reciprocal of the number of VCs participating in the first investment round. When a project is very risky, VCs tend to form a large syndicate with the intention of risk sharing. As a result, the more VCs involved in an investment round, the less risky the company is for each individual VC. This risk-sharing argument is the dominant view in the literature on syndication. See, for example, Lockett–Wright (2001). Finally, the liquidation value is measured by the firm's liquidation value for common stock at the first installment.

Table 1 shows correlations among the five variables, with the following observations:

1. Consistent with Figure 5, we find a negative correlation between cost and initial investment.
2. Consistent with Figure 6, we find a negative correlation between cost and effort.
3. Largely consistent with Figure 11, we find a negative correlation between risk and initial investment. As explained in the paragraph above Figure 11, Kaplan–Strömberg (2003, p.22) has the same empirical finding.
4. Consistent with Figure 12, we find a positive correlation between risk and effort. Here, we consider only the risk interval $\sigma \geq 0.7$ in which staged financing occurs, since upfront financing is rare in reality.
5. Consistent with Figure 16, we find a positive correlation between liquidation value and initial investment.
6. Finally, consistent with Figure 17, we find a positive correlation between liquidation value and effort. Again, we restrict to the interval of θ in which staged financing occurs. When θ is large enough, the VC chooses upfront financing (Figure 16). In reality, upfront financing is rare. In fact, Gampers (1995, p.1464) finds that the average value of θ is about 0.2.

Table 1. Correlations

Correlation	Initial Investment	EN's Effort	Cost	Risk
Initial Investment	1			
EN's Effort	0.2733***	1		
Cost	-0.2473***	-0.1048**	1	
Risk	-0.2220***	0.1106**	0.0302	1
Liquidation Value	0.2030***	0.1703***	-0.2012***	0.0476

Table 1 also shows a positive correlation between the two endogenous variables: effort and initial investment. This is understandable, if the relationship were negative, the VC would have invested less initially to reduce her risk exposure and also enhance the EN's incentive. This positive correlation is also consistent with our analysis. By comparing Figure 5 with Figure 6, Figure 11 with Figure 12, Figure 16 with Figure 17 (under staged financing), and Figure 21 with Figure 22, we expect the two variables to be positively correlated. Finally, the rest three correlations are between two parameters; they are not directly related in our model and we do not expect them to be closely related in reality.

In summary, we indeed find strongly evidence supporting much of our theoretical predictions.

5. Concluding Remarks

Staged financing is a widely used strategy of investment in corporate finance. To carry out this financing strategy, many financial instruments are feasible. It turns out that convertibles are particularly popular in reality, especially in early stages of a firm's development and in firms with ample potential and risk. We build a model that contains a few basic features of staged financing using convertibles. In particular, we take into account double moral hazard, information revelation, and various possible ex-post decision events. Being consistent with reality, conversion is not guaranteed to happen in equilibrium in our model; instead, it depends on a realization of uncertainty and the firm's performance. Also consistent with reality, we find that the firm's equilibrium strategy can be defined by a few preset milestones. We find that staged financing using convertibles can almost completely resolve all the potential problems in venture capital financing. We also find that risks can reduce agency costs by putting pressure on the parties to invest and to perform. In fact, staged financing is a way to create such uncertainty.

There are many studies on staged financing and there are some studies on convertibles using the incomplete-contract approach. However, there are few studies that justify the needs for carrying out staged financing by convertibles or show an efficient use of convertibles in staged financing.

The main limitation of our analysis is that it is a parametric analysis, which limits the generality of our conclusions. However, a parametric analysis frees us from many technical difficulties. This allows us to analyze the key characteristics of various variables graphically. With the help of intuition, we expect these characteristics to hold generally.

Finally, we do not consider an approximation result to be a weakness in our theory. In the real world, there are transaction costs. For example, when a firm raises funds, it incurs issue costs. According to Smith (1977), for small equity issuers (such as VC-backed companies), the issue cost for raising funds can amount to 15% of funds raised. By taking into account such transaction costs, our solution may well be the first best.

Appendix

We show Proposition 1 in this appendix. We solve the problem backwards.

First, at time $t = 2$,

$$\begin{array}{ll} \text{if } (1+r)K < \tau y, & \text{the VC converts;} \\ \text{if } \tau y \leq (1+r)K \leq y, & \text{the VC holds debt;} \\ \text{if } (1+r)K > y, & \text{the VC holds debt and the firm is bankrupt.} \end{array}$$

Hence, at $t = 2$,

$$\begin{array}{ll} \text{if } y_3 < y, & \text{the VC converts;} \\ \text{if } y_2 \leq y \leq y_3, & \text{the VC holds debt;} \\ \text{if } y_2 > y, & \text{the VC holds debt and the firm is bankrupt.} \end{array} \tag{4}$$

Here, if the firm goes bankrupt and if the VC is still holding debt at $t = 2$, the VC is paid y.

At time $t = 1$, uncertainty about output is resolved and inputs (x, k) are known. Before the VC decides to continue her investment, the two parties can renegotiate the existing agreement, which implies ex-post efficiency. If the firm defaults, the total payoff is θk; and if the firm continues, the total payoff is $y - (K - k)$. This means that, at $t = 1$, if and only if

$$y - (K - k) \geq \theta k \qquad \text{or} \qquad y \geq y_1, \tag{5}$$

the project will continue and the VC's second investment will be made.

Combining the decisions at $t = 2$ in (4) with the decisions at $t = 1$ in (5), we then have Proposition 1.

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Notation

Notation	Meaning
x	EN's Effort
y	Output
k	Initial Investment
K	Total Required Investment
μ	Technology shock
y_1	Milestone of Default
y_2	Milestone of Bankruptcy
y_3	Milestone of Conversion
τ	Conversion Ratio
$C(x)=cx^2$	Cost Function
$f(x)=\alpha\sqrt{x}$	Production Function
$g(k)=k^\beta$	Easiness of Liquidity Constraints
$\psi(\mu)=\frac{1}{\sqrt{2\pi}\sigma}e^{-\frac{(\mu-1)^2}{2\sigma^2}}$	Density Function for $\mu\in N(1,\sigma^2)$
Π_{EN}	Profit for the EN
Π_{VC}	Profit for the VC
EN	Entrepreneur
VC	Venture Capitalist
SW	Social Welfare
SB	Second-Best
FB	First-Best
IC	Incentive Compatibility
IR	Individual Rationality