Bank as a Venture Capitalist

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Abstract

Traditional banks finance entrepreneurs through loans. But more ingenious banks explore other forms of financing, such as venture capital (VC), as well. In this paper, I argue that the banks offer VC together with traditional (collateralized) loans in response to the natural constraints of asymmetric information that they face. Innovative entrepreneurs pursue new technology that promises a high return but runs a high risk of failure. The more innovative entrepreneurs also have higher reservation utility. This interaction between type dependent returns and reservation utility creates a situation where collateral alone is not sufficient to screen entrepreneurs and the bank needs an additional screening device. VC fulfils that role. I also introduce a fairly general returns function that can generate various risk–expected returns relations, including a risk–expected returns trade-off.

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1 Introduction

Venture capitalists play an important role in providing entrepreneurial finance. Traditionally, a venture capitalist was thought to be an expert investor financing the high risk–high returns projects, that the bankers shied away from. However, banks have always shown interest in pursuing VC financing alongside their lending business. Although, their VC business has gone through cycles of regulatory tightening and loosening, banks have always found ways to continue VC financing. For instance, in the USA, before the Gramm-Leach-Bliley Act-1999 allowed them to engage in various *private equity* related activities, banks undertook VC financing by setting up Small Business Investment Corporations.[1] Again, after the Volcker rule under the Dodd-Frank law-2010 in the USA, that restricted the banks' participation in private equity, banks have resorted to measures to find ways around these sanctions.[2]

All major banks in the advanced economies have venture capital arms.[3] This trend has picked up recently in emerging economies as well. For instance, in India and Indonesia the large banks have entered into venture capital market with the aim to fund start-ups (Shukla and Vyas, 2016, The Jakarta Post, 2017). In China, the largest banks were allowed by the China Banking Regulatory Commission to enter VC markets on a pilot basis in 2016 (Mak, 2016). However, Chinese banks had been making VC investments through their offshore investment affiliates before that as well (Reuters, 2016).

Since the banks frequently resort to make use of the regulatory loopholes to make indirect VC investments, it becomes very difficult to gauge the precise size of the VC investments that banks have made. Therefore, the best we can do is to look at the officially announced investments made directly by the banks, for example, through their VC arms. Studying this data from the Thomson One database, we observe a large cross-regional variation: With banks' investment accounting around 6% percent of the total VC investments in Western Europe and East Asia and around 2% percent in North America in the period 2013-17 (Figure A.1 in Appendix).[4] Indeed, the recent evidence points that banks have become even more active with their VC investments following the boom in fintech start-ups (Barba and Macheel, 2016, Lorenzetti, 2014).

One explanation that is proposed for the banks' foray into the venture capital market is that it allows them to build relationships with firms that are seen as potential future customers for its banking services (Hellmann et al., 2007). I propose another explanation: in a credit market marred with information asymmetry, banks use venture capital finance along with collateralized credit as tools to screen the entrepreneurs of different risk types. In a classic adverse selection setting of credit market, I show that for the bank, VC emerges endogenously a choice of financing

[1]See the discussion in (Hellmann, Lindsey and Puri, 2007) and Hellmann (1997).

[2]For example, see the news reports by Barba (2016) and Rothacker (2013). Given these experiences, in fact, the Federal Reserve is mulling over revising the part of the Volcker rule governing bank investment in VC (Federal Reserve Board, 2018).

[3]Citibank with its VC arm, Citi Ventures and Mitsubishi UFJ Financial Group with its VC arm Mitsubishi UFJ Capital are some examples.

[4]Other than missing the indirect investments that the banks do in VC due to regulatory reasons, Thomson One also has another shortcoming that its categorization of bank affiliated VC investments is not perfect (Hellmann et al., 2007). An alternative source, for the European countries, is the annual report of *Invest Europe*. They report, of the Euro 7.7 billion raised by the VC funds in 2017, banks contributed around 6% percent in 2017 (Invest Europe, 2018). For the USA, the National Venture Capital Association (NVCA) states that this number was actually 7% in 2011 and in the areas outside of the traditional VC centers, this share is even larger, for example, it might be 13% in the upper Midwest region (NVCA, 2017).

the more innovative type entrepreneurs[5] with high risk–high return projects. A VC contract consists of an equity position for the bank and a suite of value-adding services and compensation offered by the bank to the entrepreneur.[6] The low risk entrepreneurs get financed through a standard collateralized credit.

In the model, the more innovative entrepreneurs own projects that have potential to generate high returns. But these projects involve an application of untested innovative technology and therefore they run a higher risk of failure. More innovative entrepreneurs also have a higher reservation utility. There is only one dimension of heterogeneity between entrepreneurs as project returns and reservation utility are perfectly correlated. I express this heterogeneity in terms of the risk of failure of the project run by the entrepreneur.[7] An individual entrepreneur's risk of failure is private information. Entrepreneurs (or equivalently their projects) come in three different risk types but appear the same to the bank. I show when the reservation utility is sufficiently sensitive to the risk type, it creates an incentive for the medium risk entrepreneurs to mimic both low and the high risk types. Using only collateralized credit in this scenario does not help the bank in fully discriminating between the types. Therefore, the bank has to use both VC and collateral as screening devices to separate the entrepreneurs.

The literature on bank's foray into VC market is quite recent and developing. The early literature on VC rather focused on how entrepreneurs choose *between* a bank and individual venture capitalist. This literature therefore, highlighted the comparative advantages of the two kind of financial institutions. Ueda (2004), for instance, assumes that venture capitalist and bank differ in their abilities to screen the entrepreneurs: a VC can perfectly observe the borrower type while a bank can do so only imperfectly. However, a venture capitalist poses a threat that it can expropriate the project from the entrepreneur. In Winton and Yerramilli (2008) venture capitalists are assumed to have better monitoring capabilities but a higher cost of capital as compared to the banks. In De Bettignies and Brander (2007), bank and VC differ in the extra-financial support they provide: venture capitalist takes active participation in the entrepreneur's business by providing value-adding services such as managerial inputs while the bank is only a passive investor. Venture capitalist's input directly affects the output of the firm it invests in. The paper derives conditions such that in the presence of moral hazard on the part of both the entrepreneur and venture capitalist, which kind of financing is chosen over the other.[8] In contrast to this literature, in this paper paper I explain why do we observe one single institution (the bank) offering financing choices, some of which resemble passive collateralized debt while other resemble active VC with support services.

Another VC literature where banks feature, albeit indirectly, studies the differences between an independent VC and a corporate owned or a captive VC. A bank affiliated VC falls into the latter category. Bottazzi, Da Rin and Hellmann (2008) study the differences in the level of activism of two types of VCs in terms of their involvement in monitoring and support of the portfolio companies. They concluded that captive VCs – including the bank affiliated VCs – showed less activism in

[5]The terms 'entrepreneurs' and 'firms' are used interchangeably in the paper.

[6]According to Kaplan, Martel and Strömberg (2007) and Cumming (2005b) although majority of VC contracts take the form of equity there can sometimes be debt or mixed contracts as well. There are large inter-country heterogeneity in the form of VC contracts. For a more detailed discussion see Section 2.4.

[7]The heterogeneity can also be expressed equivalently in terms the reservation utility. This interpretation of the model is described in more detail in Section 2.

[8]Da Rin, Hellmann and Puri (2013) provide an excellent survey of this literature.

their portfolio companies than the privately held independent VCs. However, the objective of this study was not to explain why banks may choose to own a VC arm at first place.

Much in line with the earlier literature on bank *versus* individual VC financing, Andrieu and Groh (2012) formulate a model comparing bank affiliated VC and independent VC. They highlight the trade-off that these two funding channels offer in a set-up where funding is required over different periods. An independent venture capital firm provide better support quality but has limited resources that future support for the start-up is not guaranteed. Bank-affiliated VC has deep pockets but has less expertise in providing any other support. The model predicts, among other things, that firms with less sophisticated ventures would choose bank-affiliated VC.

In contrast to the two papers discussed above in this paper, I ask a more fundamental question why banks might choose to offer a venture capital financing to entrepreneurs when they also have the option of financing them with debt contracts? A crucial feature of a *banking corporate* is that it has traditionally specialized in granting loans. These models do not allow a bank to offer this choice to the entrepreneur. My model addresses this by endogenizing the funding choice that the bank can use. In other words we can see VC as an alternative form of finance to credit, and banks — given the informational constraints they face — would like to use that as part of the financing menus they can offer, in an attempt to separate types.

Emphasising on the strategic motives, Hellmann et al. (2007) provides an explanation of banks' move into VC market. They point to the cross-selling benefits accruing to the bank, of building relationships with companies, by funding them initially with VC. Using the data on venture deals for the the period 1980–2000 the authors find the evidence that companies that were funded by a bank affiliated VC were more likely to be granted loan by the same bank than the companies that were not funded by the bank. My explanation for emergence of VC financing by banks, on the other hand, points to the constraints of informational asymmetry that the banks face when screening the entrepreneurs. Of course both the explanations are consistent with each other and perhaps a combination of both the motives might be behind banks' VC investments.

Another contribution of my paper is in terms of modelling risk-returns relationship. In a classical set up with one dimensional heterogeneity, following Stiglitz and Weiss (1981) (henceforth SW), entrepreneurs are assumed to differ only in risk (of project failure), producing a homogeneous expected returns. While, models that allow entreprenuers to differ in the expected returns of the project as well as in risk, keep the problem simple by assuming these two parameters to be perfectly correlated (in contrast note in SW this correlation is zero, by design). Further, this kind of models usually assume a homogeneous returns conditional on success. The most prominent paper employing the latter are Besanko and Thakor (1987) (henceforth BT) and De Meza and Webb (1987) (henceforth DW). In Hellmann and Stiglitz (2000) entrepreneurs differ on two privately observed dimensions – both in risk and in expected returns with no perfect correlation in the two dimensions. In this paper I continue with two dimensions of heterogeneity (risk and expected returns) with perfect correlation, however, I do not restrict entrepreneurs to produce same conditional returns. Furthermore, I also allow for negative (and perfect) correlation between risk and expected returns i.e. the case of risk-expected returns trade-off.

This paper is organized as follows: in Section 2, I describe the basic elements of the model. In Section 3, I analyse the full information benchmark with which all other results will be compared. In Section 4, I discuss the interaction of the uninformed bank with heterogeneous entrepreneurs. This section contains the main results of the paper along with some numerical examples. In

Section 5, I discuss the alternative assumptions to those that I make in earlier sections. I conclude the discussion in Section 6.

2 The Model

The economy consists of risk neutral entrepreneurs and a risk neutral bank. Each entrepreneur has a project that requires one unit of capital. However, the firms do not own any capital and, therefore, need to borrow one unit from the bank if they decide to run the project. For the bank, the gross financing cost of capital (can be thought of as the cost of deposits) is the risk free rate that I normalize to be equal to one. The economic activities are organized over two periods. In the first period projects are financed and in the second period, project outcomes are materialized.

2.1 Entrepreneurial heterogeneity

Entrepreneurs differ in how innovative their project is. In a binomial outcome scenario that we assume, more innovative entrepreneurs run project that promise high returns conditional on being successful, but face a higher risk of failure. In case of failure, a project gives zero returns. This situation can arise, for example, when the more innovative projects involve an application of an untested technology. Returns function with this property are quite common in the banking literature. For instance, the binomial outcome version of the returns function in Stiglitz and Weiss (1981) would have the same property (other examples include Karlan and Zinman (2009), Minelli and Modica (2009), De Aghion and Gollier (2000), Ghatak (2000, 1999), House (2006)). More innovative entrepreneurs also find better opportunities for themselves if they do not run the project. This translates into a higher reservation utility for the more innovative entrepreneurs. Given the three parameters – success state returns (Y), probability of failure (θ) and reservation utility (V) – are perfectly correlated we can choose to index heterogeneous entrepreneurs in any of the three parameters. In line with the convention in the literature, I will index the firms with the probability of failure, θ. The next sections discuss the functions, $Y(\theta)$ and $V(\theta)$. We will assume the individual θs, that captures all the economically relevant characteristics of an entrepreneur are private information.

It is also interesting to think about the interpretation of model if, instead of θ, we had expressed the entrepreneurial heterogeneity in terms of the reservation utility, V. In this case our starting point would be entrepreneurs differing in terms of the outside opportunities. For example, entrepreneurs differ in their ability in the paid employment in the outside economy (Parker, 2003, Scheuer, 2013). Heterogeneous reservation utility could also arise because entrepreneurs belong in different job networks (such as university alumni networks) with differing level of support from their networks such that even for the same level of ability, people from more connected and supportive job networks get higher paid jobs. In any case better paid employment opportunities increases reservation utility of a prospective entrepreneur and impacts the risk and target return the entrepreneur can choose when running the project. An entrepreneur with high V would target a high return Y offered by more innovative technology even as they come with higher risk of failure θ. This creates the same correlation between θ, Y and V as we described in the earlier case.

In summary, the idea behind our type dependent returns and reservation utility functions is that the most enterprising type entrepreneurs are the ones pursuing innovative, but unestablished technologies. These projects offer high returns if successful, but also have higher probability to fail. This is a characterization of the technology in industries that are hi-tech driven (for example, information technology, software, biotechnology and now also financial services). The quality of the entrepreneurs that we call 'enterprising' or being 'innovative'could be due to their ability or (for a given ability) just the tendency to undertake more rewarding projects albeit at a higher risk. In other words, more able entrepreneurs target high return that come with risky technologies. Such entrepreneurs also have higher reservation utility. Thus, both the approaches described above are equivalent and produce the same results. Therefore, I continue to index the entrepreneurs with θ.

2.2 Project returns and risk

A project indexed by θ gives zero returns with probability θ and $Y(\theta) > 0$ with probability $(1-\theta)$. An entrepreneur can repay the bank if and only if the project is successful and therefore the failure probability, θ is also the probability of default. The firm's individual default probability is private information but the distribution of θ is a common knowledge.

There are broadly two distinct approaches to specifying the relation between project returns and risk in the banking literature. In the first — the BT/DW approach — returns conditional on success are assumed to be constant across all risk types (failure state returns which is usually assumed to be zero, is by design same across all risks). Therefore, the project returns are ordered in the first order stochastic dominance (FOSD) sense (Besanko and Thakor, 1987, De Meza and Webb, 1987). This specification imply that expected returns are decreasing in risk.

On the other hand in the SW approach, *expected returns* are assumed to be constant across all risk types. All the projects produce the same expected returns but a more risky project's returns are more spread around the mean than the returns of the less risky project. This kind of mean preserving spread implies that the returns are ordered in second order stochastic dominance (SOSD) sense (Stiglitz and Weiss, 1981). Minelli and Modica (2009) (henceforth MM) also allow returns to be ordered in SOSD sense but unlike SW, they do not require all the projects to produce the same expected returns.

It is easily conceivable that other risk-return relations are possible. The most notable of which is the risk-expected returns trade-off. That is projects earning high *expected* returns must be more risky. The project returns function I employ is capable of generating not only risk-expected returns trade-off but also all the risk-returns relations discussed above. In fact, this returns function can generate a whole range of stochastic dominance relations as well as a risk-expected returns trade-off which is associated with no stochastic dominance.

The returns function, conditional on the project being successful, is given by:

$$Y(\theta) = \frac{\kappa - \gamma\theta}{1-\theta}; \quad \kappa \geq 0. \tag{1}$$

This gives rise to different returns functions based on the value of the parameters κ and γ. In this formulation BT/DW, SW and MM type returns functions are special cases of stochastic dominance relations that can be generated by varying our parameters. Figure 1 presents all such stochastic dominance relations that can be generated in the κ–γ plane. The BT/DW type returns functions correspond to $\kappa = \gamma$ in (1) and lie at the boundary of returns functions that can be ordered purely in SOSD and FOSD terms. MM return functions lie in the region marked SOSD that corresponds to the region $\kappa > \gamma > 0$. SW returns functions correspond to $\gamma = 0$ and are special in the sense that they lie at the boundary of returns functions that exhibit SOSD and no stochastic dominance. The risk-returns trade-off discussed above is obtained with $\gamma < 0$.

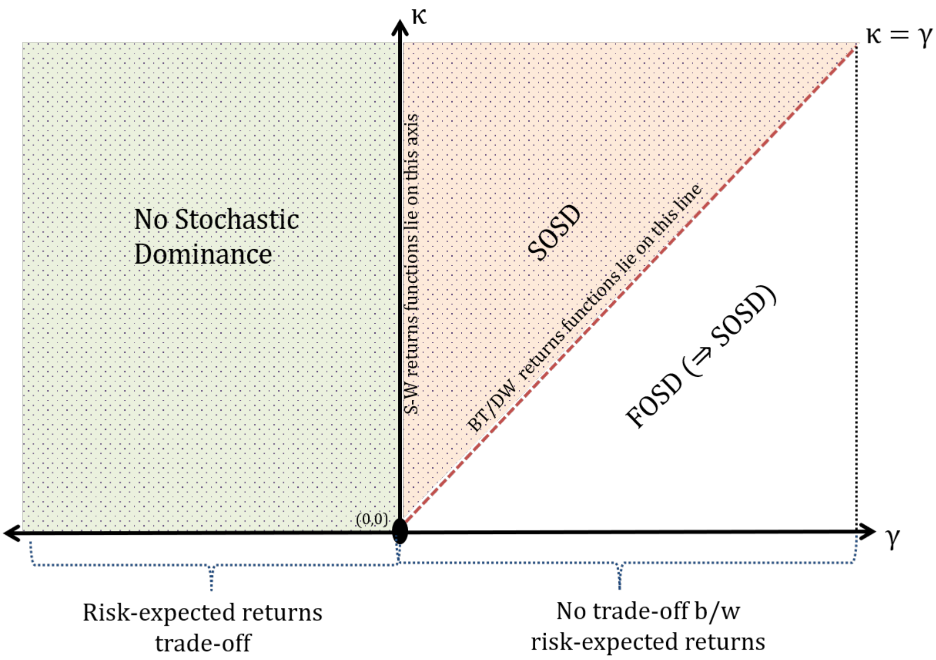

Figure 1: Project returns functions

In line with the discussion above that high return projects come with high risk i.e. $Y(\theta)$ function is increasing, we make the following restriction on γ.

Assumption 1 $\gamma \leq \kappa$

Assumption 1 tells us to consider returns functions in the two colored regions in Figure 1.

2.3 Type dependent reservation utility

If an entrepreneur does not run its risky project, she earns non-stochastic returns $V(\theta)$. We consider a type dependent reservation utility function that is increasing in θ.

Assumption 2 *Reservation utility function is non-decreasing in θ and is quadratic*

$$V(\theta) = v_0 + v_1\theta^2 \qquad where \quad v_0, v_1 \geq 0 \tag{2}$$

In contrast to our assumption, SW, BT and DW assume a homogenous reservation utility ($v_1 = 0$). Type dependent reservation utility function is used by Freixas and Rochet (2008) and Sengupta (2014) in their models of credit market. However, both these papers assume that the reservation utility function is decreasing in θ. The structure of their model is similar to Parker (2003), whose idea is that higher ability of a person shows up as higher wage for the person in a paid employment and as a lower failure probability if the person chooses to be an entrepreneur. This gives a decreasing $V(\theta)$ function. In all these models the return function takes the form of BT/DW returns function where success state returns (Y) is same across all θ.

An increasing $V(\theta)$ function appears to be a more natural assumption with the increasing $Y(\theta)$ function as we discussed in Section 2.1. Type dependent utility functions are common in models that study occupational choice and taxation in the presence of credit market imperfections. For instance, Ghatak, Morelli and Sjöström (2007) has a setting with one dimensional hetereogeniety where high risk types have lower outside opportunity. However, consistent with our explanation above, the success output is either constant or decreasing (in different cases) in risk in this model as well. Scheuer (2013) also allows type dependent reservation utility in an occupational choice model with two dimensional heterogeneity. In his model entrepreneurs differ in both risk and reservation utility as well but unlike our model in his model these two heterogeneities are not necessarily perfectly correlated. However, in Scheuer (2013) returns are ordered in FOSD sense, similar to BT/DW.

Our quadratic specification of $V(\cdot)$ function is a simplification. All the main results in the paper will hold with many other specifications. We will discuss this in detail in section 5.

2.4 Collateralized credit and venture capital finance

2.4.1 Collateralized credit

A typical bank credit relation involves a loan of capital by the bank to the entrepreneur against a contract outlining an interest repayment (R) in the success state and the amount of collateral (C) that the bank gets in case the borrower defaults. There is a dichotomy in collateral valuation. Bank valuation of the pledged collateral C is always βC, with $\beta < 1$ to account for the liquidation costs of collateral that the bank incurs when there is a default (Besanko and Thakor, 1987, Sengupta, 2014, Barro, 1976).

2.4.2 Venture capital finance

An investor-entrepreneur relationship under a VC contract is more dynamic compared to the relationship through a credit contract. First, under a VC contract, on top of providing the capital, the investor (bank) invests in several other value adding services to provide to the venture. Some of these additional investments result in private benefits for the entrepreneur, sometimes also as an outright cash compensation. Second, although securities governing venture capitalist's cash flow and control rights may take varied forms in different jurisdictions, in general under VC investments, the investor takes an active participation in the venture taking board seats for example. We discuss each of these in detail below.

A crucial feature of venture capitalist-entrepreneur relationship is the value-adding services that that venture capitalist provides to the venture – the benefits of which are likely to accrue to the entrepreneur as well (Da Rin et al., 2013). These value-adding services may take several forms: professionalization of the company (Hellmann and Puri, 2002), mentoring of entrepreneur and taking board seats and performing monitoring (Gorman and Sahlman, 1989, Sahlman, 1990). The entrepreneur and their project may also benefit from the reputation of the investing venture capitalist through a certification effect and from the existing professional network of the venture capitalist (Hsu, 2004). While some of these benefits cannot be enforced and therefore contracted upon, they still play an important role in the contractual relationship between the two parties. Hsu (2004) finds that the venture capitalists of repute acquire start-up equity at a 10-14% discount. Another form of private benefit accruing to the entrepreneur from a VC investment is derived from the cash compensation paid by the venture capitalist (Bengtsson and Hand, 2011, Wasserman, 2006). According to a study by Bengtsson and Hand (2011) of 755 venture backed firms in the U.S. in the period 2002-06, cash compensation is rather small compared to the implied value of the equity that the entrepreneur holds in the venture, yet the venture capitalist provides it because equity is a noisy and risky kind of compensation.

In what follows we will denote by B, the additional VC investment. Here the term investment is referred to in a broad sense. More precisely, it refers to that part of provisions additional to the capital, that can be contracted upon. For example, it includes the cash compensation that the VC (bank) commits, the outlays the bank makes in order to undertake value-adding services and for its board activity etc.. The VC investment of amount B has two effects. First, similar to De Bettignies and Brander (2007), it increases the output conditional on success by an amount δB, where $\delta \geq 0$. Thus, under success the total output is $Y + \delta B$. An alternative way to model the effect of value adding services would be through a reduction in the probability of failure as in Hellmann (2002) and Casamatta (2003). We restrict our attention to the first approach as it facilitates, in our set-up, to see the results more cleanly. Once we discuss the results diagrammatically in the Section 4.1.1, it will be apparent that modelling it in the alternative way will not change the results in any fundamental way. Second, a VC investment of amount B gives the entrepreneur a private benefit of λB where $\lambda > 0$. This benefit includes the cash compensation and other benefits that may accrue to the entrepreneur due to mentoring and managerial inputs from the VC.

As will see below ours is a static model while some of the value-adding services that we have talked about above are either dynamic in nature or require richer model of capturing the private benefits accruing to the entrereneur. We have assumed that the entrepreneur still find them valuable as these enter her utility function. One reason why entrepreneur might still value them is because she can use the skills acquired through mentoring and professionalization in her next venture. Indeed, a study by Gompers, Kovner, Lerner and Scharfstein (2010) of the VC backed start-ups in the US suggests that in the 1990s almost 10% of the start-up founders were serial entrepreneurs and their ventures performed better than the ventures of the first time entrepreneurs.

VC investment is costly for the bank. The bank incurs a cost ϕ, with $\phi > 1$, to provide one unit of VC investment. Note, that this cost is higher than the capital cost (fixed at one) as this include the additional cost that the bank has to incur for its active participation in the venture. A ϕ strictly higher than one may also reflect the higher financing cost of VC due to stricter capital requirements associated with private equity business of the banks. Indeed, we would assume that the bank conducting the VC business is socially costly in the sense that the cost of VC faced by the bank is higher than the benefits it brings to the ventures. That is $\phi > \lambda + \delta(1-\theta)$ for all θ. This assumption is consistent with the evidence found in the literature that banks are less active and less effective as a VC investor (Bottazzi et al., 2008, Andrieu and Groh, 2012, Cumming and Murtinu, 2016). This points that banks perhaps face a bigger cost of VC business and undertake that activity only to the extent that helps them separate the entrepreneurs, as explained by our model.

2.4.3 Securities in the VC finance

Another interesting aspect of VC financing is the securities that govern the cash flow and control rights of the venture capitalist in the venture. Interestingly, there is a significant variation across countries on which securities are used. In the USA venture capitalists deal in convertible preferred equity almost exclusively (Kaplan et al., 2007) while in other regions of the World there is prevalence of common equity and debt (Lerner and Schoar, 2005). In Canada common equity is the most prevalent form of security for the seed funding followed by preferred equity and debt (Cumming, 2005a,b). In Europe, as well the picture is quite similar to Canada (Bottazzi, Da Rin and Hellmann, 2009). These differences are explained by tax treatments of capital gains (Gilson and Schizer, 2003) and legal and institutional set-up (Kaplan et al., 2007). In summary, in a VC relationship a whole spectrum of securities may be observed: ranging from common equity to pure debt, including convertible preferred equity–that combines debt-like features with equity-like features.[9]

Instead of mulling over the nuances of the differences in various forms of securities in VC financing we will rather follow a simple approach. We will interpret a VC contract as one that involves the bank providing cash compensation and value-adding benefits in addition to the capital. In return, the bank may get 'repaid' through an equity or debt and we leave that interpretation open since our set-up allows us to capture the complex debt and equity contracts in a simple way. In the binomial outcome possibility that we have, we need not write equity contracts explicitly as a share of output and rather express them as like any other debt contracts ex-ante. We can interpret them ex-post based on the repayment conditions that emerge in the equilibrium (Tirole, 2010, p. 119). An equilibrium contract that requires interest repayment in the success state as well as asks for collateral to be put up for the failure state, is a standard debt contract. An equilibrium contract that does not require any collateral payment in the failure state but requires only a repayment in the success state then can be interpreted as an equity. Therefore, in this sense in our model an uncollateralized loan contract can also be interpreted as an equity contract. In the same vein, an equilibrium contract that requires no collateral and entails a provision of an additional VC investment can also be interpreted an equity contract – the contract that we will call a VC contract. However, we will reserve the option of calling an uncollateralized contract an equity contract only when it involves a VC arrangement. The reason for that is explained next.

2.4.4 Informational requirements in debt versus equity

Another important aspect of distinction between a debt and equity contract is the informational requirements they put on the contractual relationship. An equity contract makes sense only if the exact return is observable to the investor while a debt contract just requires that the event of success or failure is verifiable by the lender and not necessarily the return. However, note in our model all the heterogeneity among agents – in terms of their output or reservation utility – is tied to only one parameter, θ. Therefore, if the exact Y is observable to the bank then it can easily infer θ. In such a case the bank will simply offer contracts that will mimic the full information contracts by making them contingent of Y. The problem of screening disappears rendering the entire exercise uninteresting.

However, it would indeed be an unrealistic assumption that for a small start-up the exact return is observable to the investor. I will, therefore, assume that while the bank can observe, costlessly, whether a firm has been successful or not it can observe the success state return only if it has signed a venture capital contract with the entrepreneur. It is because of this assumption we

[9] For a review of literature on optimal contract *within* VC finance see Da Rin et al. (2013) and Burchardt, Hommel, Kamuriwo and Billitteri (2016).

will not call the uncollteralized loan contract an equity contract but we are still free to interpret our VC contract an equity contract. I believe this assumption is reasonable for the following reasons.

As discussed above a VC contract entails a more active monitoring role for the investor such as seat in the board of the directors of the firm (Gorman and Sahlman 1989, Kaplan and Strömberg 2004, Tirole 2010, p. 90-91). Therefore, being closely engaged in the business of the firm, the VC has a pretty good understanding of the firm's cash flow and that makes any equity contract enforceable. Second, we get the same conclusion if we assume that the investor bank can observe returns of any entrepreneur but does so only with an error. These observational errors may lead to confounding observations such that the bank cannot infer the θ with certainty from the observed Y. However, making VC investment eliminate these errors for the bank – making an equity contract enforceable.

2.5 Model Timing and agent pay-offs

We do not distinguish between a credit contract and a VC contract at the outset and rather start from a possibility that the lender can offer a contract that has elements of both kinds of financing and it is determined endogenously whether the credit or a VC contract is offered. Therefore, we allow the bank to offer contracts that specify an Interest rate (R), Collateral requirement (C) and VC investment (B). R is the gross repayment that the firm has to make to the bank in case of success. The bank captures the pledged collateral (C), if the project is unsuccessful and there is a default. The bank makes the provision of VC investment (B) at the same time as transferring capital to the borrowing entrepreneur. Indeed, we will see later that it is an equilibrium outcome that the bank never offers a contract where it requires a collateral (a characteristic of a bank debt finance) and also makes a VC investment. An equilibrium contract with $B > 0$ and $C = 0$ is a VC contract. As discussed in the previous section when an entrepreneur gets a contract with $B > 0$ the repayment, R, can also be interpreted as gross returns on equity. A contract with $B = 0$ and $C > 0$ is a standard bank debt contract and an equilibrium contract with $B = 0$ and $C = 0$ is an uncollateralized debt contract.

We assume there are two periods t_0 and t_1. At t_0, the bank offers (possibly a menu of) take-it-or-leave-it contracts to the entrepreneurs. Contracts are signed (if accepted by the entrepreneur), capital and additional VC investment are provided in period t_0. Consequent on the VC investment, the entrepreneur draws the private benefit in the period τ_0 regardless of the outcome of the project.

If an entrepreneur of type θ does not accept any contract then she gets her outside opportunity $V(\theta)$ in t_1. Project outcomes materialize in period t_1 and conditional on the outcome firms make repayment or lose collateral the bank. Timing of the model is described in Figure 2.

In order to make capital investment, the bank, collects deposits at t_0 and promises to repay at a gross market risk free interest rate of one to the depositors at t_1. To finance VC investment, the bank raises deposits but also incur additional cost, giving us a cost of VC ϕ greater than one. We also assume the discount rate is the same as the risk free rate i.e. equal to one.

We assume for simplicity that the entrepreneurs do not have any constraints in putting up collateral and their ability to put up collateral is the same. .

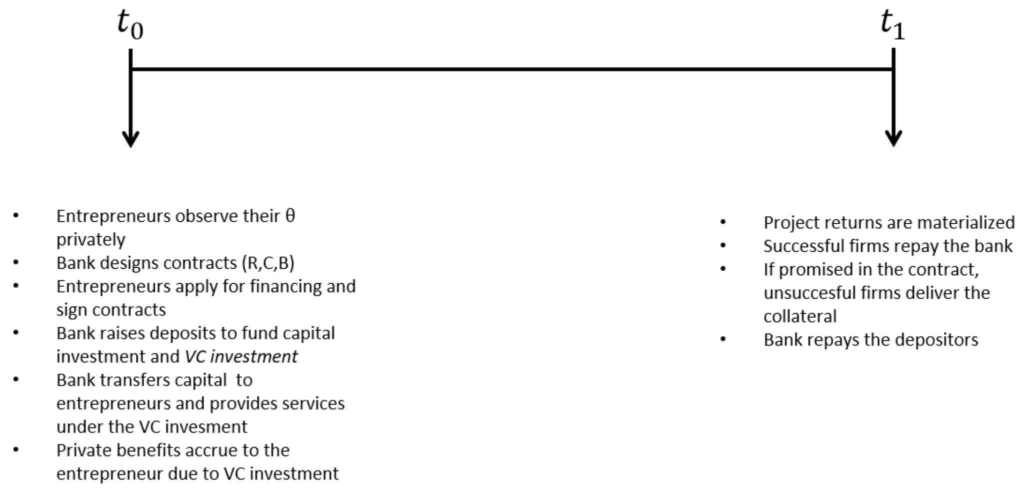

Figure 2: Model Timing

The social surplus associated with the project of a type θ firm is:

$$S(\theta) = (1-\theta)Y(\theta) - V(\theta) - 1 \tag{3}$$

For a given contract (R, C, B), the expected profit of a type θ firm in excess of the outside opportunity $V(\theta)$ is

$$u(R,C,B;\theta) = \lambda B + (1-\theta)\{Y(\theta) + \delta B - R\} - \theta C - V(\theta) \tag{4}$$
$$= (1-\theta)\{Y(\theta) - R\} - \theta C + \{\lambda + \delta(1-\theta)\}B - V(\theta), \tag{5}$$

Bank's expected profit from the same contract can be compactly written as

$$\pi(R,C,B;\theta) = (1-\theta)R + \theta\beta C - \phi B - 1. \tag{6}$$

Therefore the surplus generated in the trade with the type θ entrepreneur signing the contract (R,C,B) is:

$$u(R,C,B;\theta) + \pi(R,C,B;\theta) = (1-\theta)Y(\theta) - (1-\beta)\theta C - \{\phi - \lambda - \delta(1-\theta)\}B - V(\theta) - 1$$
$$= S(\theta) - (1-\beta)\theta C - \{\phi - \lambda - \delta(1-\theta)\}B \tag{7}$$

From our assumptions that $\beta < 1$ and $\phi > \lambda + \delta(1-\theta)$, equation (7) demonstrates that using collateral and VC investment entail social loss.

3 The symmetric information benchmark

Since offering collateralized credit and making VC investment leads to social loss, a fully informed social planner would always choose $C(\theta) = 0 = B(\theta)$ for all θ. Further, to maximize the aggregate social surplus, a social planner would finance all the projects that have $S(\theta) \geq 0$. This is the first best allocation.

In the case when the bank is fully informed it will offer type specific contracts such that it captures the entire surplus from a borrower. Again, since there is a deadweight loss if the bank offers collateral or VC investment, the bank would choose $C(\theta) = 0$ and $B(\theta) = 0$ for all θ. Therefore the bank would offer contracts with type specific interest repayment such that $u(R(\theta), 0, 0; \theta) = 0$. The full information contracts are therefore given as:

$$(I(\theta), 0, 0) := \left(Y(\theta) - \frac{V(\theta)}{1-\theta}, 0, 0 \right) = \left(\frac{\kappa - \gamma\theta - v_0 - v_1\theta^2}{1-\theta}, 0, 0 \right) \tag{8}$$

Where $I(\theta)$ is the interest repayment that the type θ firm pays in the success state to the fully informed bank. This says that the symmetric information contracts are uncollateralized debt contracts.

Since the bank's profit from a given borrower type now is the same as social surplus from that type, it chooses to finance all the projects with $S(\theta) \geq 0$. Therefore, the fully informed bank implements the first best allocation.

Assumption 3 *We make the following assumption to ensure that $I(\theta)$ has a unique global maximum*

$$v_1 > \kappa - \gamma - v_0 > 0$$

Let the global maximum is achieved at θ^*, where

$$0 < \theta^* := 1 - \frac{\sqrt{v_1(v_1 + v_0 + \gamma - \kappa)}}{v_1} < 1$$

Thus, contract in (8) shows that with complete information, initially the more risky entrepreneurs (with higher θ) pay higher interest rate than the less risky entrepreneurs (with lower θ) but as the reservation utility becomes high enough with increasing θ, the bank has to reduce the interest rate eventually to attract the more innovative entrepreneurs to borrow. This is an interesting contrast with more conventional models of like Besanko and Thakor (1987) and Lengwiler and Rishabh (2017) where the less risky types always pay higher interest rate under full information (i.e. $I(\theta)$ function is monotonically decreasing in θ). This is a special case in our model. If we assume $\kappa = \gamma > 0$ and $v_1 = 0$ we get the same $I(\cdot)$ function as these papers.

4 Asymmetric information

In a more realistic scenario, the bank cannot observe the types and therefore it cannot offer personalized contracts as above. This information asymmetry gives incentives to the entrepreneurs to lie about their true types. In what follows we assume that there are three types of entrepreneurs - low (θ_l), medium (θ_m) and high (θ_h) default probability types, where $0 < \theta_l < \theta_m < \theta_h < 1$. The share of the types θ_l, θ_m and θ_h are f_l, f_m and f_h respectively where $f_i > 0$ for $i \in \{l, m, h\}$ and $\sum_i f_i = 1$.

For notational convenience we will change the index of types from θ to i. That is we denote $S(\theta_i)$ as S_i, $V(\theta_i)$ as V_i, $Y(\theta_i)$ as Y_i and so on. We also assume for that all the types are socially productive, producing positive social surplus.

Assumption 4 $S(\theta_i) > 0 \, \forall i \in \{l, m, h\}$

Given that the $I(\cdot)$ is concave, with three types we can have four possible combinations of full information interest rate. These are (i) $I_l \le I_h \le I_m$ (ii) $I_h < I_l \le I_m$ (iii) $I_l < I_m < I_h$ and (iv) $I_h < I_m < I_l$. Given θs are distinct there can be at most one equality in (i). To keep the analysis concise, we will focus on only cases (i) and (ii).

Assumption 5 *θs are such that either $I_h < I_l \le I_m$ or $I_l \le I_h \le I_m$ with at most one equality.*

That is, we assume θ_m is the top type throughout our analysis. We do not make any assumption about the bottom type (the borrower with lowest $I(\theta)$). Once we explain the first two cases, it will become clear why cases (iii) and (iv) do not require much discussion. We discuss cases (iii) and (iv) in section 5. In what follows we ignore the possibility of equal Is as it requires us to qualify every exposition every time with two distinct possible equalities. Since the results with equalities are going to be obvious as we will see in section 4.1.1, we skip any qualification on that aspect for the rest of the paper.

Now consider what will happen, if the bank offers the full information contracts, as given in (8), in the presence of asymmetric information. If we have $I_l < I_h < I_m$ then θ_m and θ_h have incentive to mimic the θ_l type as it is the θ_l that is asked to pay the lowest interest rate. Therefore, all the types will pool at the contract for θ_l. This will give θ_m and θ_h informational rent, $u(I_l,0,0;\theta_i) = (1-\theta_i)[I_i - I_l] > 0$, for $i = m,h$. Clearly bank looses out compared to the full information case as now it cannot capture the entire surplus from θ_m and θ_h types. Symmetrically, θ_l and θ_m types earn informational rents by pooling at the contract for θ_h type, if $I_h < I_l < I_m$.

The bank will certainly want to do better by possibly separating the types by designing a self selecting menu of contracts. An menu of contracts would contain the triples, (R_i,C_i,B_i) i.e. where R, C and B are functions of the entrepreneurial types. To look at the optimal contracts menu, using the revelation principle, we only need to focus on the menus that give rise to truth telling (Myerson, 1979). A menu of contracts induces truth telling by ensuring that the contracts are incentive compatible and satisfy participation constraints (PC) of the agents. An incentive compatibility constraint, IC$_{ij}$, requires that the type θ_i firm finds the contract designed for herself at least as attractive as the contract designed for any other type, θ_j. That is:

$$u(R_i,C_i,B_i;\theta_i) \ge u(R_j,C_j,B_j;\theta_i) \qquad \forall i,j \in \{l,m,h\}$$

Which can be written in as,

$$R_i + \frac{\theta_i}{1-\theta_i}C_i - \left[\delta + \frac{\lambda}{1-\theta_i}\right]B_i \le R_j + \frac{\theta_i}{1-\theta_i}C_j - \left[\delta + \frac{\lambda}{1-\theta_i}\right]B_j \qquad \forall i,j \in \{l,m,h\} \tag{9}$$

The PC requires that each type prefers to run the project than exercise her outside option. The bank achieves this by ensuring

$$u(R_i,C_i,B_i;\theta_i) \ge 0 \qquad \forall i \in \{l,m,h\}. \tag{10}$$

Bank's profit maximization problem, therefore, can be written as:

$$\left.\begin{aligned}
&\max_{R_i,C_i,B_i} \sum_{i\in\{l,m,h\}} \left[(1-\theta_i)R_i + \theta_i\beta C_i - \phi B_i - 1\right] f_i && \text{subject to}\\
&R_i + \frac{\theta_i}{1-\theta_i}C_i - \left[\delta + \frac{\lambda}{1-\theta_i}\right]B_i \le R_j + \frac{\theta_i}{1-\theta_i}C_j - \left[\delta + \frac{\lambda}{1-\theta_i}\right]B_j && \forall i,j\in\{l,m,h\}\\
&u(R_i,C_i,B_i;\theta_i)\ge 0 && \forall i\in\{l,m,h\}\\
&R_i \le Y_i && \forall i\in\{l,m,h\}\\
&R_i,B_i,C_i \ge 0 && \forall i\in\{l,m,h\}
\end{aligned}\right\} \quad \text{(P-I)}$$

The first constraint is the set of IC constraints discussed above. There are six such constraints for the three types. Second is the PC that ensures that the agents find running the project worthwhile compared to the next best alternatives they have. There are three participation constraints, one for each type. Next is the constraint requires that, for each type, repayment in the success state cannot be higher than the income of the entrepreneur. The last set of constraints impose non-negativity for all the choice variables.

In the following discussion, we will find the conditions under which the bank can separate the types and solve for the optimal contracts in separation. These conditions would clearly depend on the cost of collateralization (β) and VC (ϕ). Afterwards we discuss the equilibrium outcomes if the complete separation conditions are not met.

4.1 Complete separation

Instead of solving the problem (P-I) we solve a relaxed problem with fewer constraints and show that the solution satisfies all the constraints in (P-I). The relaxed problem is given as:

$$\left.\begin{aligned}
&\max_{R_i,C_i,B_i} \sum_{i\in\{l,m,h\}} \left[(1-\theta_i)R_i + \theta_i\beta C_i - (1+\phi)B_i - 1\right] f_i && \text{subject to}\\
&R_m + \frac{\theta_m}{1-\theta_m}C_m - \left[\delta + \frac{\lambda}{1-\theta_m}\right]B_m \le R_l + \frac{\theta_m}{1-\theta_m}C_l - \left[\delta + \frac{\lambda}{1-\theta_m}\right]B_l &&\\
&R_m + \frac{\theta_m}{1-\theta_m}C_m - \left[\delta + \frac{\lambda}{1-\theta_m}\right]B_m \le R_h + \frac{\theta_m}{1-\theta_m}C_h - \left[\delta + \frac{\lambda}{1-\theta_m}\right]B_h &&\\
&u(R_i,C_i,B_i;\theta_i)\ge 0 && \forall i\in\{l,m,h\}\\
&R_i,B_i,C_i \ge 0 && \forall i\in\{l,m,h\}
\end{aligned}\right\} \quad \text{(P-II)}$$

Problem (P-II) has only two of the six IC constraints viz. IC_{ml} and IC_{mh} and contains no viability constraint as in problem (P-I). Indeed we will ignore this condition for the rest the paper as it can be checked for θ_m and θ_l types in any equilibrium this condition is satisfied. In the case of θ_h and when the complete separation is achieved it reduces into a technical condition[10], that we will assume to be satisfied always. Indeed, in all the numerical examples presented later, this condition is easily satisfied.

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Lemma 1 *In any solution to the relaxed problem P-II, the participation constraints for θ_h and θ_l must bind.*

[10]The condition is given as $\delta(1-\theta_h)+\lambda \le \frac{V_h}{v_1(\theta_h+\theta_m-\theta_h\theta_m)-(\kappa-\gamma-v_0)}$. Essentially it is a condition on the slope of the participation constraint (indifference curve), relative to its intercept in the R–C–B space.

Proof. Suppose not. Then there is a solution to P-II in which for some $k \in \{l,h\}$ we have:

$$\begin{aligned} & u(R_k, C_k, B_k; \theta_k) > 0 \\ \Rightarrow \quad & \lambda B_k + (1-\theta_k)[Y_k + \delta B_k - R_k] - \theta_k C_k - V_k := \varepsilon_k > 0 \end{aligned}$$

Consider the new contract $(\overline{R_k}, \overline{C_k}, \overline{B_k})$ such that $\overline{R_k} = R_k + \varepsilon_k/(1-\theta_k)$, $\overline{C_k} = C_k$ and $\overline{B_k} = B_k$. The new contract preserves the participation constraint for the type θ_k, continues to satisfy the two ICs and does not impact PC for any other types. However, this leads to an unambiguous increase in profit for the bank. QED

We show in the appendix, under the conditions that support complete separation, the solution to the relaxed problem P-II is given by:

$$\begin{aligned} R_l &= I_l - \frac{\theta_l}{1-\theta_l} C_l, & C_l &= \frac{I_m - I_l}{\Delta_{ml}}, & B_l &= 0 \\ R_m &= I_m, & C_m &= 0, & B_m &= 0 \\ R_h &= I_h + \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h, & C_h &= 0, & B_h &= \frac{I_m - I_h}{\lambda \Delta_{hm}} \end{aligned}$$

Where $\Delta_{ij} := \dfrac{\theta_i - \theta_j}{(1-\theta_i)(1-\theta_j)} = \left[\dfrac{\theta_i}{1-\theta_i} - \dfrac{\theta_j}{1-\theta_j}\right] = \left[\dfrac{1}{1-\theta_i} - \dfrac{1}{1-\theta_j}\right]$ and $\Delta_{ml} > 0$, $\Delta_{hm} > 0$.

As a next step, we demonstrate in the appendix, the above solution under complete separation is also a solution to the original problem by showing that this solution satisfies all the constraints in P-I.

Lemma 2 *Solution to P-II is also a solution to P-I.*

Proof. See appendix. QED

Finally, the following proposition summarizes all the results relating to complete separation including the conditions that ensure that.

Proposition 1 *Under the conditions,*

$$\frac{1}{f_m}\left[(1-\beta)\theta_l f_l \left(\frac{1-\theta_l}{\theta_m - \theta_l}\right) + \{\phi - \lambda - \delta(1-\theta_h)\}\frac{f_h}{\lambda}\left(\frac{1-\theta_h}{\theta_h - \theta_m}\right)\right] \leq 1 \tag{C.1}$$

$$C_l^s \leq \frac{S_l}{\theta_l\,(1-\beta)} \tag{C.2}$$

$$B_h \leq \frac{S_h}{\phi - \lambda - \delta(1-\theta_h)} \tag{C.3}$$

the bank separates all the three types offering the contracts:

$$\begin{aligned} R_l^s &= I_l - \frac{\theta_l}{1-\theta_l} C_l^s, & C_l^s &= \frac{I_m - I_l}{\Delta_{ml}}, & B_l^s &= 0 \\ R_m^s &= I_m, & C_m^s &= 0, & B_m^s &= 0 \\ R_h^s &= I_h + \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h^s, & C_h^s &= 0, & B_h^s &= \frac{I_m - I_h}{\lambda \Delta_{hm}} \end{aligned} \tag{11}$$

Proof. Follows directly from solution to P-II and Lemma 2. QED

The superscript 's' stands for separation.

4.1.1 Characterization of separating equilibrium

There are some interesting properties of the separating contracts in (11), that we can readily see. First is that the medium type gets the full information contract i.e. it pays no collateral, gets no additional VC investment and pays the interest I_m. This result is called 'no distortion at top' for θ_m is the top type in our analysis. If the bank offered full information contracts, no type would try to mimic this type as under full information θ_m type pays the highest interest rate. It is for this reason there is no need for the bank to distort the full information contract for θ_m type.

Second, $C_i B_i = 0, \forall i \in \{l, m, h\}$. That is the bank does not offer any hybrid contract involving both collateral and VC investment. We explained above why it holds for θ_m type. For θ_h and θ_l types the reason is that of the two variables, VC investment (B) and collateral (C), only one is effective as a screening device for any given type. To see that remember the bank needs to distort the first best contract for the types other than the θ_m type, such that no one has any incentive to mimic any one else (contracts are incentive compatible). As an illustration, suppose, θ_h is the bottom type. In other words, θ_h type has the *smallest* interest repayment i.e. $I_h < I_l < I_m$. Therefore, θ_l and θ_m types jeopardize the full information contract of the θ_h type.

How should the bank distort the full information contract for the θ_h type to prevent θ_m and θ_l from mimicking it? Offering collateralized credit (combined with lower R) to θ_h type will not help as both θ_m and θ_l types like contracts with collateral even more than the high type because these types are less likely to default than the θ_h type and are therefore, less likely to part-away with the collateral. However, if the θ_h type gets a contract with VC investment combined with a high R, the other types will be dissuaded to mimic it as the other two types succeed (and hence are required to pay R) with greater probability.

Now consider the θ_l type whose contract has to be distorted such that no other type mimics it. Paying any VC investment to the θ_l type (and charging high interest rate simultaneously) will not help as the higher default probability types, viz. θ_m and θ_h types will like such a contract even more. While requiring high enough collateral (and reducing the interest required simultaneously) from θ_l type might dissuade the other types from mimicking it.

This gives us a clean separation of types into different kinds of contracts. The high default probability types get a VC investment. The bank does not get anything back from these types in the failure state but enjoys a 'high' R in the success state. This is in essence a venture capital contract. The low default types on the other hand get a standard collateralized credit contract. The middle types get uncollateralized credit contracts. Finally, note that although all the types end up at their PCs (PCs of all three types bind), the bank still does not get the full social surplus because it has to incur deadweight cost of screening.

The figure 3 shows three-dimensional indifference curves associated with $u(R, C, B; \theta) = 0$, i.e. participation constraint – one for each type. By implication of our result that the bank will not offer any hybrid contract i.e., $C_i B_i = 0, \forall i \in \{l, m, h\}$, we can ignore all the contracts in the shaded part of the indifference curves. We need to focus only on the edges of the indifference curves lying in the R–C and R–B coordinate planes. These edges are depicted in bold lines in the figure. Indeed, this can be visualized in a two dimensional diagram, making it easier to optically identify the optimal contracts.

Figure 4 plots C on the horizontal axis starting from origin and moving towards right, and

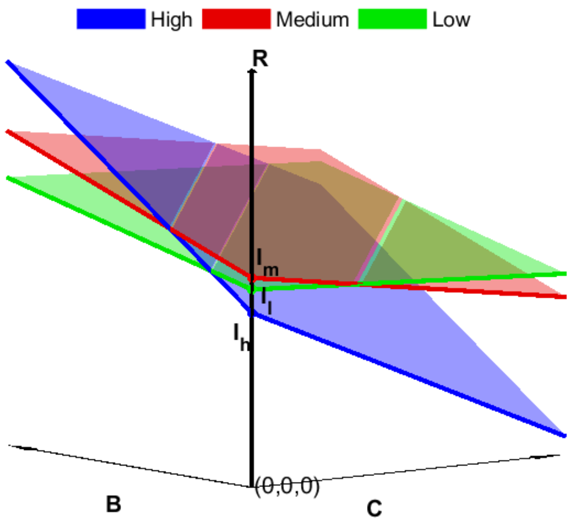


Figure 3: Participation Constraints

B on the horizontal axis as well but starting from origin and moving towards left. Essentially in this figure, the horizontal axis plots two different variables, both taking non-negative values, with the values increasing farther you are on the axis in any direction.

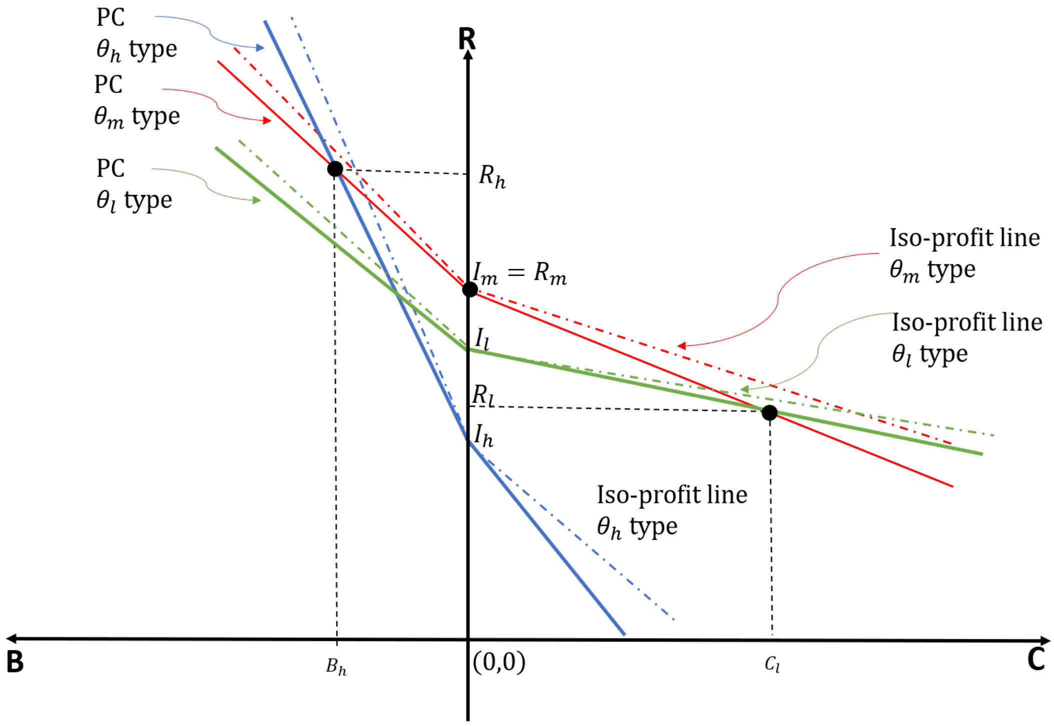


Figure 4: Participation Constraints and Separating Contracts

In addition to the participation constraints drawn in bold lines, the figure 4 also includes the iso-profit lines through the benchmark symmetric (full) information contracts. The three bold points depicted are the separating contracts. It can be quickly checked that although bank is able to push all the types to their respective participation constraints, it still earns less profit than the symmetric information benchmark, except in the case of the θ_m type, whose full information contract is not distorted. Note that figures 3 and 4 are drawn for the case $I_h < I_l < I_m$. As our solution shows above, for the alternative case $I_l < I_h < I_m$ how the conditions that determine the optimal contracts remain the same.

Let us look at the conditions for complete separation. (C.1) specifies conditions on parameters such as distribution of θ, heterogeneity of types and relative cost of screening. The condition seems quite intuitive: *ceteris paribus* lower cost of collateralization $(1-\beta)$ and VC (ϕ) makes separation more likely. Also, a higher λ or δ reduce the net cost of VC investment and therefore make separation more likely. Similarly, other things remaining the same, the more heterogeneous the entrepreneurs are (i.e. bigger is the difference between θs) the more likely there will be a separation of types. Finally, higher the share of the top type (f_m) relative to f_h and f_l, higher are the chances that the bank will separate. The reason is that the bank does not have to distort the contract of the top type and hence there are no profit losses attributable to inefficiency of the screening process for the θ_m type. Thus, larger the share of θ_m types the more leeway the bank has on incurring cost of screening for the other two types. If this condition is satisfied with equality then the bank may give θ_m types some informational rent (allows the PC of θ_m types to be slack) by allowing some kind of pooling (partial or complete) involving θ_m types with at least one other types. However, this gives the bank no additional profit. We will assume in such a case the bank will continue to separate completely such that the PC for θ_m types also binds.

We also require conditions that ensure that by separating the types the bank does not make negative profits from the types whose full information contracts are distorted. Given the result from Lemma 1 that the types θ_h and θ_l do not earn any informational rent, this condition requires that the social surplus net of the deadweight loss of using collateral or VC investment should be non-negative. This is what conditions (C.2) and (C.3) encapsulate.

4.2 Partial and complete pooling

In the case any one of the conditions in proposition (1) is violated, bank will find it profitable to pool some or all the types. Let us begin by considering the violation of condition (C.1) assuming the other two conditions are satisfied. We know from the discussion above that the bank will never find it useful to offer a collateralized debt contract to high type and a VC contract to low type and would not distort the contract for θ_m types. Additionally, it is also clear that any kind of partial pooling will involve θ_m types, otherwise the bank cannot deter θ_m type to mimic the pooled agents. Finally, any pooling contract (partial or complete) must correspond to the full information contract – involving no collateral and no VC investment. Since, both collateral and VC contracts incur cost, and at most only one type needs to be separated in a partial pooling scenario the bank needs to distort the full information contract of only one type at most. And by the same reasoning, it does not need to distort the full information contract of any agent in the case of complete pooling.

Whose full information contract is distorted in the case of partial pooling? We can answer this by referring to figure 4. The partial pooling should be of the top two types and the 'bottom' type should be separated, for any other combination of pool of two will be ineffective in separating the remaining type. In the set-up of figure 4, under partial pooling θ_m and θ_l types will be pooled while the θ_h will be separated with a VC contract, distinct from the one in (11). Of course, there is also a condition, similar to (C.1) that needs to be satisfied for the bank to partially pool rather than completely pool the types. The following propositions sum up the discussion:

Proposition 2 *If* (C.1) *is violated while* (C.2) *and* (C.3) *are satisfied and $I_h < I_l < I_m$ holds, then under the condition*

$$\frac{1}{f_m}\left[\{\phi-\lambda-\delta(1-\theta_h)\}\frac{f_h}{\lambda}\left(\frac{1-\theta_h}{\theta_h-\theta_m}\right)-f_l\left(\frac{1-\theta_l}{1-\theta_m}\right)\right]\leq 1 \tag{C.4}$$

the bank pools θ_m and θ_l types, and separates θ_h types offering the contracts:

$$\begin{aligned} &R_l^{pp}=R_m^{pp}=I_l, && C_l^{pp}=C_m^{pp}=0, && B_l^{pp}=B_m=0\\ &R_h^{pp}=I_h+\left[\delta+\frac{\lambda}{1-\theta_h}\right]B_h^{pp}, && C_h^{pp}=0, && B_h^{pp}=\frac{I_l-I_h}{\lambda\Delta_{hm}} \end{aligned} \tag{12}$$

Proof. See appendix. QED

Where the superscript '*pp*' is for partial pooling.

Proposition 3 *If* (C.1) *is violated while* (C.2) *and* (C.3) *are satisfied and $I_l < I_h < I_m$ holds then under the condition*

$$\frac{1}{f_m}\left[(1-\beta)\theta_l f_l\left(\frac{1-\theta_l}{\theta_m-\theta_l}\right)-f_h\left(\frac{1-\theta_h}{1-\theta_m}\right)\right]\leq 1 \tag{C.5}$$

the bank pools θ_m and θ_h types, and separates θ_l types offering the contracts:

$$\begin{aligned} &R_h^{pp}=R_m^{pp}=I_h, && C_h^{pp}=C_m^{pp}=0, && B_h^{pp}=B_m^{pp}=0\\ &R_l^{pp}=I_l-\frac{\theta_l}{1-\theta_l}C_l^{pp}, && C_l^{pp}=\frac{I_h-I_l}{\Delta_{ml}}, && B_l^{pp}=0 \end{aligned} \tag{13}$$

Proof. See appendix. QED

Propositions 2 and 3 show that only the bottom type's contract is distorted. In the first case, since high default probability entrepreneurs are the bottom type, they are offered a VC contract while the other two types are offered an uncollateralized credit contract. In the latter case, low probability types are the bottom types and they get the collaterlaized credit contract, while the other two types get the uncollateralized credit contract. In summary, in a partial pooling equilibrium, in combination with the uncollaterlized credit contract, either a VC contract is offered or a collateralzied credit contract, but not both.

Another notable feature of optimal contracts under partial pooling is $R_m^{pp} < R_m^s$ in either case and $B_h^{pp} < B_h^s$ in the former case and $C_l^{pp} < C_l^s$ in the latter. This is because given that the bank is pooling the top two types, the amount of distortion required to keep them from mimicking the bottom type is small.

The conditions (C.4) and (C.5) for partial pooling require that medium types form a relatively high proportion of the population compared to the bottom type. Additionally, the cost of screening in either case should be sufficiently low and heterogeneity among θs sufficiently high. The negative terms we see at the end is new in these conditions. These say that the higher is proportion of the type with whom the top type is pooled the more likely it is that the bank will partially pool rather than fully pool. It follows from the fact that larger is the number of these types, the more surplus the bank can extract potentially by separating them from the bottom type. No surprise that the violation of condition (C.4) in the first case and of condition (C.5) in the second case leads to complete pooling.

Proposition 4 *If* (C.1) *is violated while* (C.2) *and* (C.3) *are satisfied then*
(i) In case $I_h < I_l < I_m$ *holds and* (C.4) *is violated, the bank pools all the borrower types at the contract* $(I_h, 0, 0)$.
(ii) In case $I_l < I_h < I_m$ *holds and* (C.5) *is violated, the bank pools all the borrower types at the contract* $(I_l, 0, 0)$.

Proof. See appendix. QED

This proposition says that the bank will pool all the types, should the conditions of separation and partial pooling are not met, at the first best contract for the bottom type. In this case we will not observe any VC or collateralised credit.

So far, we have focused only on the violation of condition (C.1) in proposition 1. In case only this condition is violated but conditions (C.2) and (C.3) are met, we showed the bank will still serve all the types, although it may not separate them always. However, if either the cost of venture capital or cost of collaterlization is too high we might see that the bank does not serve some entrepreneurs and that leads to an additional inefficiency resulting from the shut-down of the entrepreneurs from the financial market.

4.3 Shutdown of entrepreneurs and inefficiency

In this section rather than completely characterizing all the possible equilibria we will highlight one extreme example to highlight the possibility of inefficient shut down of a type from the market. We will assume that cost of VC is prohibitively high, such that the bank cannot offer any VC contract. This can also be thought of as a case when the bank is not permitted to undertake any VC investment. A parallel analysis could be done by assuming that the cost of collateralization is prohibitively high (or the entrepreneurs do not have collateral to pledge). In either case there might be inefficiency due to limited market access: in the first case the θ_h type might get shut down and in the second case the θ_l type. We will focus on the shut down of the former kind. Conditions for shutdown of θ_l types when (C.2) is violated can be derived following similar arguments and are available on request.

In case complete separation is rendered unviable due to high cost of VC, condition (C.3) is violated for any $B > 0$. Therefore, with the lack of a screening device at its disposal, the bank might find it worthwhile sometimes to not serve the θ_h types.

Take the example of figure 4 again. Here type θ_h is the bottom type. If condition (C.2) is not met and even if (C.1) is satisfied, the bank will no longer separate the high default probability type. It is because if it did, it would incur a negative profit on these types. Indeed, in order to serve θ_h types, the bank needs to pool them with at least one other type. Therefore, unless the θ_h types are close enough to other types or they are present in high numbers relative to other types, they might not be served.

Further, note the only pooling involving θ_h types that is consistent with profit maximization in this case is where the bank pools all the types i.e., complete pooling. A partial pooling of θ_h types with any other type is not incentive compatible. However, note the complete pooling will occur a the contract $(I_h, 0, 0)$ and at this contract the bank is giving the θ_m and θ_l types an informational rent. We can imagine if this joint informational rent turns out to be higher than what the bank gets by serving the θ_h types, viz. their social surplus (net of any cost in alternative scenarios), then the bank will not serve θ_h types. Thus, an inefficient equilibrium ensues with the high type shut down from the market. The exact conditions for these are summarized in the proposition below.

Proposition 5 *If $I_h < I_l < I_m$,* (C.2) *is violated for all $B > 0$ and* (C.3) *holds then if*
$$f_h S_h \geq \max\left\{ f_m(1-\theta_m)(I_m - I_h) + f_l(1-\theta_l)(I_l - I_h) - (1-\beta)\theta_l\left[\frac{I_m - I_l}{\Delta_{ml}}\right], [f_m(1-\theta_m) + f_l(1-\theta_l)](I_l - I_h)\right\}$$
The bank pools all the entrepreneurs at $(I_h, 0, 0)$.
If the above condition is not satisfied and if
(i) $\frac{1}{f_m}\left[(1-\beta)\theta_l f_l\left(\frac{1-\theta_l}{\theta_m - \theta_l}\right)\right] \leq 1$*, then the bank shuts down the θ_h type entrepreneurs and separates the θ_m and θ_l type entrepreneurs offering contracts:*

$$\begin{aligned} R_m^{sds} &= I_m, & C_m^{sds} &= 0, & B_m^{sds} &= 0 \\ R_l^{sds} &= I_l - \frac{\theta_l}{1-\theta_l} C_l^{sds}, & C_l^{sds} &= \frac{I_m - I_l}{\Delta_{ml}}, & B_l^{sds} &= 0 \end{aligned} \tag{14}$$

(ii) $\frac{1}{f_m}\left[(1-\beta)\theta_l f_l\left(\frac{1-\theta_l}{\theta_m - \theta_l}\right)\right] > 1$*, then the bank shuts down the θ_h type entrepreneurs and pools the θ_m and θ_l type entrepreneurs offering the contract:*

$$R_m^{sdp} = R_l^{sdp} = I_l, \quad C_m^{sdp} = C_l^{sdp} = 0, \quad B_m^{sdp} = B_l^{sdp} = 0 \tag{15}$$

Proof. See appendix. QED

Here, the superscript $'sds'$ stands for shutdown with separation and $'sdp'$ stands for shutdown with pooling.

The conditions in the above proposition are intuitive. The first condition has on the left side the gains from serving the θ_h types viz. the surplus produced by θ_h types. The right side contains the cost of serving the θ_h types viz. the informational rents the bank gives to the other types when it pools them. However this cost of serving θ_h type has to be adjusted with the costs that the bank incurs in cases when it decides not to serve the θ_h type. That is the cost corresponding to screening in $'sds'$ and cost of pooling in $'sdp'$. Only when the gain by serving θ_h types is higher than the net costs in the two cases when θ_h types are kept out of the market, that the bank chooses to pool all. In case the bank decides not to serve θ_h type (i.e. not to pool all the types) it chooses between pooling or separating the rest of the types and the second condition determines that. Its interpretation is similar to the interpretation of condition (C.1) in the case of complete separation in Section 4.1.1.

To see diagrammatically, the consequence of prohibitively high cost of VC bank we can refer to Figure 4 again keeping in mind that no point in R–B plane is achievable any more. Focusing on the R–C plane, note that collateral alone can not help separate the three types. Why? Starting from the full information contract for the θ_h type, denoted by the point I_h, the bank can in no way distort this contract to dissuade the other types from mimicking it. Any attempt to offer a contract with more collateral combined with lower interest rate will make the contract even more desirable to lower default probability types. Therefore, the bank might decide not to serve the θ_h types if it finds its profits to be lower when pooling all than serving only the θ_m and θ_l types. This would lead to inefficient exclusion of the high types from accessing credit and a loss in social welfare. No surprise that a similar shut down may occur even when θ_l is the bottom type. Consider the same scenario with prohibitively high cost of VC with $I_l < I_h < I_m$. The situation, however, is slightly benign here. Now, the bank finds it harder to exclude the θ_h types because now the bank also has the option of involving the θ_h types in a partial pooling equilibrium – which the bank didn't have in the previous case. The following proposition sums up the results for this case:

Proposition 6 *If $I_l < I_h < I_m$,* (C.2) *is violated for all $B > 0$ and* (C.3) *holds then if*

$$f_h S_h \leq \min\left\{[I_m - I_l](1-\theta_m)f_m + [I_h - I_l]\left((1-\theta_h)f_h - \frac{(1-\beta)f_l\theta_l}{\Delta_{ml}}\right), [I_m - I_h]\left((1-\theta_m)f_m - \frac{(1-\beta)f_l\theta_l}{\Delta_{ml}}\right)\right\}$$

The bank shuts down the θ_h type entrepreneurs and separates the θ_m types with θ_l types offering the contracts in (14). *If the above condition is not satisfied and*

(i). Condition (C.5) *holds, then the bank pools θ_h with θ_m types and separates θ_l type entrepreneurs offering contracts in* (13)

(ii). (C.5) *does not hold then the bank pools all the entrepreneurs at the contract* $(I_l, 0, 0)$.

Proof. See appendix. QED

4.4 Numerical Examples

In this section I present a few numerical examples to elaborate on the results in the previous sections. We first start with understanding the role of heterogeneity and cost of screening in determining the type of equilibrium. To do that we make some normalizations. First is that for this section we assume that the heterogeneity across the three types is uniform. That is the parameter, $d := (\theta_h - \theta_m) = (\theta_m - \theta_l)$ determines the heterogeneity in the economy. We fix the parameters as in the table below for both the examples in this section.

Parameter	**Value**
κ	7
γ	2
v_0	2
v_1	4
θ_m	0.5
λ	1
δ	0

Table 1: Parameter values for the numerical examples

Given these parameters, $S(\theta) > 0$, $\forall\theta \leq 0.78$. Therefore, a social planner would finance any firm with default probability less than 0.78. Keeping our assumption that all firms are socially desirable and assuming that $\theta_m = 0.5$, we will, therefore, allow a maximum d equal to 0.27.

Example 1: when separation is viable

In this example we will work in an environment where complete separation is a viable option for the bank in the sense that conditions C.2 and C.3 hold throughout. The idea is to find which combinations of ϕ, β and d give rise to which type of equilibrium – complete separation, partial pooling, complete pooling. To reduce the dimensionality of the problem in this example, we assume a symmetric cost of credit and venture capital, so that both types of cost can be represented by one parameter. We define cost of screening parameter (ϕ_n) as the cost of VC which is tied to the cost of collateral such that $\phi = \phi_n := \frac{1}{\beta}$. This says the higher the cost of collateralization $(1-\beta)$, the higher the cost of VC (ϕ).

Note, given θ_m, each value of d fixes values of θ_l and θ_h. Given parameters in table 1, this gives us symmetric information interest rates, $I_i \, \forall i \in \{l,m,h\}$ and that determines the bottom and top type. Continuing with our assumption, all our parameters ensure that θ_m is the top type. Finally, the distribution of types, and the cost of screening parameter ϕ_n pins down the equilibrium and the optimal contracts in the equilibrium.

Assuming uniform distribution of types, figure 5 draws which kind of equilibrium arise and what type of contracts are offered in that equilibrium. A higher heterogeneity and lower screening cost support a separating equilibrium. Further, starting from a separating equilibrium, and holding the cost of screening fixed, as heterogeneity decreases first partial pooling and then complete pooling emerge as equilibrium. This is so because when the types are closer to each other they produce surpluses close to each other and it becomes less attractive to separate them as it incurs a cost. For a given level of heterogeneity and again starting from a separating equilibrium, a higher screening cost first shifts the equilibrium to be partial pooling and then to pooling as the cost become higher.

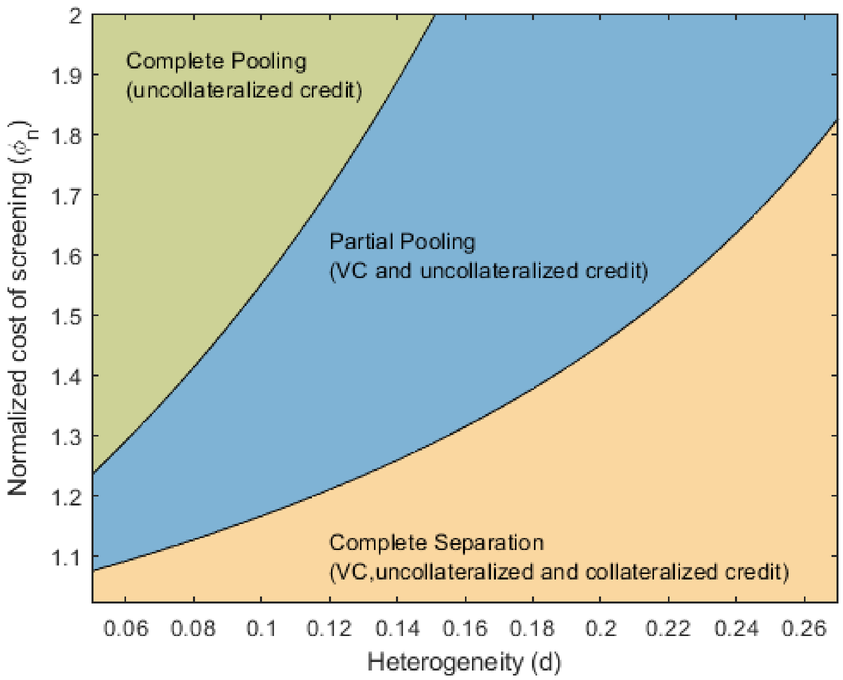


Figure 5: Equilibria with varying heterogeneity and cost of screening

Note on the figure: Uniform distribution with $f_l = f_m = f_h = 1/3$ and $I_l > I_h$

The parameters chosen in this example are such that they give rise to $I_h < I_l < I_m$, just like the way figure 4 is drawn. Therefore, from Proposition 2 we know that in figure 5 under partial pooling, VC is offered alongside uncollateralized credit. If we had $I_l < I_h < I_m$, then according to Proposition 3, under partial pooling collateralized credit will be offered alongside uncollateralized credit.

To see the effect of distribution on the possible equilibria, let us deviate from the uniform distribution and consider a uni-modal distribution with higher proportion of θ_m types. With a bigger population of θ_m types, as discussed in earlier, the bank has more leeway in separating the types. Thus, with the distribution skewed towards the θ_m types, the separation region in the figure 5 should expand at the expense of the partial pooling and complete pooling regions. Figure 6 is drawn with $f_m = \frac{1}{2}$ and $f_l = f_h = \frac{1}{4}$ to demonstrate this.

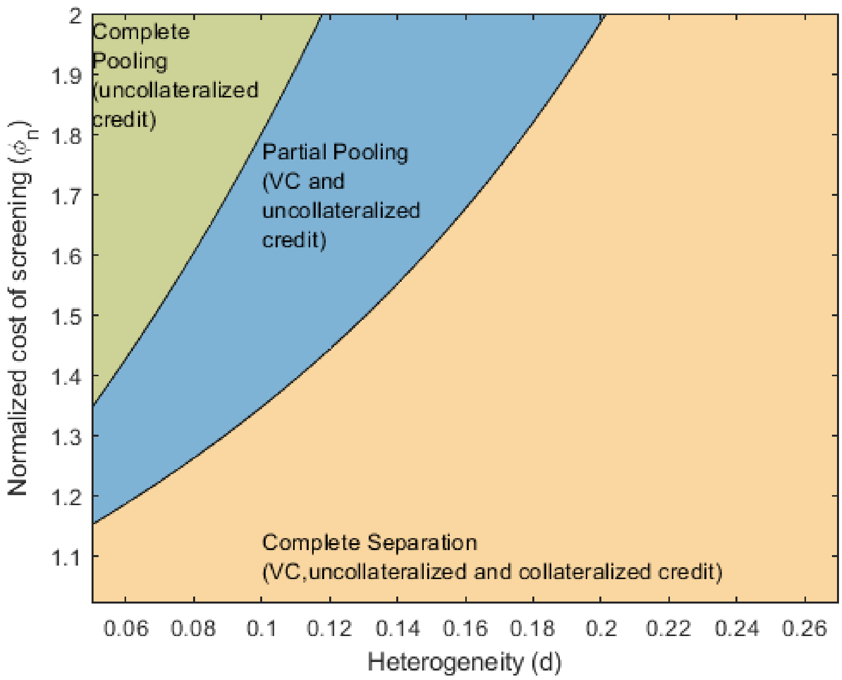


Figure 6: Equilibria with varying heterogeneity and cost of screening

Note on the figure: Uni-modal distribution – $f_m = \frac{1}{2}$, $f_l = f_h = \frac{1}{4}$ and $I_l > I_h$

Example 2: when separation is not viable

Let us now look at an example where cost of separation is too high such that condition (C.2) is not met and that ensures that the bank will never choose to separate the types.

Suppose conducting VC business for the bank is prohibitively expensive (ϕ is too large). As discussed in section 4.3 this can also be thought of as a case where the bank is prohibited from conducting VC business. Therefore, the bank will serve the high type only when it finds the conditions optimal for pooling all the types, in other cases it will set the terms of the contracts such that the high default probability types do not find funding attractive enough to participate. This entails a loss of welfare, for a socially desirable project is left unfunded.

In a similar exercise to the previous example, we analyze the role of heterogeneity and cost of screening on equilibrium outcome. However, this time the cost of VC and collateral are not tied to each other. However, the dimensionality this time is reduced because we do not need to care about the role of cost of VC once it is set prohibitively high. So, we analyze the problem with cost of collateral $(1-\beta)$ and heterogeneity (d).

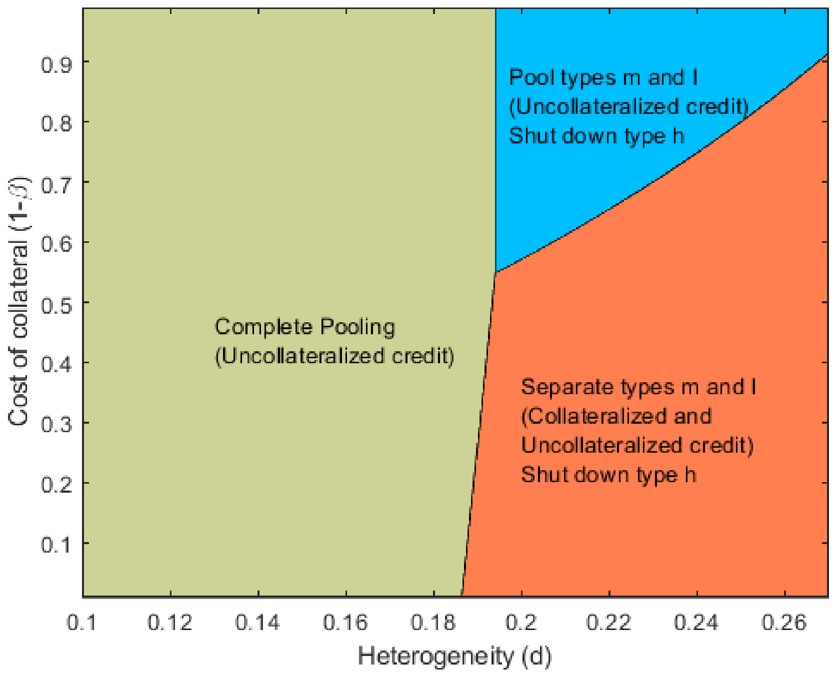


Figure 7: Equilibria with varying heterogeneity and cost of collateral

Note on the figure: $f_l = 0.5, f_m = 0.3, f_h = 0.2$, cost of VC is set to be prohibitively high and $I_l > I_h$

We see in figure 7 the bank can shut down the high default probability types for higher heterogeneity. The intuition is similar to above, that with highly heterogeneous entrepreneurs, the incentive to separate is higher as the bank can extract surplus from each type. With higher d, θ_h is higher as well and the surplus it produces is smaller (though positive) and any attempt to separate it will not be worth given the high cost of VC. Therefore, instead of pooling it with the others, the bank chooses to not serve the high type. These are the two shut-down regions in the right. As discussed earlier these regions generate social loss due to exclusion of socially desirable projects.

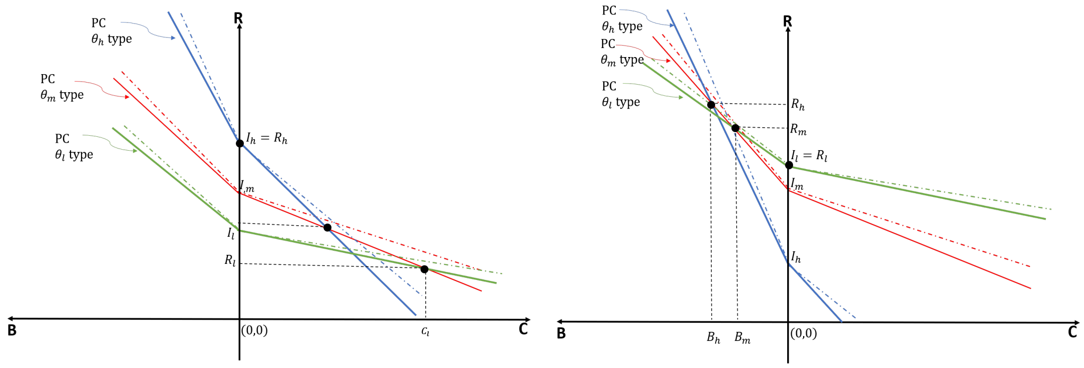
5 Alternative assumptions

In this section we discuss the alternative assumptions to the ones made in the previous section.

5.1 If $I_l < I_m < I_h$ or $I_h < I_m < I_l$

Let us start with the violation of assumption 5. Suppose instead of the two possibilities discussed in section 4 where θ_m is the top type, we have the θs such that either $I_l < I_m < I_h$ or $I_h < I_m < I_l$ holds. We can analyse these two scenarios with the graphical tool developed in the previous section. Using the fact that the bank will never use both VC investment and Collateral in a contract we can restrict our attention again to the 2-dimensional planes as in figure 4.

Let us consider the case when $I_l < I_m < I_h$. The low type is the bottom type and under asymmetric information all the other types would mimic it should the bank offer the symmetric information contracts. How does the bank distort the contract of the θ_l type to prevent that? Offering a VC contract will not help as the higher default probability types would prefer such a contract even more. So, the bank can offer the low type a collateralized credit, asking it to put up a collateral and pay a lower interest rate – something that the higher default probability types would not find attractive. However, there is still a threat of θ_h type selecting the first best contract of the θ_m type. To address that the bank needs to distort it as well. Again VC contract will not be effective, but requiring a collateral will still work as the high risk type would prefer not to put up a collateral (figure 8a).



(a) An example of a 'credit-only' equilibria when $I_l < I_m < I_h$

(b) An example of a 'VC-only' equilibria when $I_h < I_m < I_l$

Figure 8: Contracts when θ_m is not the top type

Thus we see, in such a scenario no VC contract is offered. Of course whether the bank ultimately separates all the types or engages in some form of pooling would depend on other parameters such as heterogeneity and cost of collateral $(1-\beta)$ but what is true regardless is that the bank will never offer a VC contract in this scenario.

A symmetric line of arguments in case of $I_h < I_m < I_l$, will establish that we will observe only VC market as collateralized credit will never be effective in sorting the entrepreneurs (figure 8b).

5.2 If $\kappa \le \gamma + v_0$ or $\gamma + v_0 + v_1 \le \kappa$

Let us discuss what happens when either of the two inequalities in assumption 3 is not met. Suppose $\kappa \le \gamma + v_0$, then using (8) we can see $I'(\theta) < 0, \forall \theta \in (0,1)$. This implies $I_h < I_m < I_l$ and we just showed above in such case we shall observe only VC contracts as collateral is not an effective screening device. This result is related to Lengwiler and Rishabh (2017) where they show for $\kappa = \gamma$ and $v_1 = 0$ but for any arbitrary type distribution that bank will not find collateral any useful. Besanko and Thakor (1987) show the same in two type borrower case. Here we show that indeed collateral will not work as a screening device but the bank can offer VC contracts to make up for that.

What about when $\gamma + v_0 + v_1 \le \kappa$? First note $I'(\theta) = \frac{\kappa - \gamma - v_0 - v_1(2\theta - \theta^2)}{(1-\theta)^2}$. Further for $\theta \in (0,1)$, $0 < 2\theta - \theta^2 < 1$. Therefore if $\gamma + v_0 + v_1 \le \kappa$ then $I'(\theta) > 0$. This implies $I_l < I_m < I_h$ but for this case we already showed that collateralzed credit will work but not the VC. Therefore, if $\gamma + v_0 + v_1 \le \kappa$ we will observe only credit contracts and no VC.

This helps us bring the results in section 4 together with the discussion here. We get three distinct regions as shown in figure 9.

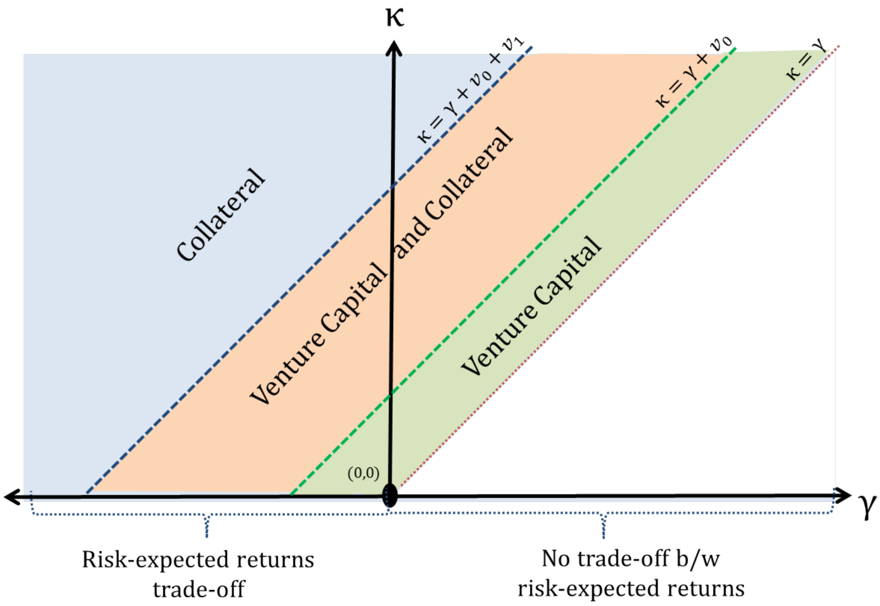


Figure 9: Set of possible equilibrium contracts

In the middle region the possible set of contracts in equilibrium support bank as a venture capitalist. In the two adjoining regions, the bank has to take form of a pure credit granting institution or a pure VC. It turns out that the parameter v_1 has a significant role in this trifurcation. As v_1 becomes larger the region that supports bank as a VC expands.

5.3 Alternative V functions

This refers to our assumption 2. We already discussed the assumption about increasing V function in section 4. Here we will talk about the assumption that V is quadratic in θ. The idea here is that when the outside opportunity increases at sufficiently high rate with the type then, under symmetric information, in order to serve the higher types, eventually the bank will need to lower the interest rate it charges on its credit. This creates incentives for the medium types to prefer symmetric information contracts of both the lower and higher types. This creates the need to distort the contracts of the non-medium types in two different directions – one through collateral and one through VC. Any V function that satisfies this property will generate these incentives and therefore a co-existence of collateralized credit with VC financing. Our quadratic V function is one such example. For instance, a cubic or quartic function would also work and in a more extreme example an exponential V function would also generate these incentives.

In contrast to non-linear V function, a linear V function would generate incentives for the higher type to mimic the lower types or lower types to mimic the higher types but never both! Our theory is capable of handling these situations as well and we showed above that in the former case the bank will employ collateral and in the latter case venture capital to screen entrepreneurs.

6 Conclusion

Large banks across several economies have forayed into the venture capital market. In this paper I have presented a model of intermediation that explains the emergence of bank as a venture capitalist. I show when the bank is in a situation that it cannot effectively separate the observationally identical entrepreneurs just with the use of collateral, it resorts to VC financing. I show this kind of situation may arise when an entrepreneur's project returns as well as her reservation utility depend on her risk type. The model predicts that from the bank's menu of contracts, the high risk entrepreneurs choose a VC contract. Where a VC contract consists of an additional investment by the bank on providing the value adding services and some other benefits, such as cash compensation against an equity share in the project. The low risk entrepreneurs self select into the collateralized credit contract. I also discuss the welfare properties of the optimal contracts. In particular, I show that if the bank's VC business is prohibited (or is prohibitively costly) then inefficiency due to restricted market access may ensue as the bank may decide not to serve all the types.

Appendix A Bank affiliated venture capital investment

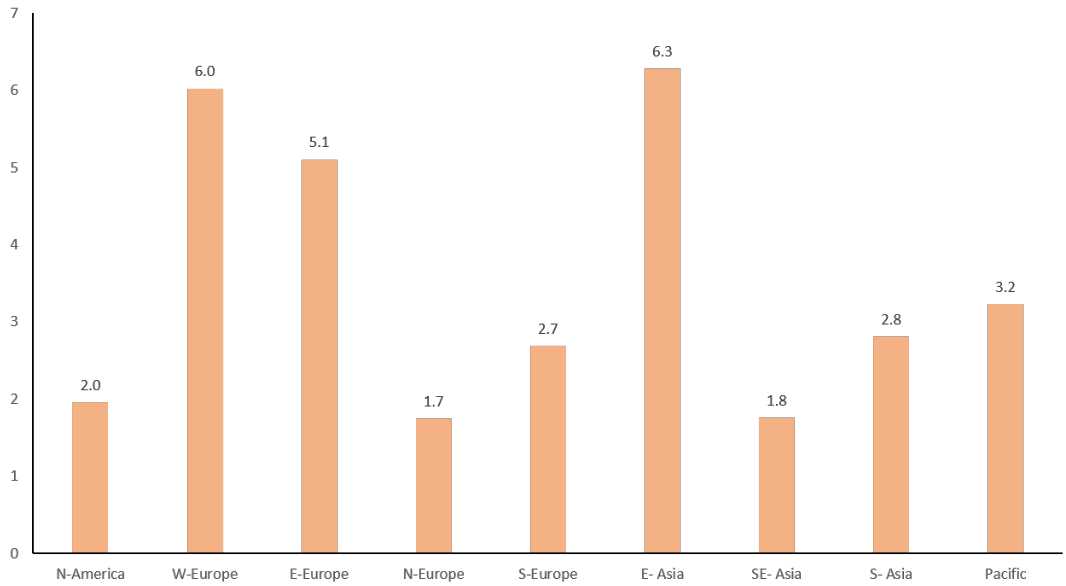


Figure A.1: Share of investment by bank affiliated venture capital firms of the total VC investment in the period 2013-17

Notes on the figure: Data is in percent. Source: Thomson One database on private equity.

Appendix B Proofs

Solution to P-II

Using Lemma 1 and equation (8) we make the following substitutions for R_l and R_h in P-II:

$$R_l = I_l - \frac{\theta_l}{1-\theta_l} C_l + \left[\delta + \frac{\lambda}{1-\theta_l}\right] B_l$$

$$R_h = I_h - \frac{\theta_h}{1-\theta_h} C_h + \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h$$

Therefore, the Lagrangian for the problem is given by:

$$\begin{aligned}
\mathscr{L} = &\left[S_l - \theta_l(1-\beta)C_l - \{\phi - \lambda - \delta(1-\theta_l)\}B_l\right] f_l + \left[(1-\theta_m)R_m + \theta_m \beta C_m - \phi B_m - 1\right] f_m \\
&+ \left[S_h - \theta_h(1-\beta)C_h - \{\phi - \lambda - \delta(1-\theta_h)\}B_h\right] f_h \\
&- \mu_1 \left[V_m - (1-\theta_m)Y_m + (1-\theta_m)R_m + \theta_m C_m - \{\lambda + \delta(1-\theta_m)\}B_m\right] \\
&- \mu_2 \left[R_m + \frac{\theta_m}{1-\theta_m} C_m - \left\{\delta + \frac{\lambda}{1-\theta_m}\right\} B_m - I_l - \Delta_{ml} C_l + \lambda \Delta_{ml} B_l\right] \\
&- \mu_3 \left[R_m + \frac{\theta_m}{1-\theta_m} C_m - \left\{\delta + \frac{\lambda}{1-\theta_m}\right\} B_m - I_h + \Delta_{hm} C_h - \lambda \Delta_{hm} B_h\right]
\end{aligned}$$

Where $\Delta_{ij} := \dfrac{\theta_i - \theta_j}{(1-\theta_i)(1-\theta_j)} = \left[\dfrac{\theta_i}{1-\theta_i} - \dfrac{\theta_j}{1-\theta_j}\right] = \left[\dfrac{1}{1-\theta_i} - \dfrac{1}{1-\theta_j}\right]$ and $\Delta_{ml} > 0$, $\Delta_{hm} > 0$. μ_1, μ_2, μ_3 are the Lagrange multipliers.

The Kuhn-Tucker conditions are:

$$-f_l\theta_l(1-\beta)+\mu_2\Delta_{ml}\le 0, \qquad C_l[-f_l\theta_l(1-\beta)+\mu_2\Delta_{ml}]=0 \tag{B.1}$$

$$-f_h\theta_h(1-\beta)-\mu_3\Delta_{hm}\le 0, \qquad C_h[-f_h\theta_h(1-\beta)-\mu_3\Delta_{hm}]=0 \tag{B.2}$$

$$-f_l\{\phi-\lambda-\delta(1-\theta_l)\}-\mu_2\lambda\Delta_{ml}\le 0, \qquad B_l[-f_l\{\phi-\lambda-\delta(1-\theta_l)\}-\mu_2\lambda\Delta_{ml}]=0 \tag{B.3}$$

$$-f_h\{\phi-\lambda-\delta(1-\theta_h)\}+\mu_3\lambda\Delta_{hm}\le 0, \qquad B_h[-f_h\{\phi-\lambda-\delta(1-\theta_h)\}+\mu_3\lambda\Delta_{hm}]=0 \tag{B.4}$$

$$f_m\theta_m\beta-\mu_1\theta_m-\mu_2\frac{\theta_m}{1-\theta_m}-\mu_3\frac{\theta_m}{1-\theta_m}\le 0, \qquad C_m[f_m\theta_m\beta-\mu_1\theta_m-\mu_2\frac{\theta_m}{1-\theta_m}-\mu_3\frac{\theta_m}{1-\theta_m}]=0 \tag{B.5}$$

$$\begin{aligned}&-f_m\phi+\mu_1\{\lambda+\delta(1-\theta_m)\}+\mu_2\left\{\delta+\frac{\lambda}{1-\theta_m}\right\}+\mu_3\left\{\delta+\frac{\lambda}{1-\theta_m}\right\}\le 0,\\ &B_m\left[-f_m\phi+\mu_1\{\lambda+\delta(1-\theta_m)\}+\mu_2\left\{\delta+\frac{\lambda}{1-\theta_m}\right\}+\mu_3\left\{\delta+\frac{\lambda}{1-\theta_m}\right\}\right]=0\end{aligned} \tag{B.6}$$

$$f_m(1-\theta_m)-\mu_1(1-\theta_m)-\mu_2-\mu_3\le 0, \qquad R_m[f_m(1-\theta_m)-\mu_1(1-\theta_m)-\mu_2-\mu_3]=0 \tag{B.7}$$

In addition, the complementary slackness conditions given the constraints in (P-II) are:

$$\mu_1\ge 0, \qquad \mu_1[V_m-(1-\theta_m)Y_m+(1-\theta_m)R_m+\theta_mC_m-\{\lambda+\delta(1-\theta_m)\}B_m]=0$$

$$\mu_2\ge 0, \qquad \mu_2\left[R_m+\frac{\theta_m}{1-\theta_m}C_m-\left\{\delta+\frac{\lambda}{1-\theta_m}\right\}B_m-I_l-\Delta_{ml}C_l+\lambda\Delta_{ml}B_l\right]=0$$

$$\mu_3\ge 0, \qquad \mu_3\left[R_m+\frac{\theta_m}{1-\theta_m}C_m-\left\{\delta+\frac{\lambda}{1-\theta_m}\right\}B_m-I_h+\Delta_{hm}C_h-\lambda\Delta_{hm}B_h\right]=0$$

Starting with (B.3), Suppose $B_l>0$, then $\mu_2=-\frac{f_l\{\phi-\lambda-\delta(1-\theta_l)\}}{\lambda\Delta_{ml}}<0$, a contradiction. Therefore, $B_l=0$. Similarly, solving (B.2) under the assumption $C_h>0$, will lead us to a contradiction implying that $C_h=0$. Note these are true regardless of whether C_l and B_h are non-zero or not.
Now consider if $C_m>0$, then $f_m\beta=\mu_1+\frac{\mu_2}{1-\theta_m}+\frac{\mu_3}{1-\theta_m}$,
if $B_m>0$ then $f_m\phi=[\lambda+\delta(1-\theta_m)]\left[\mu_1+\frac{\mu_2}{1-\theta_m}+\frac{\mu_3}{1-\theta_m}\right]$ and,
if $R_m>0$ then $f_m=\mu_1+\frac{\mu_2}{1-\theta_m}+\frac{\mu_3}{1-\theta_m}$.
Comparing any two of the three conditions, pairwise, will lead to contradiction implying $R_mB_m=0$, $C_mB_m=0$ and $R_mC_m=0$. This leaves us with the following possibilities:
(i) $R_m=0$, $C_m=0$, $B_m=0$ (ii) $R_m=0$, $C_m=0$, $B_m>0$ (iii) $R_m=0$, $C_m>0$, $B_m=0$ and (iv) $R_m>0$, $C_m=0$, $B_m=0$.
Offering (i) and (ii) are irrational and therefore are ruled out. Offering (iii) cannot be profit maximizing: suppose to the contrary, it is and (iii) satisfies all the constraints but then by reducing C_m slightly and increasing R_m at the same time such that constraints are still satisfied will lead to an unambiguous increase in profit. Therefore, the only possibility that remains is $R_m>0$, $C_m=0$, $B_m=0$ as a result $f_m=\mu_1+\frac{\mu_2}{1-\theta_m}+\frac{\mu_3}{1-\theta_m}$ holds.

Finally, given that $C_h=0=B_l$ under the assumption of complete separation bank must choose positive values of C_l and B_h, otherwise there are not enough devices to screen the entrepreneurs. Thus, under complete separation $C_l > 0$ and $B_h > 0$, that gives us

$$\mu_2 = \theta_l(1-\beta)\frac{f_l}{\Delta_{ml}} \tag{B.8}$$

$$\mu_3 = \{\phi - \lambda - \delta(1-\theta_l)\}\frac{f_h}{\lambda\Delta_{hm}} \tag{B.9}$$

Given that $0 < \beta < 1$, $\phi - \lambda - \delta(1-\theta_l) > 0$ and $\Delta_{ml}, \Delta_{hm} > 0$ we have $\mu_2 > 0$ and $\mu_3 > 0$. Therefore, complementary slackness conditions imply that the IC_{ml} and IC_{mh} in (P-II) bind.

Also $\mu_1 \geq 0$ implies, $f_m - \frac{\mu_2}{1-\theta_m} - \frac{\mu_3}{1-\theta_m} \geq 0$. Now using the expressions for μ_2 and μ_3 from (B.8) and (B.9) above we get the following necessary condition for complete separation:

$$\frac{1}{f_m}\left[(1-\beta)\theta_l f_l\left(\frac{1-\theta_l}{\theta_m-\theta_l}\right) + \{\phi-\lambda-\delta(1-\theta_h)\}\frac{f_h}{\lambda}\left(\frac{1-\theta_h}{\theta_h-\theta_m}\right)\right] \leq 1$$

We also require conditions that ensure that by separating the types the bank does not make negative profits on any type. Given the result from Lemma 1 that the types θ_h and θ_l non-negative profit condition puts upper bounds on C_l and B_h as below:

$$C_l \leq \frac{S_l}{\theta_l\,(1-\beta)} \quad \text{and} \quad B_h \leq \frac{S_h}{\phi-\lambda-\delta(1-\theta_h)}$$

Now we can solve for the optimal contracts under complete separation using the above results. The optimal contracts are given in the main text in (11).

Proof of Lemma 2

We show that solution in (11) is also a solution to the original problem, P-I by showing that this solution satisfies all the remaining constraints in P-I. There are four remaining ICs from P-I that are to be checked. These are IC_{lm}, IC_{hm}, IC_{hl} and IC_{lh}.

Proof.
Solution to P-II already satisfies IC_{ml} and IC_{mh}. We consider the remaining four ICs.
IC_{lm} and IC_{hm}:
Consider a $k \in \{l,h\}$

$$I_k < I_m \quad \text{[By assumption for } k \in \{l,h\}\text{]}$$

$$\Rightarrow \quad I_k - \frac{\theta_k}{1-\theta_k}C_k + \left[\delta + \frac{\lambda}{1-\theta_k}\right]B_k + \frac{\theta_k}{1-\theta_k}C_k - \left[\delta + \frac{\lambda}{1-\theta_k}\right]B_k < I_m$$

$$\Rightarrow \quad R_k + \frac{\theta_k}{1-\theta_k}C_k - \left[\delta + \frac{\lambda}{1-\theta_k}\right]B_k < R_m + \frac{\theta_k}{1-\theta_k}C_m - \left[\delta + \frac{\lambda}{1-\theta_k}\right]B_m$$

The last step uses the solution to P-II. This implies IC_{km} is satisfied for $k \in \{l,h\}$ using the definition in (9).
IC_{hl}:
For IC_{hl}, we need to consider the two possible cases: $I_h < I_l$ and $I_h > I_l$. If $I_h < I_l$ then,

$$I_h < I_l$$

Since $\Delta_{hl} > 0$ and $C_l > 0$, the above inequality still holds with the following addition on the right hand side:

$$I_h < I_l + \Delta_{hl} C_l$$

Now noting that $B_l = 0 = C_h$

$$\begin{aligned}
& I_h + \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h + \frac{\theta_h}{1-\theta_h} C_h - \frac{1}{1-\theta_h} B_h && < I_l + \Delta_{hl} C_l - \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_l \\
\Rightarrow \quad & R_h + \frac{\theta_h}{1-\theta_h} C_h - \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h && < I_l + \Delta_{hl} C_l - \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_l \quad \text{[using solution to P-II]} \\
\Rightarrow \quad & R_h + \frac{\theta_h}{1-\theta_h} C_h - \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h && < I_l - \frac{\theta_l}{1-\theta_l} C_l + \frac{\theta_h}{1-\theta_h} C_l - \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_l \\
\Rightarrow \quad & R_h + \frac{\theta_h}{1-\theta_h} C_h - \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h && < R_l + \frac{\theta_h}{1-\theta_h} C_l - \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_l \quad \text{[using solution to P-II]}
\end{aligned}$$

This implies IC_{hl}. For the case when $I_h > I_l$ we have,

$$\begin{aligned}
& I_l < I_h \\
\Rightarrow \quad & I_h - I_l < I_m - I_l && \text{[since } I_m > I_h > I_l\text{]} \\
\Rightarrow \quad & I_h - I_l < [I_m - I_l] \underbrace{\left(\frac{\theta_h - \theta_l}{\theta_m - \theta_l}\right)}_{>1} \underbrace{\left(\frac{1-\theta_m}{1-\theta_h}\right)}_{>1} \left(\frac{1-\theta_l}{1-\theta_l}\right) && \text{[since } \theta_h > \theta_m > \theta_l\text{]} \\
\Leftrightarrow \quad & I_h - I_l < [I_m - I_l] \frac{1}{\Delta_{ml}} \Delta_{hl} \\
& \quad \Rightarrow \quad I_h < I_l + \Delta_{hl} C_l && \text{[using solution to P-II]}
\end{aligned}$$

Now we are back in the second step of proof in the previous case from where we already showed IC_{hl}.

IC_{lh}:

Again there are two possible cases. We start with $I_l < I_h$.

$$I_l < I_h$$

Since $\Delta_{hl} > 0$, $\lambda > 0$ and $B_h > 0$ the above inequality still holds with the following addition on the right hand side:

$$I_l < I_h + \lambda \Delta_{hl} B_h$$

Now noting that $B_l = 0 = C_h$

$$
\begin{aligned}
& I_l - \frac{\theta_l}{1-\theta_l}C_l + \frac{\theta_l}{1-\theta_l}C_l - \left[\delta + \frac{\lambda}{1-\theta_l}\right]B_l && < I_h + \lambda\Delta_{hl}B_h + \frac{\theta_l}{1-\theta_l}C_h \\
\Rightarrow\ & R_l + \frac{\theta_l}{1-\theta_l}C_l - \left[\delta + \frac{\lambda}{1-\theta_l}\right]B_l && < I_h + \lambda\Delta_{hl}B_h + \frac{\theta_l}{1-\theta_l}C_h \quad \text{[using solution to P-II]} \\
\Leftrightarrow\ & R_l + \frac{\theta_l}{1-\theta_l}C_l - \left[\delta + \frac{\lambda}{1-\theta_l}\right]B_l && < I_h + \frac{\lambda}{1-\theta_h}B_h - \frac{\lambda}{1-\theta_l}B_h + \frac{\theta_l}{1-\theta_l}C_h \\
\Leftrightarrow\ & R_l + \frac{\theta_l}{1-\theta_l}C_l - \left[\delta + \frac{\lambda}{1-\theta_l}\right]B_l && < I_h + \left[\delta + \frac{\lambda}{1-\theta_h}\right]B_h - \left[\delta + \frac{\lambda}{1-\theta_l}\right]B_h + \frac{\theta_l}{1-\theta_l}C_h \\
\Rightarrow\ & R_l + \frac{\theta_l}{1-\theta_l}C_l - \left[\delta + \frac{\lambda}{1-\theta_l}\right]B_l && < R_h + \frac{\theta_l}{1-\theta_l}C_h - \left[\delta + \frac{\lambda}{1-\theta_l}\right]B_h \quad \text{[using solution to P-II]}
\end{aligned}
$$

This implies IC_{lh}. In the case $I_h < I_l$ we have,

$$
\begin{aligned}
& I_h < I_l \\
\Rightarrow\ & I_l - I_h < I_m - I_h \qquad \text{[since } I_m > I_l > I_h\text{]}
\end{aligned}
$$

Noting that the function $\frac{\theta_h - \theta}{1-\theta}$ is decreasing in θ, we have,

$$
\begin{aligned}
& I_l - I_h < [I_m - I_h] \underbrace{\left(\frac{\frac{\theta_h-\theta_l}{1-\theta_l}}{\frac{\theta_h-\theta_m}{1-\theta_m}}\right)}_{>1} \left(\frac{1-\theta_h}{1-\theta_h}\right) \\
\Leftrightarrow\ & I_l - I_h < [I_m - I_h]\frac{1}{\Delta_{hm}}\Delta_{hl} \\
\Rightarrow\ & I_l < I_h + \lambda\Delta_{hl}B_h \qquad \text{[using solution to P-II]}
\end{aligned}
$$

Now rest of the proof follows the same steps as in the previous case, giving us IC_{lh} again. QED

Proof of Proposition 2

Following the discussion in section 4.2, $BiCi = 0\ \forall i \in \{l, m, h\}$ will hold. Further, any partial pooling must involve two top types (i.e. θ_m with one other type). Since the optimal contracts depend upon who the bank separates, we discuss each case separately.

If $I_h < I_l < Im$, then the bank would pool types θ_m and θ_l and separate θ_h types. As we discussed earlier in order to separate the θ_h types, distortion should be through a VC contract that satisfies all the constraints in (P-I).

Proof.
For the pooled types, an undistorted contract that would attract the two top types is the first best contract of θ_l type. Therefore the bank would offer

$$
R_l = R_m = I_l, \qquad C_l = C_m = 0, \qquad B_l = B_m = 0
$$

Clearly this contract, would not be attractive for θ_h type and therefore satisfies IC_{hm} and IC_{hl}. IC_{mh} and IC_{lh}, are the ICs that imply distortion in the first best contract of of the θ_h type. That is offering a benefits (VC contract) to θ_h type. How much should the benefits be? Enough that IC_{mh} is satisfied with equality. Keeping in mind $C_h = 0$ and $B_m = C_m = 0$, IC_{mh} is:

$$R_m = R_h - \left[\delta + \frac{\lambda}{1-\theta_m}\right] B_h$$
$$\Rightarrow \quad I_l = R_h - \left[\delta + \frac{\lambda}{1-\theta_m}\right] B_h \qquad\qquad [\text{since } R_m = I_m = I_l]$$

Using the PC for θ_h.

$$I_l = I_h + \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h - \left[\delta + \frac{\lambda}{1-\theta_m}\right] B_h$$
$$\Rightarrow \quad B_h = \frac{I_l - I_h}{\lambda \Delta_{hm}}$$

And $R_h = I_h + \left[\delta + \frac{\lambda}{1-\theta_h}\right] B_h$. It can be checked this contract will satisfy IC_{lh} as well.

Therefore, the bank's profit under partial pooling is:

$$\pi^{pp} = \left[f_l\{(1-\theta_l)I_l - 1\} + f_m\{(1-\theta_m)I_l - 1\} + f_h\{(1-\theta_h)R_h - \phi B_h\}\right]$$

and can be expressed as:

$$\pi^{pp} = f_l S_l + f_m S_m - f_m(1-\theta_m)[I_m - I_l] + f_h S_h - \{\phi - \lambda - \delta(1-\theta_h)\} f_h \frac{I_l - I_h}{\lambda \Delta_{hm}}$$

Before finding the condition for partial pooling, let us consider the optimal contracts for complete pooling. Since $I_h < I_l < Im$, in the complete pooling equilibrium the bank would offer $R_l = R_m = R_h = I_h$, $C_h = C_m = C_l = 0$, $B_l = B_m = B_h = 0$. Bank's profit under pooling equilibrium is

$$\pi^{pool} = f_l S_l + f_m S_m + f_h S_h - f_l(1-\theta_l)[I_l - I_h] - f_m(1-\theta_m)[I_m - I_h]$$

The bank would partially pool if $\pi^{pp} \geq \pi^{pool}$, which gives us:

$$\frac{1}{f_m}\left[\{\phi - \lambda - \delta(1-\theta_h)\} \frac{f_h}{\lambda} \left(\frac{1-\theta_h}{\theta_h - \theta_m}\right) - f_l \left(\frac{1-\theta_l}{1-\theta_m}\right)\right] \leq 1$$

QED

Proof of Proposition 3

Proof.

For the case $I_l < I_h < Im$, the proof follows the same steps as in the proof of the proposition 2. In this case the top two types – θ_m and θ_h are pooled. The separated type is the low type. Since, the bank will not use benefits to separate the low type, the bank will set $B_l = 0$. Following the same steps as above we can show that the optimal contracts are:

$$R_h = R_m = I_h, \qquad C_h = C_m = 0, \qquad B_h = B_m = 0$$
$$R_l = I_l - \frac{\theta_l}{1-\theta_l} C_l, \qquad C_l = \frac{I_h - I_l}{\Delta_{ml}}, \qquad B_l = 0$$

Further, optimal contracts under complete pooling in the case of $I_l < I_h < Im$ are given by: $R_l = R_m = R_h = I_l$, $C_h = C_m = C_l = 0$, $B_l = B_m = B_h = 0$ Comparing profits in the two cases will gives us:

$$\frac{1}{f_m}\left[(1-\beta)\theta_l f_l\left(\frac{1-\theta_l}{\theta_m-\theta_l}\right)-f_h\left(\frac{1-\theta_h}{1-\theta_m}\right)\right]\leq 1$$

QED

Proof of Proposition 4

Proof. Follows directly from the proofs of propositions 2 and 3. QED

Proof of Proposition 5

Proof. Since the only screening device that is effective in screening the θ_h types is too costly to be employed if the bank wants to serve the θ_h types it needs to pool them with at least one other type. However, θ_h types cannot be partially pooled with any other type given $I_h < I_l < I_m$ because it will not be incentive compatible. Thus, given (C.2) is satisfied, the bank has three options given $I_h < I_l < I_m$ (a) pool all the types, (b) shut down high default probability type and separate the other two types and (c) shut down high default probability type and pool the other two types. The conditions that govern which of the three options are chosen are derived by comparing the profits under the three options.

Therefore, given $I_h < I_l < I_m$, the only equilibrium consistent with profit maximization where θ_h is served must be pooling at the contract that just satisfies the PC of the θ_h types. That is at $(I_h, 0, 0)$.

Bank's profit under pooling equilibrium is

$$\pi^{pool} = f_l S_l + f_m S_m + f_h S_h - f_l(1-\theta_l)[I_l - I_h] - f_m(1-\theta_m)[I_m - I_h]$$

If the bank instead does not serve the θ_h types, the contracts that serve the remaining types should not be attractive to the θ_h types. Focusing on the remaining types and considering the separation between θ_m and θ_l types, the incentive compatible solution can be derived in a similar manner as in the separation problem (P-I). This will give us the contracts in (14). It can be checked that these contracts deliver strictly less utility than V_h to the θ_h types. Bank profit in this case is given by:

$$\pi^{sds} = f_l S_l + f_m S_m - f_l\theta_l(1-\beta)\left[\frac{I_m - I_l}{\Delta_{ml}}\right]$$

Finally, when the bank shuts down the θ_h types but pools the remaining types it must involve no collateral as well. Thus, the only profit maximization consistent contract that serves the purpose is the full information contract for θ_l type, i.e., $(I_l, 0, 0)$. The bank profit in this case is:

$$\pi^{sdp} = f_l S_l + f_m S_m - f_m(1-\theta_m)[I_m - I_l]$$

Now we know the bank will pool all the type if: $\pi^{pool} \geq max\{\pi^{sds}, \pi^{sdp}\}$ and this gives us the first condition in the proposition. The bank will shut down θ_h type if the above does not hold. It will in turn either separate or pool the other types depending upon if $\pi^{sds} \geq \pi^{sdp}$ and this gives us the two other conditions. QED

Proof of Proposition 6

Proof. Similar to Propositions (3) and (5). QED

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