The Asian Crisis: Business As Usual?*

Khang Min Lee
Department of Economics and Statistics (NUS)

Jim Storey
Faculty of Commerce and Business Administration (UBC)

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Khang Min Lee can be contacted at ecsleekm@nus.edu.sg and Jim Storey can be contacted at james.storey@commerce.ubc.ca

Abstract In this paper, we make the first steps at a modeling exercise which explicitly considers interactions between the real and financial sectors of an economy that features irreversible investment, and privately observed information about uncertain demand. This economy has entrepreneurs and a representative bank; the entrepreneurs derive (non-dissipative) private benefits from project management as well as receiving the net revenues from successful projects. These entrepreneurs also face a personal cost associated with default on debt obligations. Entrepreneurs are presumed unable to meet the costs of financing their continuing investment needs through internal sources. These financing requirements are primarily met through recourse to a competitive banking sector.

We are particularly concerned with the influence on the entrepreneurs' real investment behaviour of the use of external financing (as opposed to internal financing measures). We address two important issues: first, given the real sector characteristics, what is the maturity structure of debt contracts that are offered, and how are the interest rates on these loans determined? Second, how does the financing environment affect the investment decisions that entrepreneurs make?

We find that tensions associated with external finance lead to inefficiencies in information aggregation. Specifically, information is revealed later than it would be in an economy with only internal financing. Further, although the investment choices are not a function of the debt contract specifics, entrepreneurs do have a preference for short-term debt contracts. We interpret the model in the context of the Asian crisis.

Although there is much about the crisis in Asia which is idiosyncratic to the different countries involved, there are some general observations which can be drawn and one of the most fundamental of these is the corporate nature of this event. Corporate crises have occurred before, but never with such ferocity or with the capacity to impoverish so many. The apparent inadequacies of self-interested entrepreneurs and their bankers has been interpreted by many as a failure of markets to deliver stable and secure growth, and has generated numerous calls for a variety of market restricting controls, regulations and interventions. It is vitally important to understand the causes of the crisis, and in particular, the relationship between the financial sector and the real sector, before such distortive measures are intoduced in the financial markets.

Modeling exercises purporting to help explain the crisis should endeavour to answer numerous questions. Among these is the question of how the crisis was triggered – why did it happen when it did? Was the trigger real or financial? In this paper, we make the first steps at a modeling exercise which explicitly considers interactions between the real and financial sectors of an economy that features irreversible investment and uncertain demand. This economy has entrepreneurs and a representative bank; the entrepreneurs derive (non-dissipative) private benefits from project management as well as receiving the net revenues from successful projects. These entrepreneurs also face a personal cost associated with default on debt obligations.[1] The default

[1] This cost is modelled in such a way as to allow interpretation of a reduction in costs as the result of an increase in outside (*i.e.,* government) guarantees of the entrepreneurs' debt. It also admits the interpretation, used here, of the uncertainty that might be generated in the absence of clearly specified and administered bankruptcy law. In other words, the entrepreneur may not be completely protected by limited liability, may have instead an implicit guarantee from the government, or may even simply be unhappy about the prospect of defaulting on a loan even in the presence of both full limited liability and full explicit government guarantees.

cost is in addition to the loss of the project.

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1 Introduction

We build a model in which the real and financial sectors interact to generate crisis events. In the simplest terms, the paper extends the model of irreversible investment of Caplin and Leahy (AER, 1994) by supposing that entrepreneurs are unable to meet the costs of financing their continuing investment needs through internal sources. In other words, entrepreneurs that choose to continue project development face positive net external financing requirements; these requirements are primarily met through recourse to a competitive banking sector. Financial market structures are taken as given rather than determined endogenously; this modeling decision reflects not only the benefits of the simplicity it generates but also our belief that the primary forces shaping financial market development in many of the economies we attempt to model are more at home in models of corruption and rent-seeking and would distract from our analysis.

Ex ante profitable projects require several (irreversible) interim payments to generate (homogeneous) output in the final period. Each period, entrepreneurs choose between suspending and continuing active projects; they base these choices on their expectations about the level of demand for the output. These expectations are in turn conditioned on privately observed signals[2] and the information revealed by the publicly observeable choices of other entrepreneurs to continue or suspend their own project development. Suspended projects can be reinitiated but this involves an extra cost. The focus is on the timing of suspensions and the influence that the first suspensions can have on other entrepreneurs. Effectively, the irreversibility of investment and the reinitiation costs generate inertia in the decision to continue that is overcome only when private information becomes bad enough; when this happens other entrepreneurs receive a large lump of negative information that may cause them to suspend *en masse* and generate a crash in investment.

The model that we use to motivate the real side of our paper has a fairly specialised structure designed to address questions of information aggregation within a single industry. We feel that basing the real sector components of our modeling strategy on the interactions of investment irreversibility and private information has a number of arguments in its favour. One of the primary considerations that we have in mind is the need to consider the *timing* of broad-based shifts in economic activity. Such widespread changes in the level of economic activity have been a central feature of the crises in Southeast Asia and it is important to understand not only their general causes but the mechanism leading to sudden and broadly unforseen collapse. There is also a strong argument to be made that much of the borrowing that occurred in both Korea and the ASEAN 4 was financing project development in industries like real estate or heavy manufacturing that feature precisely the long gestation periods and irreversibility that the model exhibits.[3] The model

[2]These signals are *costly* in the sense that they are received only after the investment for that period is made. As such, the model can reasonably be thought of as similar to one of sequential purchases of signals.

[3]ASEAN 4 refers to Indonesia, Thailand, Malaysia, and the Philippines, each of which

also generates the apparent over-capacity that now exists in these industries. Perhaps most importantly, it is consistent with the regional declines in export demand and physical investment that *preceded* the floating of the Thai baht, often identified as the start of the crisis.

At the same time, financial sector crisis has also been fundamental to recent events, leading many to speculate that these crises may be entirely financial in nature. It is thus important to have a model in which the financial and real sectors interact in a meaningful way. Incorporating the financial sector allows us to explicitly examine a number of important questions including the maturity structure of debt contracts that banks are willing to offer to borrowing entrepreneurs. This is an important consideration because the preponderance of short-term debt has been singled out as an important aspect of the crisis.[4]

Although we have built our model to reflect some of the institutional

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are members of the Association of Southeast Asain Nations, or ASEAN. Korea is not a member of ASEAN as it is not a Southeast Asian country. The four are generally distinguished from the rest of ASEAN as the countries that were most heavily influenced by the crisis.

[4]We are currently working at extending the model to consider the much-discussed but ill-understood issue of *contagion* in an inter-industry context. The goal is to address the nature of the apparent liquidity crises which have crippled supposedly viable industries, especially exporters. In effect, substantial shifts in the viability of loans outstanding to one industry can constrain banks' ability to continue lending to other sectors, providing a clear channel for cross-sectoral contagion when intermediaries are sufficiently exposed to a sector in which activity crashes. This extended model is one in which real sector problems in one industry are transmitted to the financial sector, and then in turn to other industrial sectors. In other words, the crisis is precipitated by a shock to one real sector, but the spread of this shock to other sectors is heavily dependent upon the nature of financial intermediation in the economy. This suggests important policy prescriptions for emerging market economies interested in questions of the optimal sequencing of reforms and appropriate financial markets development. Recent work examining the possible role of the financial sector in transmitting small real shocks to other real sectors includes Kiyotaki and Moore (JPE, 1997) though their paper is motivated very differently and features a different transmission mechanism. For example, their paper looks only at idiosyncratic risk whereas our paper considers only aggregate risk.

features of the Asian countries that have been most affected by the recent crises, we feel that our work also makes a contribution in its focus on the interactions between investment irreversibility and the need to find external financing for those investments. Of course, a number of papers in corporate finance have considered problems associated with financing projects that feature some aspects of irreversibility, but there has been relatively little explicit and systematic investigation of this tension.

2 The Model

We model a real sector and a financial sector consisting of a banking industry which meets the financing needs of the real sector. The real sector is essentially built around the model of Caplin and Leahy (AER, 1994), whose notation we adopt, though we do depart from their model in some areas.

2.1 The Real Sector

There is a continuum of risk-neutral entrepreneurs considering operation within an industry that features free entry. Each potential entrant is faced with the choice of undertaking a project which will produce one unit of homogeneous output at time T. In order to realise this output at T, the entrepreneur must make an initial payment of κ and incremental investments at each $t < T$. We assume that the net financing requirement in each period can be normalised to one dollar. The mass of intial entrants is denoted E.

In each period, entrepreneurs with active investment projects must choose between continuing with the project or suspending the project for one period. The following period, a suspending entrepreneur must choose between abandonment and reinitiation.[5] The original suspension is costless, but should the

[5] At $T-1$ a choice of suspension is identical to a choice of abandonment.

entrepreneur choose to reinitiate the project in the following period the cost of doing so is $\mu\kappa + 2$ where $\mu\kappa \in [1 + r, \kappa]$. This cost structure means that entrepreneurs which initiate and never suspend incur total (undiscounted) costs of $\kappa + T$ while those who suspend once (and reinitiate) incur costs of $\kappa + T + \mu\kappa$.

Demand is uncertain, and will be either 0 or $P(Q)$; each of these demand outcomes occurs with *ex ante* probablilty of 1/2.[6] In addition to these common priors, entrepreneurs have two sources of information they can use to assess the conditional probability of the two demand states. First, they observe the past actions of other entrepreneurs. Thus at any t all entrepreneurs are aware of the mass of entrepreneurs that are in the continuation, suspension and abandonment states, and in particular, are aware of the mass of entrepreneurs who changed states at $t - 1$.[7]

Second, private information is acquired by entrepreneurs that are in the continuation state. Each period, entrepreneurs that make the continuation payment receive a private signal regarding the level of demand. Private signals can take one of two realisations (good and bad); the probability of receiving a good signal given that demand is in fact high is $p \in (0.5, 1)$; p is known to the entrepreneurs and is constant across the industry. As Caplin and Leahy point out, this implies that p can be interpreted as a measure of the informativeness of the signal received.[8] Signals are conditionally independent across entrepreneurs and through time, so the only way a given entrepreneur

[6] Each entrepreneur's project is assumed to be infinitesimal in relation to the market so entrepreneurs behave as a price-takers. We assume that the demand function is such that it is profitable *ex ante* for entrepreneurs to borrow and invest

[7] Note that the assumption of the existence of a continuum of entrepreneurs achieves substantial simplification, as incentives for strategic suspension are thereby avoided as are any concerns about the specific identity of suspending entrepreneurs.

[8] Entrepreneurs who reinitiate suspended projects receive two signals upon making the reinitiation payment.

can make inferences about the information received by other entrepreneurs is through observations of their behaviour. The vector of private signals received to time t is denoted by σ^t, and the conditional probability that demand is high given σ^t is denoted $h(\sigma^t)$.

The equilibrium concept applied is symmetric Nash equilibrium, implying that an equilibrium strategy π is one that is optimal conditional on the information revealed by the actions of other entrepreneurs, assuming that these other entrepreneurs are playing the same strategy. Note that π must therefore specify not only the entrepreneurs' investment strategy but also their financing strategy.

The key to finding an equilibrium is to note that the first suspensions fully reveal the state of demand. Why? Suppose that first suspensions occur at τ. Until τ, each entrepreneur shares the same priors and the same information about the others' financing and investment behaviour (*i.e.* that all of the other entrepreneurs have continued with their projects). Thus each entrepreneur can solve the problem that each other entrepreneur is solving. This means that at $\tau + 1$ each of the entrepreneurs knows the mass of entrepreneurs that suspended at τ, and knows the proportion of bad signals that each of the suspenders must have received in order to suspend.

Intuitively, the entrepreneurs that suspend are those who are most pessimistic about final demand – those who have received a sequence of only bad signals. The proportion of entrepreneurs that suspend is a function of the state of demand and reveals the true state of demand explicitly.[9] That the

[9] That is, you know the probability of a good signal given low demand ($q = 1-p$) and of course the probablility of a bad signal given low demand (p). You also know that because there is a continuum of entrepreneurs each profile of signals will occur with the appropriate probability. Thus, for example, after two periods, if demand is high the probability of σ^2 consisting of two good signals is p^2, two bad signals is q^2, and one good and one bad is $2pq$. Alternatively, if demand is low, the probability of σ^2 consisting of two good signals is q^2 and two bad signals is p^2 (the probability of σ^2 consisting of one good and one bad signal

true state of demand is known to all once the first suspensions take place substantially eases the characterisation of the suspension decisions. Throughout the paper, we denote by τ the lower bound on the suspension times that will be observed in equilibrium; τ plays an extremely important role in the analysis.

The final point of note has to do with the incentives of the entrepreneurs. We assume that the entrepreneurs derive (non-dissipative) utility, or private benefits, denoted by B, from managing an active project. Thus there is an incentive for a entrepreneur to continue operating a project even after a bad demand state has been revealed. Entrepreneurs also face a cost associated with a failure to pay back any funds they have borrowed to finance the project. This cost is modeled as a linear function of the face value of outstanding debt, with sensitivity parameter $\alpha \in [0, 1]$. We model α as a simple utility 'cost' (in dollar value terms); note that there are interpretations associated with α which may be quite instructive in the present context. For example, the existence of government guarantees of private sector corporate debt will mean a lower alpha, *ceteris paribus*. Alternatively, α can be viewed as a bankruptcy loss. In countries where bankruptcy laws are not well-defined, the entrepreneurs would be less accountable in a bad state and α would be low.

2.2 The Financial Sector

The financial sector consists of a representative bank that lends money to entrepreneurs in the real sector. The banking sector also features free entry so that the bank makes zero profits in expectation. The bank will lend to any entrepreneur which has a project with non-negative net present value.

is still $2pq$). Since $p \neq q$ and only the most pessimistic entrepreneurs will suspend, this means that the proportion of suspenders (either p^2 or q^2) will reveal the state of demand.

Entrepreneurs and banks begin the game with the same information.

In order to highlight the role played by the investment irreversibility in the face of uncertain demand, demand uncertainty is assumed to be the only source of credit risk. Banks do not see the private signals in any given industry; that is, as time proceeds for a given industry, banks have two information sources: the (common) priors and the observed actions of the entrepreneurs in the industry.[10]

Banks may offer a menu of debt contracts to the entrepreneurs. For simplicity, we restrict consideration of the maturity structure to just two contracts – short-term (or 1-period) debt and medium-term debt designed to fund entrepreneurs until the state of demand is known.[11] The lending rates associated with the short- and medium- term debt are denoted r_S and r_M respectively. In the case of the medium-term loan, entrepreneurs borrow the initial costs and the present value of the period-by-period investment requirements for the next $\tau - 1$ periods up-front. Loan proceeds are assumed to remain in an account earning risk-free interest with the bank that has made the loan.

We assume that the use of funds to make investments is observeable, and

[10]One might suppose that in a real world setting, banks could also draw information from the sequence of debt service payments that individual entrepreneurs' make. In general this is of course true. We abstract from this possibility by assuming that entrepreneurs do not make any debt service payments – a modeling decision which reflects our interest in the systematic (and not the idiosyncratic) aspects of the crisis. Because it is costly for the entrepreneur to default, the information that would be contained in a choice to miss a debt service payment is revealed immediately by the choice to suspend.

[11]The restriction of the debt contract space is justified by noting first that contracts with maturities longer than 1 period but shorter than the medium-term debt can be expressed as an equivalent sequence of 1-period contracts because during this period nothing relevant to the setting of the lending rates changes. Learning about aggregate demand, the only source of risk in the problem, occurs only after the first suspensions. On the other hand, debt contracts with maturities longer than the medium-term contract would not be chosen by the entrepreneurs as the medium-term contracts involve lower expected costs and hence are preferred.

contractible (*i.e.* the bank can seize any remaining loan balances and the rights to the project in the event that an entrepreneur chooses to abandon). In cases where banks will eventually control the project due to loan default, banks want this transfer to occur sooner rather than later. The only real concern is that heavily indebted managers who think that the true demand is likely to be low will continue borrowing to fund the project in order to prolong their access to private benefits. The default cost α helps to mitigate this concern.

Short-term loans are made at the beginning of each period and cover any previous indebtedness plus the incremental investment required in the current period. Similar provisions regarding the conditions under which the banks can seize the project apply in the case of short-term loans as well. Prior to τ, the banks do not have new information regarding the state of nature, and short-term debt will be rolled over.[12]

A final assumption that plays an important role in the problem is the parameterisation of what the bank expects to receive in the event of low demand. We assume that banks expect to receive $\beta \in [0, 1]$ back in the event that demand is low and the loans to industry are defaulted upon. In a world with perfect limitation of liability, no government guarantees, and no other means by which banks might expect some return when things are bad, β would take on a value of zero. In a world of perfect moral hazard, where banks always expected to be fully bailed out, β would be one. A final case of some interest is $\beta = \alpha$.

To recap, then, the world works as follows: at time 0, entrepreneurs approach banks with investment options in hand. The banks offer a menu of

[12]It is optimal for the banks to roll over the short-term debt rather than suffer a 1-period loss and terminate lending to the entrepreneurs before the state of nature is known. The proof is available upon request.

loan contracts, and the entrepreneurs decide whether to borrow and invest or to walk away. Each period afterward, the entrepreneurs who made the initial investment choose between suspending their projects, or continuing them. Entrepreneurs who suspended in the previous period choose between reinitiating or abandoning. Entrepreneurs who have medium-term financing make incremental investments out of the original loan, while entrepreneurs with short-term financing return to the bank, roll over their existing debt and borrow the incremental investment needed in the current period. Banks continue to provide this short-term debt unless the projects they are financing are in an industry that is revealed to have low demand. If demand is revealed to be low, banks move to rescue what they can of the loans they have made by demanding repayment as soon as possible.

3 An Example: Short-term Debt

In order to illustrate the model, we begin with an example. Later, we will motivate the choice of this particular specification for the example. The algebra underlying this section is provided in Appendix 1. Assume that only short-term debt contracts are available, and that the short-term interest rate (r_S) entrepreneurs face is constant through time. Further assume that the bank is able to fund its capital needs at a constant (riskless) rate $r < r_S$. The analysis proceeds by characterising the entrepreneurs' investment decision at some time $\tau \in [1, T-1]$, through a comparison of the expected payoffs of suspension *vs.* continuation. All values are expressed in time-τ terms.

Begin by supposing that the entrepreneur is trying to decide at τ whether to suspend at that period. The probability that demand is low, given the signals received to date, is $1 - h(\sigma^\tau)$. If the entrepreneur suspends, and demand is revealed to be low, the entrepreneur will not reinitiate the project.

The payoff in this case will simply be the (negative of the) default cost α times the bank loans that have been used to finance the project thus far. The principal due at τ given short-term loans have been used and the project is suspended at τ is $\kappa(1+r_S)^{\tau}+\sum_{i=1}^{\tau-1}(1+r_S)^i$. We denote this value by $D_S(\tau)$.

On the other hand, demand may turn out to be high. In this case, the entrepreneur will reinitiate the project. Note that because demand has now been revealed, the source of default risk has been removed and thus any further loans are made at the riskless rate of interest. The decision to reinitiate involves an extra cost of $\frac{\mu\kappa}{1+r}$ in time τ terms. It also involves future investments, borrowed from the bank at the riskless rate r, with a time T value of $\sum_{i=0}^{T-\tau}(1+r)^i$. Recall that at $\tau+1$ the entrepreneur must not only pay the reinitiation cost but also the investment that was skipped at τ (and has become $(1+r)$ in $\tau+1$ terms). The revenue from reinitiation is given by $\frac{P_H}{(1+r)^{T-\tau}}$. Finally, the entrepreneur is assured of a steady stream of private benefits B. After a bit of re-arranging, the expected payoff from suspending at τ, given σ^{τ}, is

$$
\begin{aligned}
&-(1-h(\sigma^{\tau}))\cdot\alpha\cdot D_S(\tau)+\\
&\quad h(\sigma^{\tau})\cdot\left(\frac{P_H}{(1+r)^{T-\tau}}-D_S(\tau)+(B-1)\sum_{i=0}^{T-\tau}\frac{1}{(1+r)^i}-\frac{\mu\kappa}{1+r}-B\right)
\end{aligned}
$$

Now consider the case of a entrepreneur that chooses to continue the project at τ. In parallel with the suspending entrepreneur, if demand is low, the entrepreneur will then suspend at $\tau+1$. If demand is high, the entrepreneur will arrange to borrow the remaining financing needs at the riskless rate. The expected payoff from continuing at τ is

$$(1 - h(\sigma^\tau)) \cdot (B - \alpha(D_S(\tau) + 1)) +$$
$$h(\sigma^\tau) \cdot \left(\frac{P_H}{(1+r)^{T-\tau}} - D_S(\tau) + (B-1) \sum_{i=0}^{T-\tau} \frac{1}{(1+r)^i} \right)$$

Obviously, the entrepreneur will suspend only if the expected payoff to doing so exceeds the expected payoff to continuation. This can, using the above expressions, be restated as the entrepreneur will suspend if

$$h(\sigma^\tau)) \cdot (B + \frac{\mu\kappa}{1+r}) \leq (1-h) \cdot (\alpha - B) \tag{1}$$

After some minor rearranging (1) implies that the lower bound on the first suspension time is the first time t such that

$$t \geq \frac{ln(\frac{B+\frac{\mu\kappa}{1+r}}{\alpha - B})}{ln(\frac{p}{q})} \tag{2}$$

This condition says first that the lower bound on the time at which suspensions occur is a function of the default costs the entrepreneur faces, and second that the presence of these default costs means that suspensions occur later than they would if the projects were self-financed. More importantly, the tradeoff between private benefits and the default cost is clearly illustrated by (2). Clearly, the lower bound on the first suspension time decreases with increases in the degree to which the entrepreneur internalises the costs of failed investments. As the magnitude of the penalty cost declines relative to the private benefits, the entrepreneur extends the suspension time even for very bad information signal sequences. If private benefits are too important, or if the presence of government guarantees reduces the penalty cost enough, then there will be no suspensions independent of the private information received.

The commensurate equation in the absence of outside financing is identical except that the α is replaced by a one – that is, α implicitly assumes its highest value as now the manager fully internalises the expected costs of the extra investment. In the event that signals are relatively uninformative, and private benefits are of a similar magnitude to the expected default costs, the difference in the suspension times may be relatively large. For example, if $p = 0.60$, $\alpha = 0.1$, and $B = 0.05$, then suspension will occur around 7 periods later for the bank-financed firm than it would for a self-financed firm. If we interpret t as one quarter, this means nearly 2 years of extra investment.

Although the inefficiencies introduced into the aggregation of public information by the use of outside finance may be substantial, perhaps the most interesting thing about (2) is not what appears in the expression but rather what does *not* appear. Specifically, the short-term interest rate is absent. Looking back at the problem we see that in characterising the tradeoffs at τ it is only time-τ magnitudes that matter – future costs and revenues wash out of the problem, as do past magnitudes like the face value of existing debt. This aspect of the problem relies heavily on the fact that all uncertainty is revealed by the first suspensions.[13]

3.1 Comparative Statics

We briefly analyse the factors that influence the timing of the initial suspensions. First we will look at the role played by the private benefits, B. We find that

$$\frac{\partial \tau}{\partial B} = \left(\ln \frac{p}{q}\right)^{-1} \left[\left(B + \frac{\mu\kappa}{1+r}\right)^{-1} + (\alpha - B)^{-1}\right] > 0$$

[13]It is this "1-period" nature of the problem that allows us to take the approach we use rather than adopting the full formalism of an optimal stopping problem.

If the entrepreneur enjoys greater benefits from keeping a project alive, then there will be more incentive to "defer" the suspension date for a given information structure. The more social status the entrepreneur gains from maintaining the project, the longer will be the delay until the first suspension period. Next we examine how the amount of loss in the event of a bad state, α, relates to the suspension period. The comparative static is found to be

$$\frac{\partial \tau}{\partial \alpha} = -\left(\ln \frac{p}{q}\right)^{-1} (\alpha - B)^{-1}$$

When $\alpha > B$ (*i.e.*, when a finite suspension time exists) this expression is negative. Higher α reduces the lower bound on the first suspension time. We have suggested that α may be interpreted as a measure of the ambiguity in bankruptcy laws in the Asian countries concerned, particularly in cases where the banks are well-connected politically. Alternatively, α might reflect (unmodelled) reputational costs (or even loss of "face"). In either case, the greater the extent to which the entrepreneur internalises the costs of default the earlier the suspensions occur.

Another important factor that determines the suspension time is the present value of reinitiation cost, $\mu\kappa/(1+r)$. The relationship is found to be positive meaning that higher reinitiation costs lead entrepreneurs to wait longer before suspending. In the current context, we might expect projects to have relatively high reinitiation costs if, for example, approvals require bureaucratic assent. Interestingly, higher riskless rates lower the present value of reinitiation costs and hence tend to favour earlier suspensions.

In our world of differential information, the equilibrium suspension period is negatively related to the precision of the signals, as measured by p/q. Signal precision may be interpreted as the degree of transparency in the market, to the extent that greater opacity (especially in terms of credit allocation and project approval) tends to obscure market-driven signals. Using this interpretation, a more transparent economy will lead to earlier suspensions.

Having outlined an example of the model, we now turn to a more detailed look at the characteristics of the debt contracts offered to the entrepreneurs.

4 Ex Ante Equilibrium Loan Contracts

We now develop the profile of loan contracts that is used in equilibrium. The essential result is that in equilibrium, we will observe only short-term loans, unless the term structure is sufficiently downward-sloping. The intuition behind the result lies in the greater flexibility afforded by the short-term loans. For example, with short-term debt only those entrepreneurs that continue at τ take on new debt at τ. If the entrepreneur suspends and demand is low, (the default cost α times) one period's principal and interest is "saved". In comparison, when the entrepreneur has medium-term debt, even if he suspends at τ and demand is low he still loses $(r_M - r)$ on the the remaining unit of the original loan, and hence he faces added default costs of $\alpha(r_M - r)$.[14] Similarly, the entrepreneur that has borrowed short-term and suspended, and finds that demand is in fact high, can borrow the skipped payment at the riskless rate rather than r_S. The entrepreneur that has borrowed medium-term and suspended, on the other hand, will pay $r_M - r$ on the skipped payment (since the entrepreneur will have earned only the riskless rate on the skipped payment between τ and $\tau + 1$.

We assume that the representative bank is making zero expected profits given the existing term structure in the market. We also assume that the riskless rate, r_t, for any period t, equals the 1-period riskless rate, r, plus a

[14]The lending rate offered prior to state realisation will always be higher than the riskless rate due the presence of default risk.

liquidity premium, $\rho(t)$; i.e., $r_t = r + \rho(t)$, where $\rho(t) > 0$ for $t > 1$, $\rho(1) = 0$, and $\frac{\partial \rho(t)}{\partial t} > 0$.[15] In equilibrium, the expected value of the loan over the life of the project must equal the time-T value that the bank will receive at the riskless rate.

The analysis of the equilibrium debt contracts proceeds in several steps. First, we show that the equilibrium suspension period, τ, does not depend on the maturity of debt contracts. To do so, we consider the cases of medium-term and short-term debt separately. Next, we compute the lending rates for the two debt contracts that ensure the banks earn zero expected profits. Finally, we allow the entrepreneur to choose between the debt contracts based upon the expected payments that will be required under the two different contracts. Due to the complexity of the expressions for the lending rates, the last stage is completed numerically.

4.1 Medium-term Debt

We assume that the entrepreneur will borrow the present value of the starting and the operating costs from $t = 1$ to τ inclusive at $t = 0$. Let the value of the medium-term loan at $t = \tau$ be denoted by $D_M(\tau)$, where

$$D_M(\tau) = D_M(0)(1 + r_M)^\tau = \left(\sum_{i=1}^{\tau} \frac{1}{[1 + r + \rho(i)]^i} + \kappa \right) (1 + r_M)^\tau$$

If the entrepreneur needs to finance the reinitiation cost $\mu\kappa$ because he has suspended and demand is revealed to be high, he can obtain a loan at the riskless rate. In the good state, the rest of the project costs from $\tau + 1$ to T will be borrowed at the riskless rate.

[15]The assumption leads to an upward sloping term structure that does not require the future short rates to be higher than current short rates. The intuition is that investors are compensated for facing illiquidity when they commit to longer term investments. Since there is no reason to expect future short rates to rise in our setting, we do not address interest rate uncertainty to keep the model simple.

If the state of nature is revealed to be low at the end of τ, then the project will be terminated. In this case, the bank will recover any remaining loan proceeds that have not been used. The entrepreneur will repay the bank α times the portion of the loan that was used, rolled over at the riskless rate in period T.

The expected payoff of suspension at τ is:

$$-(1-h(\sigma^\tau))\cdot\alpha\cdot[D_M(\tau)-1]+$$
$$h(\sigma^\tau)\cdot\left[\frac{P_H}{(1+r+\rho(T-\tau))^{T-\tau}}-D_M(\tau)+(B-1)\sum_{i=1}^{T-\tau}\frac{1}{(1+r+\rho(i))^i}-\frac{\mu\kappa}{1+r}\right]$$

The expected payoff of continuation at τ is:

$$(1-h(\sigma^\tau))\cdot[B-\alpha\cdot D_M(\tau)]+$$
$$h(\sigma^\tau)\cdot\left[\frac{P_H}{(1+r+\rho(T-\tau))^{T-\tau}}-D_M(\tau)+\right.$$
$$\left.(B-1)\sum_{i=1}^{T-\tau}\frac{1}{(1+r+\rho(i))^i}+B\right]$$

With a bit of rearranging, the lower bound on τ implied by the two equations above works out to be the same as (1). The determination of the equilibrium suspension period with short-term debt was presented in Section 3 and will not be repeated. Since the equilibrium condition for τ for both debt contracts is identical, we have shown that τ is independent of the maturity of the debt contract and the lending rates charged. Next, we need to determine the interest rates offered by the bank given the equilibrium τ.

4.2 Determination of Lending Rates

In an environment where the bank earns zero expected profits, it will set lending rates such that the expected payout of the risky loan equals the payout of a riskless loan. Before turning to the analysis, a couple of observations are in order.

First, we assume that the bank can raise capital at the riskless rate $r_t = r + p(t)$. The extent to which this compromises the generality of results may be substantial – in particular, we do not specify whether the bank is raising this capital from depositors or from domestic or international capital markets, and we do not consider how the demand realisation in the model may be correlated with investor/depositor liquidity demand. We simply assume that there is a fixed term structure from which the bank can raise its funds.

Second, recall that once the true state of demand is known, there is no more risk in the model and hence all subsequent loans will be made at the riskless rate. It is important to note that from the bank's perspective, all entrepreneurs are identical throughout the exercise. Although the bank knows that borrowers are differentially informed, and the borrowers have more information than the bank does, that information is not individually payoff-relevant. Put slightly differently, even those firms which have received a series of bad signals and have decided to suspend the next period do not know whether the true state of demand is high or low until they observe the mass of other firms that suspend. Therefore the bank offers loans at the same interest rate both across borrowers and, in the case of short-term debt, through time, to all borrowers in the industry. This is very convenient. First, it allows us to analyse the problem specifying a constant short-term rate (as we did in Section 3). More importantly, the lack of borrower-specific risk means that we need only consider the profitability of an average loan.

So, to recap, lending rates are determined by setting the expected profit of the risky portion of an average loan to zero. The only other wrinkle of note is that the bank will need to take into account the expectation of the proportion of firms which will be suspending in each state. The mass of entrepreneurs that the bank expects to suspend if demand is high and low, respectively, is denoted $F(H) = q^\tau$ and $F(L) = p^\tau$.[16]

We need to consider the pricing the loans up till $\tau + 1$ when the state is realised. All further loan funds that will be required will be lent at the riskless rate and hence are not part of the calculation of r_M. We solve for r_M given the expected zero-profit condition, which sets the expected value of a risky loan maturing at $\tau+1$ equal to the value of a riskless loan maturing at the same date:

$$\frac{1}{2}D_M(0)(1+r_M)^{\tau+1} + \frac{1}{2}$$
$$\left\{F(L)\left[\beta\left(D_M(0)(1+r_M)^{\tau+1} - (1+r)\right) + (1+r)\right] + (1-F(L))\beta D_M(0)(1+r_M)^{\tau+1}\right\}$$

$$= D_M(0)(1+r+\rho(\tau+1))^{\tau+1}$$

Hence, we obtain the following:

$$(1+r_M) = \left[\frac{1+\beta}{2}D_M(0)\right]^{\frac{-1}{\tau+1}}$$
$$\left[D_M(0)(1+r+\rho(\tau+1))^{\tau+1} + \frac{F(L)}{2}(1+r)(1+\beta)\right]^{\frac{1}{\tau+1}}$$

Now we will determine r_S. The cashflow received by the bank is dependent upon whether the entrepreneur suspends the project. If the project is continued, the bank will lend the entrepreneur an extra unit of cost at τ will be borrowed. If the project is suspended, the bank can only competitively lend out the extra unit at the riskless rate. To reduce the notational complexity, we work it time-τ values. Recall that at each period $t < \tau$, the 1-period loan is rolled over. Thus, we have

$$D_S(\tau) = \kappa(1+r_S)^\tau + \sum_{i=1}^{\tau-1}(1+r_S)^i$$

[16]Note that one signal is received upon payment of the intial payment κ, so entrepreneurs have a signal vector of length τ at time τ although they have not yet received their time-τ signals.

while we denote by

$$D(\tau) = \kappa(1+r)^{\tau} + \sum_{i=1}^{\tau-1}(1+r)^{i}$$

the cost to the bank of the short-term loan sequence. Therefore, in the case of short-term debt the *ex-ante* zero-profit condition at $\tau + 1$[17] is:

$$\frac{1}{2}\left(F(H)[D_S(\tau)(1+r_S)+(1+r)]+(1-F(H))[D_S(\tau)(1+r_S)+(1+r_S)]\right) + \frac{1}{2}\left(F(L)[\beta D_S(\tau)(1+r_S)+(1+r)]+(1-F(L))\beta[D_S(\tau)(1+r_S)+(1+r_S)]\right) = D(\tau)(1+r)+(1+r)$$

After substituting for $F(L)$ and $F(H)$, this cumbersome equation defines a polynomial in r_S:

$$(1+r_S)[(1+\beta)(D_S(\tau)+1)-(q^{\tau}+\beta p^{\tau})] = (1+r)[2(D(\tau)+1)-(p^{\tau}+q^{\tau})] \quad (3)$$

which cannot be solved analytically. Numerical solutions show that for $T = 20$, $\kappa = 10$, $r = 0.05$, $\alpha = 0.10$, $\rho = 0.0005$, $p = 0.6$, $q = 1-p$, $\beta = 0.8$, $B = 0.05$ and $\mu = 0.3$, the equilibrium suspension period is 11 and this tranlates into $r_M = 6.53\%$ and $r_S = 6.16\%$. Keeping ρ at 5 basis points, the numerical solutions point to $r_M > r_S > r$. Despite the difficulties in comparing the lending rates offered by the bank across maturities analytically, it is important to remember that they serve to determine the equilibrium type of debt contracts but they do not affect the equilibrium suspension period in this model.

4.3 Entrepreneurs' Choice of Contracts

Given the lending rates structure described by (3) and (3), we determine the type of debt contract that will be chosen by the entrepreneur. As loan

[17]From $\tau + 1$ to T, the state is known and all $\tau + 1$ values will have a time value of $(1+r)^{T-(\tau+1)}$ which will cancel out on both sides of the equation presented.

payments are made on completion of project, the entrepreneur will choose the debt contract with the lowest expected payout at T, given priors.

The expected payment required on medium-term debt at T is:

$$\frac{1}{2}\left[D_M(0)(1+r_M)^{\tau+1}(1+r)^{T-(\tau+1)} + \sum_{i=1}^{T-(\tau+1)}(1+r)^i\right] +$$

$$\frac{\alpha}{2}\left\{F(L)\left[D_M(0) - \frac{1+r}{(1+r_M)^(\tau+1)}\right] + (1-F(L))D_M(0)\right\}(1{+}r_M)^{\tau+1}(1{+}r)^{T-(\tau+1)}$$

where r_M is defined by (3).

On the other hand, the expected payment on short-term debt at T is:

$$\frac{1}{2}\Bigg([D_S(\tau)(1+r_S) + F(H)(1+r)+(1-F(H))(1+r_S)](1+r)^{T-(\tau+1)} + \sum_{i=1}^{T-(\tau+1)}(1+r)^i\Bigg) + \frac{\alpha}{2}[D_S(\tau)+(1-F(L))](1+r_S)(1+r)^{T-(\tau+1)}$$

where r_S is characterised by (3).

It is difficult to compare these equations analytically, except in special cases like $r_M = r_S$. However, numerical solutions show that the short-term payout is lower than the medium-term payout unless the term structure is sufficiently downward sloping. With the parameters and lending rates described previously, the medium-term and short-term payouts are 36.53 and 32.02 units, respectively. Therefore, entrepreneurs will choose short-term debt over medium-term debt. The preference result does not change with other parameter settings. In the special case with flat term structure and $\alpha = \beta = 1$, there is no default risk and the lending rates become the riskless rate. Here, the entrepreneur is indifferent between the two debt contracts.

5 Conclusions

[To be completed]

Appendix 1

In this appendix we present the derivation of the lower bound on the suspension time, and compare it to the case in which projects are internally financed. The analysis proceeds by comparing the expected costs and benefits to suspension at some time t.

Begin by supposing that the enetrepreneur suspends the project at time τ. We know that with probability $1 - h(\sigma^\tau)$ demand will be revealed to be low. In this case, the entrepreneur has loans outstanding in the amount of $\kappa(1+r_S)^\tau + \sum_{i=1}^{\tau-1}(1+r_S)^i$, and by assumption, experiences a cost of α times this amount (expressed in dollar terms). On the other hand, demand might be revealed to be high. In that case, the entrepreneur will reinitiate the project at $\tau + 1$, incurring the reinitiation costs and paying the extra $1 + r$ (representing the payment of 1 skipped at τ) at $\tau + 1$. The entrepreneur will receive revenues of P_H at T, and will be responsible for full repayment of loans outstanding up to time T. Because loans made after τ are made at the riskless rate, the total value at τ of loans is given by

$$(\kappa(1+r_S)^\tau + \sum_{i=1}^{\tau-1}(1+r_S)^i) - \sum_{i=0}^{T-\tau}(1+r)^i \cdot \frac{1}{(1+r)^{T-\tau}} - \frac{\mu\kappa(1+r)^{T-\tau-1}}{(1+r)^{T-\tau}}$$

If demand is revealed to be high, the entrepreneur will also enjoy private benefits (having a dollar value of) B each period following τ. Note, however, that the entrepreneur will not receive these benefits at τ since the project is suspended during this period. Since the probability, given information signals received to τ (*i.e.,* not including the time-τ signal) is $h(\sigma^\tau)$ we can express the expected value of suspending the project at τ as

$$-(1-h(\sigma^\tau))\cdot\alpha\cdot(\kappa(1+r_S)^\tau+\sum_{i=1}^{\tau-1}(1+r_S)^i)+h(\sigma^\tau)\cdot(\frac{P_H}{(1+r)^{T-\tau}}-(\kappa(1+r_S)^\tau+\sum_{i=1}^{\tau-1}(1+r_S)^i)$$

$$-\sum_{i=0}^{T-\tau}(1+r)^i \cdot \frac{1}{(1+r)^{T-\tau}} - \frac{\mu\kappa(1+r)^{T-\tau-1}}{(1+r)^{T-\tau}} + B\sum_{i=0}^{T-\tau-1}(1+r)^i \cdot \frac{1}{(1+r)^{T-\tau}})$$

The goal is to compare the expected value given above with the expected value of continuing the project at time τ. To make this comparison we need first to consider how the various costs and benefits are affected by the entrepreneur making the decision to continue rather than to suspend.

If demand is revealed to be low, then the entrepreneur faces a debt load which is higher by one unit (we consider the analysis in time-τ terms so the entrepreneur has no interest to pay on the new loan made at τ). Given the entrepreneurs' penalty function this implies a cost to the entrepreneur of α. On the other hand, the entrepreneur will enjoy one final period of private benefits B.

If demand is revealed to be high, the entrepreneur will contnue to borrow to invest in the project, and will receive revenues, pay back loans, and enjoy private benefits much as he did in the suspension case. The primary difference lies in the extra period of private benefits that the entrepreneur receives because the project is not suspended at τ, and the absence of the need to pay reinitiation costs. Therefore we can express the expected value of continuing the project at τ as

$$-(1-h(\sigma^\tau))(\alpha\cdot(\kappa(1+r_S)^\tau+\sum_{i=1}^{\tau-1}(1+r_S)^i)+\alpha-B)+h(\sigma^\tau)\cdot(\frac{P_H}{(1+r)^{T-\tau}}-(\kappa(1+r_S)^\tau+\sum_{i=1}^{\tau-1}(1+r_S)^i)$$

$$-\sum_{i=0}^{T-\tau}(1+r)^i\cdot\frac{1}{(1+r)^{T-\tau}}+B\sum_{i=0}^{T-\tau}(1+r)^i\cdot\frac{1}{(1+r)^{T-\tau}})$$

Now, collecting terms and substituting for $D_S(\tau)$ yields the equations given in the text:

$$-(1-h(\sigma^\tau))\cdot\alpha\cdot D_S(\tau)+h(\sigma^\tau)\cdot(\frac{P_H}{(1+r)^{T-\tau}}-D_S(\tau)+(B-1)\sum_{i=0}^{T-\tau}\frac{1}{(1+r)^i}-\frac{\mu\kappa}{1+r}-B) \tag{4}$$

$$(1-h(\sigma^\tau))\cdot(B-\alpha(D_S(\tau)+1))+h(\sigma^\tau)\cdot(\frac{P_H}{(1+r)^{T-\tau}}-D_S(\tau)+(B-1)\sum_{i=0}^{T-\tau}\frac{1}{(1+r)^i}) \tag{5}$$

In order to consider the derivation of the (lower bound on the) first suspension time we look for the first time at which (4) exceeds (5), or the τ such that

$$-h(\sigma^\tau)\cdot(B+\frac{\mu\kappa}{1+r})\geq-(1-h)\cdot(\alpha-B)$$

Again rearranging terms, this means that we are searching for the t such that

$$\frac{\alpha + \frac{\mu\kappa}{1+r}}{\alpha - B} \leq \frac{1}{h(\sigma^\tau)}$$

Now recall that $h(\sigma^t)$ is the conditional probability that demand is high given the sequence of signals received. Because the signals are conditionally independent across time and across firms, and because we know that the first entrepreneurs to suspend will be those who have received the most pessimistic sequence of signals, we can write $h(\sigma^t)$ as

$$\frac{q^t}{q^t + p^t}$$

This implies that we can write $\frac{1}{h(\sigma^\tau)}$ as $\frac{p^\tau}{q^\tau} + 1$. Substituting this into the earlier relationship yields

$$\frac{B + \frac{\mu\kappa}{1+r}}{\alpha - B} \leq \frac{p^\tau}{q^\tau}$$

Taking natural logarithms of both sides and isolating for τ then provides the following relationship (as given in the text)

$$\tau \geq \frac{ln(\frac{B+\frac{\mu\kappa}{1+r}}{\alpha - B})}{ln(\frac{p}{q})}$$

It is instructive to consider how the analysis would proceed if entrepreneurs self-financed their projects. In this case, any investments made prior to τ are of course sunk and do not play an important role in the decision process. However, the entrepreneurs now internalise the full cost of the investment should they choose to continue and the demand turn out to be low. In this case equations (4) and (5) are expressed as

$$-(1-h(\sigma^\tau))\cdot 0+h(\sigma^\tau)\cdot(\frac{P_H}{(1+r)^{T-\tau}}-D_S(\tau)+(B-1)\sum_{i=0}^{T-\tau}\frac{1}{(1+r)^i}-\frac{\mu\kappa}{1+r}-B)$$

and

$$(1-h(\sigma^{\tau}))\cdot(B-1)+h(\sigma^{\tau})\cdot(\frac{P_H}{(1+r)^{T-\tau}}-D_S(\tau)+(B-1)\sum_{i=0}^{T-\tau}\frac{1}{(1+r)^i})$$

This means that in order for τ to be the first suspension time it must be that

$$-h(\sigma^{\tau})\cdot(B+\frac{\mu\kappa}{1+r})\geq-(1-h)\cdot(1-B)$$

leading to a lower bound on the first suspension time of

$$\tau\geq\frac{ln(\frac{B+\frac{\mu\kappa}{1+r}}{1-B})}{ln(\frac{p}{q})}$$