FINANCING LONG-GESTATION PROJECTS WITH UNCERTAIN DEMAND

By

JIM STOREY

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M.A., The University of British Columbia, 1993

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Abstract

Financial crises in East Asia, Russia, and Latin America have caused some to wonder if there is something inherently unstable about financial markets that thwarts their ability to allocate capital appropriately and ultimately causes these crises. I build a multi-period, industry-level credit model in which debt-financed entrepreneurs develop homogeneous projects with long gestation periods, sequential investment requirements, and no intermediate cash flows. Entrepreneurs accumulate private signals about terminal demand, and if the signals are bad enough, may decide to halt project development before completion. The prevalence of project suspensions aggregates information and permits the industry size to adjust to the true state of terminal demand. Debt contracts depend upon the pricing power of the creditor; these contracts impact the size of the industry and the timing of the information aggregation. When demand realisations are poor, some investors will be disappointed ex post; aggregate disappointment will depend upon how long the investment behaviour has carried on before suspensions occur, and how large the industry is. I interpret situations of substantial aggregate disappointment as a 'crisis'.

Principal results relate to the impact of debt finance on the timing and likelihood of project suspensions. With all equity (self) financing, suspensions will typically be observed, but they may occur relatively late in the game. In contrast, debt finance may lead to very rapid suspensions, depending upon the tools allocated to the creditor. When creditors exercise monopoly control over credit allocation and pricing, profit-maximising creditors can and will force suspensions. This may involve reducing the entrepreneurs' equity contribution and / or subsidizing credit in order to ensure entrepreneurial participation. When credit markets are competitive, creditors lack the pricing power that can be used to structure credit policies that force early suspensions. As debt accumulates and the entrepreneurs' share of liquidation proceeds dwindles, entrepreneurs may not voluntarily suspend operations as this will lead to loss of private benefits. Therefore, there may be no suspensions observed in equilibrium. This problem will be particularly acute when the entrepreneurs' initial equity stake is small.

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Kuni yaburete, san ga ari... Toho (712-770 AD), from *Shunbō*

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Chapter 1

Introduction

"The future's uncertain and the end is always near." Morrison (1970)

How does external finance impact the likelihood and severity of economic contractions? Does the structure of the financial market matter?

The proximate motivation for this thesis is drawn from the East Asian financial crisis of the late 1990s. Between July and November of 1997, Thailand, Indonesia, and South Korea all experienced widespread financial sector problems and debilitating currency depreciations (after abandoning fixed or quasi-fixed exchange rate regimes), and ultimately sought financial assistance packages from the International Monetary Fund (IMF, various dates). Although Malaysia and the Philippines managed to avoid new IMF assistance,[1] both shared the regions' experiences with currency depreciation, and financial sector difficulties.

There was much about the crisis in East Asia that was idiosyncratic to the different countries involved, but there are also some general observations which can be made. Among the most fundamental of these is the private sector, corporate nature of this event. In each of the crisis economies unhealthy banking systems, heavily levered firms, and evidence of rapid and apparently excessive

[1]The Philippines was already in the latter stages of an IMF program when Thailand devalued the *baht*. The country requested, and received, an extension on, and expansion of, its existing program but the amounts involved were small and most of the domestic policy adjustments were already underway. Malaysia – by most accounts – only narrowly averted requesting IMF assistance, and at least initially, appeared to be implementing many of the policy prescriptions adopted by its neighbors.

fixed capital formation was present (see, among others, Sachs and Woo (2000), and Shirai (2001)). The poster child for such 'excess' may be the property sector in Thailand (and particularly in Bangkok) where, the *Far Eastern Economic Review* (p. 43, May 16, 2002) reports, construction work on over 350 buildings was suspended during the Asian crisis. In January 1997, the *Asian Wall Street Journal* reported estimates of 850,000 unsold residential units, as compared with average annual sales of 130,000 units. The apparent inadequacies of self-interested entrepreneurs and their bankers raise important questions about the failure of markets to deliver stable and secure growth. In the aftermath of the crisis, two broad schools of academic and practitioner thought emerged regarding the role played by financial markets.[2] The first suggests that financial markets are inherently unstable and prone to multiple equilibria, and typically sees the direction of causality in crisis situations as running from financial markets to the real economy, often featuring a 'panic' of some sort. Perhaps the most difficult challenge for such models is to explain how / why / when an economy is likely to move from one equilibrium to another. The second group focused more heavily on institutional and structural factors that might exacerbate underlying information imperfections and/or asymmetries, create moral hazard problems, or prevent efficient resolution of financial distress – and thereby lead to financial sector problems. This group thus focuses on issues associated with adherence to financial sector regulations, transparency, good governance and rule of law, appropriate sequencing of liberalisation activities, 'crony capitalism' and so forth.

These descriptions are very broad – and by no means mutually exclusive – but nonetheless they can be seen as leading to differing policy prescriptions. In particular, problems of the first kind may be best addressed via controls, regulations and/or interventions designed to mitigate or prevent inherent financial market instabilities from creating or worsening real economy problems. On the other hand, the second group generally focuses on policy prescriptions that improve transparency, governance, and regulation precisely so that unfettered markets might work better. Generally speaking, policy suggestions made by this latter group are likely to be acceptable to proponents of both views of the crisis, but they will not go far enough for those that feel markets are fundamentally unstable.

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[2] 'Emerged' may be somewhat misleading; one might argue that the Asian crisis provided (another) convenient context for debating some longstanding and deep-seated differences of opinion. For example, in a discussion of whether there is something concrete that can be done about emerging market crises Stiglitz (1999) explains that

> 50 years after Keynes, however, a school of thought emerged – real-business cycle theory – which argued that all fluctuations in output are efficient movements to new equilibria given by the ever-changing technology and tastes of the economy. In this view, the great Depression was the optimal outcome of a collective desire to take vacations pending the higher wages expected in the future.

I work with a model in which the real sector (or at least elements of the real sector) might be subject to possibly sharp adjustments, and consider the role played by the financial sector in the model. The theoretical portion of the thesis is therefore *not* intended to explain the Asian crisis *per se*. Rather, it is motivated by the crisis in Asia, and I therefore adopt a modelling strategy that is consistent with certain features of the East Asian economies where the crisis occured. I interpret the model results in the context of the East Asian crisis, but not in the sense of formally testing the model. Rather, I ask whether model features that point to relatively more severe crises are consistent with features of the economies most severely affected by the regional crisis.

In the remainder of this introduction I describe (in very general terms) the modelling strategy and discuss the appropriateness of some of the model features. I end the Introduction by arguing that there was no single 'cause' of the crisis. Following the Introduction, Chapter Two considers related literature, Chapter Three discusses the benchmark case of self-financed entrepreneurs and Chapter Four analyses the model with a financial sector added, under various configurations. One of the key issues considered in Chapter Four is the degree to which the financial sector exercises market power in the pricing (and ultimately the allocation) of its lending. Finally, in Chapter Five, I discuss the model in the context of the crisis in Asia and describe some econometric approaches that might be used to estimate the degree of market power exercised by the banking sectors in Indonesia, Korea, the Philippines, Malaysia, and Thailand.

The thesis makes two contributions. First, I extend the investment model of Caplin and Leahy (1994) by adding several features including non-zero liquidation values and an interval of possible demand realisations. This allows for behavior not possible in the original model, and generates outcomes similar to those observed in the growth of new industries. Klepper and Graddy (1990) document the time path followed in 46 new industries[3] from their inception forward, and draw attention to the fact that 38 of the 46 experienced a 'shakeout' within the time period covered by their data set.[4] The model developed here generates shakeout behaviour and permits analysis of the impact of various parameters on these events.

Second, I add to the work on financing of entrepreneurial projects. In particular, I show that

[3]Examples include electric blankets, transistors, and penicillin.

[4]They define shakeout as a stage of industry development in which the *number* of firms declines through exit, consolidation, bankruptcy etc, rather than focusing on the size of the industry (as measured by total production or capacity). Strictly speaking, I cannot say anything about the number of firms in my model as I work with a continuum of firms. Moreover, their focus is on firm-specific attributes like technology choice, cost structures, adaptability and so forth rather than industry-wide factors that I am interested in.

entrepreneurial recourse to external debt finance can either facilitate or hinder the aggregation of information of public value. I do so by embedding some traditional entrepreneurial finance issues in a somewhat different setting than is generally considered. The entrepreneurs learn about a parameter of common interest as time passes, and their endogenous investment decisions determine when (if at all) this information will be aggregated. I study the impact of debt finance on these investment decisions.

The debt contracts used can be interpreted as loan commitments. Commitments (as opposed to spot loans or straight long-term debt) account for approximately 80% of domestic lending in the United States, and as I illustrate in Table 1.2, represented over 40% of *total* financing in emerging Asia just prior to the crisis. Despite the empirical importance of loan commitments, they have received relatively little attention in the literature.[5]

In addition to extending this part of the investment literature, I argue that the thesis has additional relevance in light of the recent emerging market crises in Asia and elsewhere. In particular, the fundamental components of the real sector in this model – uncertain demand for goods whose production requires sequential, partly irreversible, externally-financed investment – were chosen to reflect pre-crisis investment activity in the crisis-stricken countries. Examples might include a semiconductor manufacturing facility, a golf course, or a real estate development. Therefore this work may help to understand the tensions that led up to the crisis, and to address the role played by banks, a topic of much recent public policy interest. But with some interpretive modifications, the model is also applicable to other contexts. One example is so-called third-generation (3G) mobile communications networks. Telecommunications companies, especially in Europe and the US, have invested heavily acquiring the required radio spectrum and now face even larger capital expenditures to build the requried physical infrastructure – all in the hopes that there will be sufficient demand for the services.

1.1 The Model

In this thesis I build a multi-period, industry-level credit market model in which wealth-constrained entrepreneurs develop identical projects with long gestation periods and sequential investment re-

[5]Selected exceptions include Maksimovic (1990), Berkovitch and Greenbaum (1991), Shockley (1995), and Shockley and Thakor (1997). See this last reference for some stylised facts and a detailed empirical discussion of loan commitments.

quirements.[6] These entrepreneurs derive (non-transferable) private benefits from project operation, enjoy limited liability, and use debt finance to overcome the difference between their wealth level and the project requirements. Entry takes place at time 0, defining the initial size of the industry.

Entrepreneurs accumulate private signals about a (terminal) demand function parameter, and if the signals are bad enough, may halt project development before completion. This decision is informative to others in the industry, who are interested in the prevalence of such suspensions – more suspensions mean more entrepreneurs with bad signal histories – and who may subsequently choose to suspend their own projects based on this information. The real sector can therefore generate a number of different patterns, including industry shakeouts, with concommitent declines in physical investment that are not prefaced by an obvious shock of commensurate magnitude.

At the beginning of each period, entrepreneurs choose between carrying on with their projects, outright liquidation, or suspending development for one period. Entrepreneurs finance investments with a combination of own capital and debt. Liquidation generates a (known) value between zero and the accumulated investment to date, which is contractible. The degree to which the liquidation value falls short of the value of investments made measures the magnitude of the irreversibility of investment. Each time they make an investment, entrepreneurs receive a private signal (binary) about the state of terminal demand (all entrepreneurs face the same demand function). If, based on these signals, a given entrepreneur's beliefs deteriorate far enough she may wish to suspend development of her project – but only if she becomes pessimistic enough soon enough. Otherwise, the outstanding debt on the project will exceed the liquidation value, there will be no residual for the entrepreneur, and thus no incentive to quit. The focus is therefore on the timing of suspensions. If some entrepreneurs do choose to halt development, their decision conveys their pessimism to both the banks and the rest of the industry. In order to simplify matters, by construction observation of the first such occurance allows for perfect inference of the true demand state, and therefore any subsequent adjustment in industry size takes place immediately. Once this has occured the model is one of full information and those with access to funds (and a desire to do so) continue to invest until T, when they produce and sell their output. Those that leave the industry receive the liquidation value (net of any debt they owe). A table containing all notation used in the thesis appears in Appendix D.2.

Debt contracts are consistent with loan commitments (or lines of credit) and depend upon real sector features and the pricing power of the creditor. Not surprisingly, these debt contracts impact

[6]The real sector in the model shares a number of features with the Caplin and Leahy (1994) model of phases of investment.

the operational decisions that entrepreneurs make, as well as the initial size of the industry. The analysis of the impact of the debt contracts (relative to a baseline of self-financed entrepreneurs) is of interest in its own right. The model can be used to consider issues relating to crisis events like the East Asian crisis of 1997-98, the original motivation for this research. When demand realisations are poor, investors will be disappointed *ex post*. I interpret situations of substantial aggregate disappointment as a crisis. Aggregate disappointment will depend upon how long ultimately unwarranted investment behaviour carried on, and on how large the industry is. I describe how both of these depend upon the nature of the debt contracts in place.

Although the model has $T + 1$ periods, in equilibrium there is at most one period in which entrepreneurial behaviour changes in an important way. As such the model boils down to either a one-period or two-period model; the distinction corresponds to whether there is one or two 'phases' of investment. However, whether there will be one or two phases (and in the latter case the timing of the change) is endogenously determined, not fixed *ex ante* as is generally the case.

In order to focus attention, many elements that might otherwise be of interest have been left out. Projects are all identical, and all payoff-relevant uncertainty is aggregate, so there is no scope for idiosyncratic elements in either project outcomes or entrepreneurs, nor is there any problem of asymmetric information. The model is strategic, but considerations not absolutely necessary (like signal jamming or the inalienability of human capital) are not present. Because I wish to consider outcomes relative to crisis events, and Asian firms were predominantly bank-financed, I have not considered the relative merits of venture capital and other forms of equity finance (except entrepreneurial wealth), nor have I justified debt as an optimal contractual form despite the assumption of universal risk neutrality and the lack of a costly state verification mechanism. I abstract from the important relationship between the bank and its depositors. Finally, this work is not intended as a complete explanation of the process of crisis, but rather as a suggestion about what may initiate that process. Thus there is no exchange rate and more generally no international variable.

To summarise, the model has the following features:

- projects are identical (all uncertainly is aggregate)
- projects are indivisible (investment is a discrete variable)
- projects are small with reference to the industry (so entrepreneurs take price as given)
- projects require positive net investment every period but generate sales revenue only at the end of time

- output is homogeneous and demand for it is uncertain
- each entrepreneur operates only one project
- entrepreneurs receive private, non-contractible signals each period
- 'banks' may or may not have some market power

Ultimately, the focus is on the timing of suspensions and the influence that the first suspensions can have on other entrepreneurs. Under what conditions does the use of external finance lead to later suspensions than would be the case with purely internal financing? Can external finance lead to earlier suspensions, thus mitigating informational inefficiencies?

1.2 Modeling Choices

In this section I describe a number of 'stylised facts' about the Asian business environment in the 1990s that justify the modelling choices I make.

1.2.1 Crisis Without a Cause?

Between 1993, when the World Bank published *The East Asian Miracle*, and July of 1997, when Thailand floated the baht, economic conditions in many countries in the region began to deteriorate. In the eventual crisis economies, at least one (and generally more than one) of local property markets, local equity markets, and key export markets, weakened, and financial sectors were beginning to show evidence of difficulty. For example, in Thailand, the country's largest finance house required a bail-out in March, and in June 16 financial institutions were shut down by the Thai government. Korea implemented a bank rescue plan in April, and each of Malaysia, Indonesia and the Philippines introduced new lending regulations aimed at restricting financial sector exposure to real estate. But following the baht devaluation, many observers were struck by the speed at which the economic situation deteriorated, and by the depths to which it extended. There seemed to be no change in circumstances that was grave enough to have triggered such significant economic convulsions. This view is captured in the following quote drawn from Sachs and Woo (2000):

> The Asian financial crisis is over. While this is a big relief, the fact that it happened at all is a matter of great concern. What is of even greater concern was the unexpected nature of the crisis... and the depth of the output collapse in some countries.

Given that one overarching goal of the research described in this thesis is to investigate the possibility that the real sector was in fact the trigger, a modeling approach capable of generating large scale shifts in behaviour without apparent triggers of commensurate magnitude is indicated.

1.2.2 Crisis Impacts Were not Uniform Across Industries or Regions

The reasoning behind the choice of an industry-based model was that the impacts of the crisis appear to have been relatively concentrated sectorally. Investment declines in Thailand, for example, were widespread during the crisis year but the lasting impacts are clear in Table 1.1, which illustrates a long-term decline in construction, real estate, and finance sectors (as measured by contribution to real GDP). The middle columns of the table present the simple percentage change in aggregate GDP attributable to the indicated sectors, relative to a base year of 1996, in 1998 and 2000. In most sectors, the crisis-related declines were less severe and have since retraced themselves, but construction, real estate, and finance remained depressed. Incidentally, in level terms, GDP has yet to return to 1996 levels, and that failure can be entirely ascribed to construction / real estate.

Table 1.1: GDP by Industrial Origin: Thailand

Industry Sector	% Growth 1996 - 1998	% Growth 1996 - 2000	GDP Share (1996)	GDP Share (2000)
Services	1.8	13.2	10.0	11.7
Agriculture	-2.4	4.5	10.5	11.4
Mining / Quarrying	6.3	21.4	1.7	2.1
Manufacturing	-9.8	7.5	31.6	35.2
Construction	-54.1	-61.2	6.3	2.5
Electricity / Gas / Water	5.1	19.1	2.6	3.3
Transport / Communication	-4.9	8.8	8.6	9.7
Wholesale / Retail Trade	-17.2	-11.6	16.0	14.6
Banks / Insurance / Real Estate	-38.5	-60.9	7.4	3.0
Other Non-Services	11.6	17.3	5.3	6.5
GDP	-11.7	-3.6	1	1

Source: Bank of Thailand (2002)

1.2.3 Capital Structure

I model entrepreneurs that are financed via own capital and bank debt. Many authors (see for example Shirai (2001)) have pointed out that the non-equity portion of the capital structure in corporations domiciled in the crisis countries was primarily comprised of loans (as opposed to bonds), and moreover, that the debt component of the capital structure exceeded the equity component by a significant margin. Of course, many firms did have outside equity in their capital structures, and just as is the case elsewhere, retained earnings provide an important source of working capital for many firms. However, outside equity represents a relatively small component of the overall capital structure in the 'typical' Asian firm (Dwor-Frécaut *et al* (2001)), and even in mature firms family ownership levels remain high and inside equity dominates (Claessens, Djankov, and Lang, 1999). Table 1.2, culled from World Bank (2000) and International Monetary Fund (1997), illustrates some of these observations, as well as providing some indication that the interpretation of the debt contracts in this model as commitments is appropriate.[7]

Table 1.2: Capital Structures and Financing Activity

Country or Region	Bank Credit (Private) to GDP	Stock Market Capitalisation to GDP	Outstanding Bond Issues to GDP	Corporate Debt to Equity	Loan Commitments to New Financing
Indonesia	55.4	40.0	1.8	310	–
Malaysia	89.8	310	45.4	150	–
Philippines	49.0	97.3	16.8	160	–
South Korea	57.6	28.6	45.0	518	–
Thailand	100.0	55.0	11.0	250	–
Emerging Asia	–	–	–	–	42.5

Source: World Bank (2000), International Monetary Fund (1997)

[7] All data is in percentage form and refers to 1996 except the debt to equity measure which is end of 1997 for all countries save Thailand (September 1998) and the Philippines (1996), and the final column, which is the average during the four-year period from 1993 to 1996.

1.2.4 Emerging Markets and Investment Behaviour

I model the birth and subsequent development of an industry that requires a lengthy period of investment prior to revenues being received. In the crisis countries, significant private infrastructure development was taking place.[8]

Table 1.3: Domestic Capital Formation to GDP

Country	1993-1996	1997	1998	1999	2000
Indonesia	30.8	31.8	16.8	12.2	17.9
Korea	36.8	34.2	21.2	26.7	28.7
Malaysia	45.8	49.0	30.1	27.0	31.8
Thailand	41.5	34.2	21.3	19.7	19.9
China, P.R.	41.2	38.0	38.1	38.3	.
Hong Kong, SAR	31.6	34.5	29.0	24.9	27.6
Japan	28.6	29.1	27.6	26.9	27.1
Philippines	23.6	26.3	22.2	21.0	20.7
Singapore	35.7	39.3	32.8	33.2	.
Russia	25.6	22.8	15.7	15.5	17.6
Mexico	21.4	25.9	24.4	23.6	23.3
Argentina	19.4	20.8	20.9	18.3	17.6
Brazil	21.5	21.5	21.2	20.4	.
Chile	25.8	27.2	27.4	22.1	23.4
Peru	22.3	24.0	23.6	21.5	20.1
Canada	17.9	20.0	19.9	20.3	20.5
United States	18.2	19.4	20.3	20.7	21.4
Euro Area	19.7	19.6	21.2	21.4	22.2

Source: International Monetary Fund (2001)

One can get a sense of the pace of capital accumulation from Table 1.3. At an economy-wide level, fixed investment to GDP ratios in Indonesia, Korea, Malaysia, and Thailand averaged 38.7% in the

[8]For example, of the ten largest privately financed infrastructure projects undertaken anywhere in the world between 1985 and 1995, two were in Thailand and one was in Malaysia. The largest was the Chunnel.

four years leading up to 1997. Of the rest of the countries and regions[9] in Table 1.3, only China and Singapore had domestic fixed capital formation rates of a similar magnitude.

1.2.5 Information Structure

The postulated information structure has a fundamental imapct on the model and its outcomes. Clearly, one must ask whether it is a reaslistic set up and in particular, whether we should believe that the information aggregation that occurs when entrepreneurs suspend will have such a large influence on the beliefs of others in the industry. More deeply, we must ask whether it is realistic to suppose that the suspensions convey *any* information to the market that it does not already have. In principle, one could come up with other formulations of the model in which this information was partially or completely revealed through other means. This begs the question of whether I have chosen an appropriate modelling strategy. Of course, I argue that the answer is yes. In a different model, of course, other sources of information might be available – market prices of substitutes, market research and/or public opinion polls, and so forth. But I argue that the tension I have focused on is still interesting at the margin; that is, even if everyone were able to observe the outcome of a market research poll, or a market price, the information held by the entrepreneurs would still be important so long as the publicly observeable variable was not fully revealing.

Ultimately, the information and revelation structure that is chosen needs to be consistent with what we observe. I argue that the assumptions made here focus attention on the information revealed by investment suspensions, and that it is reasonable to assume that these suspensions contain information. This is particularly likely to be true in markets for infrastructure goods that are typically not traded before substantial investment has taken place, and in emerging markets that may be illiquid or suffer from limited investor participation. In this context, it is probably useful to return to an example I mentioned earlier – the development of third generation (3G) mobile communications networks. The relevant firms in this market are typically publicly traded in very liquid and well-developed capital markets, and there is no shortage of press and analyst coverage, market research, or investor interest. Despite this there is little consensus on whether there will ultimately be significant demand for the technology.

[9]The Euro Area consists of Austria, Belguim, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain.

1.3 Explaining the East Asian Crisis

As noted above, my focus is the impact of the financial sector on the likelihood and severity of crisis given that a demand shock may occur. The model is entirely domestic; there is no exchange rate, and no international capital flow. Additionally, there is no role for monetary policy. A comprehensive model of the East Asian crisis would almost certainly have to say something about all three of these. As an indication of the diverse factors that contributed to the crisis, Table 1.4 is a tabulation of opinions gleaned from a series of interviews with officials from central banks, finance ministries, and academic and quasi-academic institutions in six Southeast Asian countries.[10] Evidently, there is little consensus on a single cause (and substantive disagreement in some cases). However, the domestic explanations were, on average, cited slightly more often.[11] This view is also reflected in much of the formal academic literature on the crisis.

[10]Sixty-four interviews were completed between September 1999 and February 2000, in Indonesia, Malaysia, Philippines, Thailand, Singapore, and Vietnam, as part of a project on the prospects for an Asian-based monitoring and surveillance system. Two of these interviews were with officials at regional organisations (ASEAN and the Asian Development Bank). Each person interviewed was asked essentially the same set of questions, the first of which requested the interviewee to describe his or her understanding of the causes of the East Asian Crisis (without prompting). As virtually no one was willing to have their interviews recorded the results in the table are based upon coding of handwritten notes taken during the interviews. The numbers in the table reflect the percentage of interviewees citing the indicated cause, by country. Terms like cronyism and globalisation mean different things to different people. In some cases respondents mentioned these terms explicitly, and in others they described factors (like the impact of cross-border capital flows) that were coded as globalisation. Results are presented and discussed in more detail in Tables 1 and 2 of Furtado and Storey (2000).

[11]Perhaps the most succinct (and memorable) comment to this effect came from the individual who suggested that the Asian Crisis was "like Mambo #5 – a little bit of this, a little bit of that" quoting from a popular music song.

Table 1.4: Causes of the East Asian Crisis

Factor	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
Over-leveraged Institutions	75	88	80	89	75	0
Poor Laws (Domestic)	83	75	50	78	67	71
Weak Financial Sector	83	75	80	100	75	57
Inadequate Domestic Management of Liberalisation	67	75	60	100	75	86
Corruption, Cronyism, Nepotism	75	75	40	89	58	14
Moral Hazard / Inadequate Risk Assessment (Foreign Firms)	75	88	40	67	67	14
Contagion	50	88	50	56	0	86
Globalisation	83	88	80	11	92	71

Chapter 2

Selected Literature Discussion

In this chapter I focus on the relationship between my modeling approach and existing studies. There are two major themes. First, I consider those elements of the intermediation literature that are most closely related to my work. Then, I look at modeling approaches that have been used by others in addressing similar questions and / or tensions. In both sections an important part of the motivation is to help identify what this thesis is *not*. Other important literature discussions appear in the body of the thesis as they arise. For example, in Chapter 5, I discuss empirical measurement of competition in banking, and cover the relevant literature there. As well, a number of studies relating to industry evolution, the Asian crisis, and financial crises in general, are referenced elsewhere in the thesis. That they are not discussed in this chapter is not meant to suggest they were any less important in motivating my work.

I begin by acknowledging a fundamental influence on this work. The underlying real sector structure I use is a modified version of the model of Caplin and Leahy (1994). To their model I add several features, including liquidation values, private benefits, demand uncertainty that is continuous rather than binary, and of course, the use of external debt finance. The change in demand construction makes the post-realisation production decision non-trivial, generating regions of different post-suspension behaviour. Reliance on external finance is shown to alter the equilibrium further, and in particular, may either hasten or prevent the process of information aggregation.

The Caplin and Leahy model was chosen as a building block because it features investment projects with long gestation and irreversibility, and the capacity to deliver relatively sudden changes in activity, based in turn upon endogenous changes in the information available to decision-makers. However, it is designed to illustrate a specific point about investment behaviour. An additional

benefit of the changes I make is showing that a somewhat richer (and smoother) structure will not make the interesting results go away. Nonetheless, the model is still highly stylised, and in particular, it continues to feature a discrete action space. That said, it is capable of producing richer industry dynamics, and generates empirical content not available in the two demand state world. The primary cost of the change is that the bulk of the analysis must be conducted numerically; analytical results are available only in the simplest case. However, given that even the original Caplin and Leahy paper partly relied on numerical results to characterise elements of their equilibrium conditions, I feel that this cost is justified by the benefits achieved.

2.1 Intermediation

The intermediation literature is vast, and so I will first highlight the important tensions in my model in order to motivate those elements of the literature on which I focus. I model the evolution of an industry of wealth-constrained entrepreneurs. The entrepreneurs are assumed to retain operational control of their projects until such time as they are no longer able to fund further project development. Limited liability and the existence of non-assignable private benefits of control create a potential moral hazard problem. Combined with the assumed structure of the investment projects (multi-period gestation, and no revenues until project completion) this means that there is at least one intermediate decision point at which the interests of the entrepreneur have the potential to diverge from those of her funders. Finally, I work within an environment in which the intermediate decisions made by these entrepreneurs have the potential to aggregate (and reveal) information of economy-wide importance. The fundamental issue of interest is the impact that external finance has on this aggregation decision. More specifically, I investigate the differences between competitive and monopolistic credit markets.

Therefore, my work is related to intermediation papers that focus on one or more of the following: control rights, limited liability and the role of collateral, long-gestation investments in irreversibility, multi-period project finance, financial intermediaries as information generators and aggregators, and the impact of financial market structure. Most of these issues are familiar ones; the primary contribution of my work is considering them together. In order to focus on the relationship between the financial sector structures and industry development, I leave aside many familiar tensions. Therefore, the model in this thesis does not have a great deal in common with much of the intermediation literature that focuses on the resolution of individual- or project-specific adverse selection or moral hazard problems. There are no unobserveable effort decisions, no good entrepreneurs that must be sorted from (or signal themselves as distinct from) bad entrepreneurs, no better or worse projects,

no issues arising from asymmetric information, and no idiosyncratic shocks. The only source of uncertainty is the state of demand, and the familiar tensions associated with the limited liability constraint are present. Entrepreneurs differ only in their assessments of the likelihood of high demand, and even in this there is nothing specific about any one individual that makes his or her assessment more valuable than that of the others.

In large part, these modelling choices (as described in the first chapter) were motivated by observations from the East Asian financial crisis. Typically, entrepreneurial models refer to the sorts of decisions that will be taken by an entrepreneur in what is implicitly assumed to be a stable environment. That allows the modeler to focus on tensions arising when entrepreneurs are asymmetrically informed about the likely success of their project. My contention is that in the case of Southeast Asia, in the sorts of industry I model, the fundamental tensions had more to do with aggregate risk than the possibility that one was dealing with a manager intent on pursuing a project that he or she knew to be unprofitable.

The issue here is whether one wants to think of the recent crisis as something that reflects an *inherently* aggregate issue, like uncertainty surrounding the state of demand. The alternative is to look for a model which aggregates inherently idiosyncratic issues and yet has the potential to generate macro events. For example, contract specifications may evolve to address some sort of agency problem. Individually, the solution to the contracting problem is a solution to the agency problem on a case-by-case basis. In aggregate, these contracts generate correlated behaviour that can, under certain circumstances, lead to crisis. Examples of this sort of approach include Allen and Gale (1998). I abstract from the sorts of agency problems that might generate the debt contracts in the first place, and examine the behaviour of the financial sector and the role they play in aggregating information across borrowers.

Caballero and Krishnamurthy (1999) shares some important modeling approach features, including the impact of investment with time-to-build features and an emphasis on collateral values. Their focus is on the role of collateral-backed lending and particularly the level of international collateral – claims on firms in the tradables sector – which impacts the ability of firms to deal with interim liquidity shocks. Although their paper is also aimed directly at the Asian crisis, the focus of their model and mine is quite different. My primary concern – also taking the potential for shocks as given – is the impact that outside finance has on the timing and severity of the shocks. As such, I see my model as complimentary to the one they use, rather than a substitute. Other recent crisis models less closely related to my work include Chang and Velasco (1998) and Edison, Luangaram, and Miller (1998).

Thematically, the thesis bears substantial similarity to the recent work on wealth-constrained intermediation in the presence of liquidity shocks by Holmstrom and Tirole (1997, 1998). A common feature in their papers and the model here is the vital importance of the limited liability constraint (alternatively, the importance of the value of the initial claimants (entrepreneurs') equity in the project). Consider a version of their model in which liquidity shocks are perfectly correlated across firms. One could try to interpret the suspensions in this model as the liquidity shocks in theirs but that would not yield very useful comparisons. There is no tension in this model preventing post-shock profitable investment in this model whereas that is the central concern in theirs. In their two-period model, considering the endogenous timing of a liquidity shock is neither possible nor sensible. More importantly, the idea that intermediaries might help to resolve or exacerbate losses by impacting that endogenous timing is, I think, of value. Other authors concerned with the impact of collateral / limited liability are Bester (1985), Besanko and Thakor (1987), and Coco (1999).

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, and none that I am aware of also incorporates issues relating to information aggregation. While there are many papers investigating financing issues in models that (implicitly or explicitly) feature irreversibility (see Faig and Shum (1999) for a recent example), I am not aware of any that address the question directly in a framework that also allows the endogenous timing of aggregation of information relevant to that investment decision.

In the intermediation literature, there are many papers that look into the question of intermediaries as information providers. The focus in such papers has typically been on the incentives for an intermediary to monitor borrowers in an attempt to sort out ability, type, prospects, effort levels, the veracity of distress claims, and so forth. Examples of such papers include Diamond (1984) on intermediaries as delegated monitors and Holmstrom and Tirole (1997), which addresses the substitute roles of monitoring and capital – higher capital levels allow for lower monitoring (and hence issuance of direct debt).

Bhattacharya and Chiesa (1990) examine the role of proprietary information in the use of bank financing as against other forms of finance. Other papers also considering the distinction between different forms of finance include Repullo and Suarez (1998), Rajan (1992), Diamond (1993), and Bolton and Freixas (2000). There has been much less work considering the *aggregate* information that might be produced as a by-product of intermediary activity. An important exception to this is Stomper (1999), which directly addresses the implications of lending to firms in a growing industry with feedback between the lending decision and the expected profitability of loans outstanding to rival firms. In this model there is demand uncertainty and banks are able to observe a signal about

the state of demand that has higher precision the larger is the monitoring effort of the banks for firms in that industry. Interdependence of firms' returns in a banking context is also addressed by Clemenz (1991). Padilla and Pagano (1996) discuss the impacts of information monopolies that may be developed by banks that become well informed about their borrowers.

A closely related literature studies the development through time of the relationship between borrower and lender, the flows of information within that relationship, and the abilities of both parties to commit to costly future actions in order to assuage some sort of moral hazard problem. Within this context, questions of credit market strucutre are raised. Many of these papers contain tensions similar to my work, but with a different focus. For example, Gehrig (2000) shows how relationships can develop, depending upon the costs of monitoring technologies, even in the presence of robust competition. Caminal and Matutes (2000a) focuses directly on the relationship between banking market structure and bank failures. While interested in similar phenomena, the structure and analysis is quite different from my work.

None of these papers, or any other banking/intermediation papers I am aware of, explicitly address the question of the financial sector's impact on the timing of information aggregation in a given industry.

2.2 Modelling Alternatives

The model being used to motivate the real side of the paper has a fairly specialised structure designed to address questions of information aggregation within a single industry. Basing the real sector components of the modeling strategy on the interactions of investment irreversibility and private information has a number of arguments in its favour. One of the primary considerations is the need to consider the *timing* of broad-based shifts in economic activity. Such widespread changes have, by definition, been a central feature of emerging market crises, 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 East Asia was financing project development in industries like real estate or manufacturing that feature precisely the long gestation periods and irreversibility that the model assumes. The model is consistent with the apparent over-capacity that now exists in these industries. It is also 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 problems have been a central feature of recent emerging

market problems, leading to speculation that these crises may be essentially financial in nature. I have chosen to treat the real sector as the ultimate source of shifts in behaviour. The financial sector anticipates this and adjusts; the point of this thesis is to investigate the precise role it plays in the likelihood and timing of this real sector feature. An alternative is to treat the real sector as inherently stable but subject to disruptions that originate in the financial sector and that are transmitted to the real sector via abrupt changes in asset valuations, credit conditions, and so forth. Ultimately, it is this latter view that underlies much of the popular condemnation of speculators, banks, capital flows, and so forth, for having brought ruin to economies with 'good fundamentals'. It is thus useful to have a model in which the financial and real sectors interact in a meaningful way. Incorporating the financial sector allows me to explicitly examine a number of important questions including the maturity structure of debt contracts that banks are willing to offer to entrepreneurs. This is an important consideration because the preponderance of short-term debt has been singled out not only as an important characteristic of the crisis, but it is also seen by many as one of its primary causes.

I note also that a number of features consistent with recent crises seem also to be consistent with the modelling outcomes here. For example, in the event that widescale suspensions occur it may suddenly become apparent that there is a hopeless over-capacity problem. Firms in the industry are likely to be nearly insolvent, and the industry will be susceptible to *ex post* criticism that it was wildly overoptimistic in its estimation of demand. There may even be much discussion of the sudden nature of the collapse indicating the presence of a 'bubble'. Will the bankers also be criticised, perhaps because the maturity of the debt seems to be too short or because the interest rates are too low? For this I need to characterise the debt contracts more explicitly.

Obviously, there is scope for such disagreements. Asset market data is typically very well-measured, and data is available very quickly relative to economy-wide or sectoral data, some of which is intentionally concealed from public scrutiny. More fundamentally, asset markets are forward-looking, and as such, respond to diverse information signals well before the broad picture is clear to the casual observer. And asset prices are built on expectations. We have only a rudimentary set of ideas of how people form expectations, and this contributes greatly to the interpretive differences.

There are several approaches that might then be considered. Perhaps asset markets sometimes become disconnected from reality, and behave incorrectly. (There is no need at this point to define 'incorrect'; the discussion is entirely heuristic.) In this event, and under the condition that there is a well-specified, causal channel between financial markets and real sector activity, then financial market instability might trigger crises. This instability may result from irrationality (irrational exuberance, panics, manias, etc), from rational but *in some sense* inappropriate behaviour (herding,

informational cascades, rational bubbles, etc) or from some simply unexplainable shift in expectations (multiple equilibria / sunspots). I have put multiple equilibria in the same class as sunspots because a casual review of the literature indicates an empirical (but not a theoretical) association between the two. In other words, the literature on equilibrium selection is rather small, and often 'resorts' to invocation of a sunspot or some similar phenomenon.

Without suggesting that there is no truth in the thought that financial sector instabilities might be to blame, there is significant merit in asking whether the real sector alternative I have chosen can not also generate realistic crisis events. I suggest this not because I am a student of finance and therefore feel compelled to defend the honour and integrity of financial markets, but rather because an incomplete understanding of the role played by the financial sector could lead to inappropriate policy / regulatory responses. This, in turn, will at best limit the effectiveness of the response, and quite possibly could involve unnecessary social costs. I am not suggesting that this thesis contains a comprehensive description of the real sector role in crisis events, but I do hope to reinforce the point that the deep causes of the crisis may involve more than purely financial features.

2.2.1 Models of Herding, Cascades, and Correlated (or Clustered) Behaviour

Imagine a crowded street, with many people walking along. Suddenly, within a few seconds, virtually everyone in the street puts up an umbrella. The umbrellas are large and unwieldy, and prevent the smooth passage of people in opposite directions. What are we to make of this?

There are a number of possible interpretations. Maybe, each person on the street has felt some rain fall on them, and they prefer to be dry. Thinking that the rain might grow heavier, they have put up their umbrellas. Maybe the wind is blowing from the east, and people observe those east of them raising their umbrellas, and assuming that the rain will soon reach them too, raise their own. Or perhaps each of these people has put up their umbrellas simply because those beside them have done so. None has actually felt any rain, but there are many Boy Scouts in the crowd and there is a strong desire to be perceived as prepared. Who first opened, and why that person chose to open, is not known. But reputational concerns cause all to keep their umbrellas open.

A street full of people with open umbrellas is an inconvenient place to be walking, but do we want everyone to put down their umbrellas? The answer crucially depends on why they were raised; the fact that everyone put them up at once is not *prima facie* evidence that there is some sort of irrational behaviour going on.

A variety of studies have examined models in which agents mimic the actions of those that act before, or contemporaneously with, them. This behaviour is often termed herd behaviour[1] or a cascade. Prominent articles in this literature include Banerjee (1992), Bikchandani, Hirschleifer and Welch (1992), and in a capital markets application, Welch (1992). Note that Chamley and Gale refer to the Banerjee paper as herding and the Bikchandani *et al* papers as herding and informational cascade respectively.

In their survey of the literature, Devenow and Welch (1996) define herding as "systematic erroneous (*i.e.*, sub-optimal relative to the best aggregate choice) decision-making by entire populations". A slightly less demanding definition appears in Banerjee: "people... do what others do rather than using their information" and is echoed in Bikchandani, Hirschleifer and Welch: "An informational cascade occurs when it is optimal for an individual, having observed the actions of those ahead of him, to follow the behaviour of the preceding individual without regard to his own information." Once such a point is reached, subsequent decisions carry no informational value.

Although similar aggregate behavior takes place, nothing like this occurs in the model I work with. Initial suspensions are based entirely on one's own information, and subsequent activity on the fact that initial suspensions are fully revealing. Systematic errors of the sort described by Devenow and Welch (1996) never occur. Put slightly differently, suspensions in this model are truly informative, and other agents act on the basis of the information that is revealed, but it is not herding, at least not as far as the definitions above would suggest.

That said, there is the question of what would happen in my model if the information structure was different, so that initial suspensions were only partially revealing. In this event, agents would of course learn from the actions of others, conditional on whatever strategic motives might be present in a more general model, but that doesn't mean that they would ignore their own information or act solely on the basis of what others had done. The key issue here is that despite the dichotomous nature of the investment choice, agents are not restricted to act at a specific point in time but can endogenously order themselves based on the strength of their beliefs.

Agents sort themselves on the basis of the information that has been revealed to them by the actions of others, and those that are most pessimistic at a given point in time are those most likely to alter their behaviour. In this sense, correlated activities in this model are more a matter of 'clustering' than they are of herding. This language is borrowed from Gul and Lundholm (1995). In their model, agents choose when to forecast a variable that they have received a signal about. By

[1] The term is sometimes used in a pejorative fashion, something that may be eminently unfair to sheep and cattle since many herding models also point out that the behaviour is rational...

assumption, agents value precision and dislike delay – those that wait learn something from those that forecast first, but bear the waiting costs of doing so. Early forecasts (made by those with the most extreme beliefs) perfectly reveal the truth to those yet to act, so laggards act immediately after the initial forecasts. In other words, the order in which individuals act is determined endogenously and agents are free to choose the time at which their actions change. These features are in common with the model I use.

Other articles with herding features have considered issues related to investment and project and/or technology choice. Most of these models turn on tensions relating to type that are not part of my approach. For example, Froot and Sharfstein (1990) address the inpact of career concerns on the investment decisions of managers that are one of two types (smart and dumb) and that make sequential decisions. Herding arises in equilibrium because smart managers receive correlated signals while dumb ones receive noise. In their paper, mimicry is consistent with having received the same signal as other managers, which *ceteris paribus* increases the likelihood of being a smart type.

A second paper that investigates issues relating to career concerns is Zwiebel (1995). In Zwiebel's paper managers of different types choose between standard projects and (frist-order) stochastically dominant innovations. Future career prospects depend on the outcome of current projects, and project outcomes in turn depend (linearly) on type – a good manager adds more to a given project outcome than a bad one. This, in combination with an assumed managerial 'minimum wage' available to managers judged after one period to meet a standard (defined by replacement costs) generates an interesting equilibrium. Very good managers innovate, because even if the project outcome is bad their type is good enough to allow inferences that support high future remuneration. The bulk of the managers pool in standard projects, fearing the inferences that would follow a bad project outcome should they innovate. Very bad types innovate, because they have nothing to lose. If they choose a safe project, they will be revealed to be bad types. On the other hand, if they choose the risky project and there is a good project outcome, labour market inferences will put them above the minimum standard, assuring them of at least the minimum wage. The assumed convexity in the payoff facing a poor type creates a desire for higher volatility. Bad managers will not end up worse off by innovating than choosing the standard project – but they may be much better off. The result is similar to risk-shifting behaviour arising from debt but in this case the costs are borne by shareholders that have effectively granted an option to bad managers.

The key issue that arises in these two papers is that behaviour is driven by tensions associated with relative performance. This in turn is a consequence of the hidden attribute of type – which is not a part of the model I work with. In my work, all managers are intrinsically equal and differ only in signals they see.

2.2.2 Real Options and Models of Investment Dynamics, Informational Cycles, and Delay

The work done in this thesis bears close resemblance to the real options literature. Obviously, an entrepreneur with an ongoing project that is faced each period with the choice of whether to continue or to mothball for one period holds a real option. But my work does differ from the quintessential real options setup. In most such models, agents choose when to take an action – for example, when to invest – and the tension comes from the possibility that as time passes, more information will be revealed that will help them to make the best decision. Thus the option to *delay* taking the real decision is valuable because waiting increases the information available. Typically, the information flow is exogenous. For example, a key price may vary through time, under the implicit or explicit assumption that the actions of the real option holder will not impact the price process.

A smaller literature has examined situations in which it is the exercise decisions themselves that create the information flow. Of particular relevance to my work, there is a series of papers on investment in markets of unknown size that includes Zeira (1987, 1994), Rob (1991), Caplin and Leahy (1993), and, in an extension to a strategic framework, Chamley and Gale (1994). In each, investment decisions benefit from information (endogenously) revealed by previous investment decisions. Caplin and Leahy (1994), the paper from which I draw a number of key modelling elements, focuses on the potential for discontinuous change in investment behaviour at the aggregate level, but incorporates this same aspect of 'endogenous' information flow.

The fundamental mechanism in the Zeira papers is the need to experiment – via investment or production decisions – in order to resolve uncertainty regarding technological, cost, or demand conditions. Firms expand production so long as it remains profitable to do so, but do not know where to stop until it is too late. This generates 'informational overshooting' that is driven by Bayesian updating and the experimental process. The overshooting is made more stark by constructing models that reveal the 'true' value of the parameter immediately after one has invested or produced 'too much' given the true parameter. Thus the information revealed with each new production decision places a new lower bound on the variable of interest – and the only way to discover the parameter is to go too far. Zeira (1999) extends the basic mechanism of informational overshooting to generate booms and crashes in asset prices based on uncertainty about the time at which changes in fundamentals (dividend growth rates, technical progess, removal of entry barriers) will cease. In the simplest terms, knowledge that technical progress is underway generates capital accumulation, which continues until the process of investment and production reveals the limits of that progress.

Rob (1991) and Caplin and Leahy (1993) are models of industry evolution that shift the focus

from self-generated information to that made available – directly or indirectly – by the decisions of others. These papers explicitly analyse the incentives to delay investment based on what can be learned from those that invest first. They predict more-or-less gradual changes in behaviour, at least insofar as aggregate activity levels go, but they also hold the potential for 'overshooting' of a sort. Again, the structure of changes in behaviour, and of the 'overshooting', is determined at a fundamental level by the information structure. In both of these models, public information evolves as rapidly or as slowly as do the changes in the investment / production decisions that generate it.

Rob (1991) is essentially a (competitve) industry version of the Zeira approach. Demand is assumed to be stationary throughout the life of the model, but uncertain at the beginning. One way to think of this is that there was a pre-history, during which the demand curve was known, and then at time 0 an uncertain number of new consumers arrived. The only information available to current and potential market participants is past and present data on production levels and prices – so (secure in the knowledge that the 'new' demand curve is stationary) capacity expansion via new entry [2] will eventually reveal the size of the expansion. The speed with which the demand shock is revealed depends upon the structure of demand. Given that firms know the functional form of demand and that it does not change after the initial shock, a single period of capacity expansion (of known size) and a corresponding price change will accurately identify the demand shift. But Rob assumes what amounts to a flat portion on the demand curve (operationalised by specifying a maximum price that consumers will pay) and in this region, small capacity changes cause no price change and hence do not reveal the demand shock. [3] More generally in this sort of model, either additional noise or some flat portion in demand (or vertical portion in supply) will be required to prevent immdeiate revelation.

In Caplin and Leahy (1993), new entrants pay a known, irreversible cost of initial investment and learn the value of marginal costs. Demand is fixed across time, so prices fall as investment (and production) increases, but the process stops when price reaches marginal cost (hence revealing it to all). Potential investors, concerned with recovering not just marginal costs but also upfront costs, observe prices and make inferences about marginal costs. Delay allows further learning at the expense of one more a period of foregone potential profits. The model is able to generate some

[2]Rob interprets capacity expansion as new entrants, but this is not the only interpretation. He has assumed that production is done via machines that produce one unit – and obviously existing firms could buy more machines. In this sense, new entrant and capacity expansion are basically synonymous in his model. This is not true in Caplin and Leahy (1993), however. Again, the fundamental difference relates to the informational assumptions.

[3]The obvious solution – sufficiently large initial capacity expansions – is something that a planner can effect but that the competitive market takes more time to identify. This welfare consideration is a major focus in Rob (1991).

satisfying results regarding industry dynamics. For example, early entrants earn positive profits while those that start-up later earn negative profits, though of course all earn zero profits *ex ante*. The negative profits earned by the late entrants are the analogue to the 'overshooting' in the Zeira models.

There is a somewhat troubling aspect to the model as well. Firms learn costs immediately – it would be more difficult to justify any other assumption – and yet do not take advantage of this information advantage. They are not allowed to increase scale or make new investments in the same industry, even by paying appropriate upfront costs. As is the case in the 'other' Caplin and Leahy model, and in the model I use, allowing scale changes could convey information in addition to that conveyed by production decisions. For example, if initial entrants were allowed to expand scale, they might (perfectly) reveal their information regarding marginal costs. In this model, though, it hardly seems relevant, because allowing scale expansion would also mean that industry capacity would expand by the second period to the zero-profit level as initial entrants used their information advantage, and this would presumably change the strategic considerations involved with the initial entry decision as well. The inference problem faced by potential entrants loses relevance. The more general issue (also the case in my work) is that one requires that there be no mechanism by which information is perfectly revealed. In this event, those less informed must still make inferences, and the model thus continues to have merit.

Perhaps the closest real options paper is Chamley and Gale (1994), which is a model of strategic delay in investment behaviour. Suppose that an unknown number (*i.e.,* proportion) of agents have access to an investment project that can be initiated at any time by making a single payment. Agents know that the value of the investment project is positively correlated with the number of such options in existence, and get a better idea of the number of options as more agents exercise them. This relationship does not reflect a strategic complimentarity – rather, it is simply the case that exercise reveals information about the state (*i.e.,* the payoff does not increase in the number of people choosing to invest but the number of people choosing to invest does tell one something about the payoff to doing so). Investment is a one-time affair. Structurally, this is different from my work, in which there is no opportunity to delay project commencement but the multiperiod nature of the investment requirement means an ongoing commitment. Further, in my work there is a 'strategic substitute' relationship that simply works from the assumption of downward-sloping demand – that is, a given individual's project payoff increases as the number of participants falls.

2.2.3 Aggregation of Information

The literature on the aggregation of information has pursued particular cases at length. A seminal paper in this area is Wilson (1977) who showed that in competitive first-price auction environments differentially informed purchasers will cause price to equal the (common) value in the competitive limit. Similar questions have since been asked in a variety of other environments, especially Cournot oligopoly, in such papers as Palfrey (1985) and Vives (1988). Some of the most recent work in this area may be the closest thematically to the model in this thesis. In Ho Lee (1998) examines the information aggregation process in the context of informational cascades and avalanches that can occur when actions are taken sequentially.

The primary question of interest in most such papers is the degree to which a specific market construct or mechanism generates prices that reflect the diverse information of market participants. Aggregation of information is also an important theme in my work, though the approach taken is quite different since there is no centrally observeable price that can bear the burden of information transmission. In my model it is only the publicly observeable actions of entrepreneurs that leads to information aggregation. However, the distinction does raise an important issue: does the result in my model hinge on the absence of a price? Yes and no. Presumably, one could specify a model that includes futures markets and with sufficient assumptions on the costs of information acquisition and so forth, the futures price would aggregate all of the information available to the market, including that held by the entrepreneurs. The investment problem would go away very quickly. Even more to the point, the government or investment coordination agency could presumably create a system of taxes and transfers that would prompt entrepreneurs to reveal their signals after one period, hence revealing information.

The central issue in this model is that those that invest acquire information as they do, that this information has bearing on an aggregate parameter of relevance to all entrepreneurs, and that the entrepreneurs reveal at least part of their information through their lumpy investment activity. Upon seeing what others have done, entrepreneurs update and this updating process may impact what they do next time around. The very specialised model that is used to illustrate this is susceptible to many criticisms, but the modelling choices are made to facilitate understanding of what is already a complicated problem. How would the update process go if there was also a semi-revealing market price floating about? This may be more difficult to solve analytically but presumably the updating will occur – and if the entrepreneur's actions are potentially informative then their actions will matter. Likewise, the system of taxes and transfers is likely to work less well, or to be gamed, in a model with fewer entrepreneurs, so that strategic issues are more relevant. Again, strategic issues

are shunted aside in this modelling framework, not because they are unimportant but because they rapidly make the model intractible, and in any case detract from the central areas being investigated.

2.2.4 Banks and the Balance Sheet

I briefly mention Kiyotaki and Moore (1997) in the section on post-thesis projects at the end of this thesis. It should also be raised here. Their paper can be seen as furthering a discussion kickstarted by several papers (Bernanke (1983), Bernanke and Gertler (1989), Bernanke and Gertler (1990)) that address the impact of borrower net worth in a macroeconomic environment. The general argument in these papers is that as borrower net worth declines (deadweight) agency costs (monitoring/costly state verification) associated with new investment increase. The paper by Caballero and Krishnamurthy described earlier also fits well in this category. This literature does address some issues in common with my interests but the degree of overlap is quite limited, especially insofar as modelling approch is concerned.

Chapter 3

Self-Funded Entrepreneurs

This chapter outlines the basic entrepreneurial model I will use. It is essentially a model of industry evolution. Uncertainty about industry conditions is the key driving force.

3.1 The Model

- Time is discrete and runs from 0 to T.
- All market participants are risk neutral and the time value of money is assumed to be zero.
- At time 0 a continuum of possible entrepreneurs with finite mass $\geq A$ (a positive constant) decides whether to undertake identical investment projects. Project initiation occurs only at time 0. There is no entry subsequent to time 0 but entrepreneurs can exit at any time.
- Entrepreneurs have initial wealth of $C \geq 0$, which is sufficient to fund the development of the entire project.[1]
- Project scale is fixed, and each entrepreneur operates a single project.
- Project completion requires investment each period, plus a one-time project initiation fee of κ. Define I_t as the total investment required from time t forward to complete a project that is active at t. For simplicity, the periodic investment requirement is assumed constant through

[1] C will play no role in the model in this chapter, but I introduce it now for later use.

time and equal to 1 per period. Thus $I_0 = \kappa + T + 1$ and at any time t, active projects are such that: $I_t = T + 1 - t$ and capital in place is $I_0 - I_t = \kappa + t$.

- At T, completed projects produce an infinitesimal amount of homogeneous output and revenue is received. Demand is represented by the inverse demand function $P(Q(\theta), \theta)$, where $Q(\theta)$ is aggregate industry output. θ is chosen by Nature at time 0 from the interval $[0, 1]$ but the draw is not observeable until the final investment decisions have been made at T. This draw is the only source of uncertainty about the operation of the project and is common to all entrepreneurs. I use a very simple demand function: $P(Q(\theta), \theta) = A\theta - Q(\theta)$, where A is a fixed constant. The dependence of Q on θ is not specified but rather results from equilibrium exit behaviour.

- At any $s \in [1, T-1]$, entrepreneurs with active investment projects choose between continuing the project, suspending the project for one period, or liquidating the project (exit). At T there are no subsequent periods in which to reinitiate so a choice of suspension is taken to be equivalent to liquidation. Entrepreneurs with suspended projects choose between liquidation and reinitiation. Any entrepreneur that chooses continue or reinitiate at T produces and receives revenue. I use $\hat{t}$ to denote the first period in which suspensions occur.

- Suspension is identified as skipping a required investment, and involves no additional costs. However, resumption of a suspended project requires payment of the skipped investment plus additional restart costs denoted by $\mu \geq 1$.

- Liquidation proceeds are an increasing function of capital in place, denoted $\alpha(I_0 - I_t)$. $\alpha(I_0 - I_t)$ indexes the degree to which investments are irreversible (the lower the liquidation value the greater the irreversibility) and is specified to ensure that it lies in $[0, 1)$. Restart costs μ do not contribute to capital in place (they are sunk once paid) and production at T entirely consumes an entrepreneur's capital in place (there is no salvage). α is initially treated as a constant (*i.e*, $\alpha(I_0 - I_t) = \alpha \times (I_0 - I_t)$).

- Projects generate (non-transferable) private benefits as follows: each period, with probability θ an entrepreneur with an active project receives a one-time private benefit of $c \in [0, 1]$ and with probability $1 - \theta$ she does not. Receipt is observeable only to the entrepreneur. Private benefits do not cause any dimunition of the project's value in production or in liquidation. Entrepreneurs with suspended projects receive no private benefit while in this state. Private benefits thus serve as the signal process and I frequently refer to them as such. Conditional

on θ, signals are independent through time and across entrepreneurs.[2]

- The mass of initial entrants is determined by an *ex ante* expected zero-profit condition and is denoted by N. In the event no entrepreneurs exit the industry, $Q = N$.

- The 'period' beginning at t and ending at $t+1$ is called 'period t'. Entrepreneurs begin period t by making operational decisions and then invest / suspend / liquidate according to the decisions they have made before making new operational decisions at the beginning of period $t+1$. If they invest, a new signal is received subsequent to the investment. Each entrepreneur observes the behaviour of all other entrepreneurs. Thus, including the signal received upon payment of the initial investment payment at time 0, investors with active projects at t are making decisions based upon priors, a total of t signals, and their observations of other entrepreneurs' behaviour.

- Define the exogenous parameter set $\Gamma = \{\alpha, \mu, \kappa, c, T, A, C\}$, which represents the data of the model: the index of irreversibility, the reinitiation cost, the initial investment in the project, the (cash equivalent) value of the private benefit, the number of periods a project takes to complete, a demand function parameter, and the entrepreneurs' inital wealth level. Each of these parameters is common knowledge.

- The endogenous variables in the model are the mass of entrepreneurs that are active in the industry at each time t, the timing of changes in this level, and the various 'cutoff' values of θ that distinguish different regions of post-revelation industry adjustments.

3.2 The Game

The game described in this chapter is a multi-stage game of *incomplete* and *imperfect* information. The state of Nature (*i.e.*, θ) is not observed and players must form beliefs using Bayes Rule. All entrepreneurs observe the operational decisions of all other entrepreneurs and perfectly recall what they observe. The degree of strategic interaction is quite limited. I search for a Bayes Nash equilibrium.

[2] An alternative interpretation is that c represents a non-observeable interim cash flow. This makes no qualitative difference to the model of this chapter.

The Players

The economy consists of a continuum of possible entrepreneurs, and Nature. The superscript e_i denotes an entrepreneur of "type" i. Entrepreneurs are *ex ante* identical, as are their projects. Type refers to the signal sequence that entrepreneurs have received. Specifically, entrepreneurs receive positive or negative signals (described below) and the entrepreneur's type is the number of positive signals received.[3] Of particular interest is type 0, defined by having received only bad signals.

Information Structure

The structure of the game is common knowledge, and all players share the same priors. The only source of uncertainty in the model is Nature's draw of $\theta \in [0, 1]$. Entrepreneurs receive a binary signal (receipt or non-receipt of a private benefit) each period they have an active project. The probability that a given entrepreneur receives a good signal in a given period is θ. Thus good signals are more likely when demand is high.[4] Entrepreneurs begin the game with priors about the value of θ, and then update these beliefs based on the signals they receive.

I use a specific information structure to facilitate the analysis.[5] Suppose one sees a sample of fixed length s from a stationary and independent Bernoulli process, where θ denotes the likelihood of observing a success on any given draw. Denote this sample by σ_s. Note that σ_s can be represented simply as the number (between zero and s) of successful trials. Suppose also that one's prior beliefs about θ can be summarised by a beta distribution $\beta e(a, b)$, $a, b > 0$. Given that σ_s contains n successes and $s - n$ failures, Bayes rule generates posterior beliefs governed by $\beta e(a + n, b + s - n)$. That is,

[3] In the special cases of $\theta = 0$ or $\theta = 1$ there is only one type, but I do not analyse these (zero-probability) cases further.

[4] The implication is that on average entrepreneurs enjoy more private benefits when the state of demand is high. Nothing depends upon this; it is straightforward to make the private benefit a constant and entirely separate from the signal process. This alternative would, however, add to the incentive to delay suspensions (other things equal). In any case, it does seem intuitively reasonable to suppose that the private benefit stream would be correlated with demand in this way. Whether one thinks of these benefits as riding to work in a limo or (the monetary value of) being recognised by your peers as important, it seems perfectly reasonable that their (expected) magnitude should be greater when demand is higher and, other things equal, the entrepreneur will operate a project to completion.

[5] The statistical material is standard and is adapted from Chapter 9 of Raiffa and Schleifer (1961).

$$f(\theta\,|\sigma_s) = \frac{\theta^{a+n-1}(1-\theta)^{b+s-n-1}}{\int_0^1 \theta^{a+n-1}(1-\theta)^{b+s-n-1}d\theta} \tag{3.1}$$

In the current context, interpret a good signal (i.e, receipt of a private benefit) as a successful trial and s as the current time period $0 < s \leq T$. Then, given the assumption of common priors, the distribution function in (3.1) describes an entrepreneur's beliefs about θ as a function of σ_s^e, the private signals the entrepreneur has received to time s.

In addition to the private signals, entrepreneurs use the observed behaviour of others to form their beliefs. The expression in (3.1) thus characterises posterior beliefs only during the initial stages of the project when no entrepreneurs have altered their investment behaviour. Let $\Sigma_s^{e_i}$ denote the time s information set of an entrepreneur of type i, which consists of $\sigma_s^{e_i}$ (containing i good signals and $s-i$ bad ones) plus the observed operational decisions made by all other entrepreneurs.

The assumption that there is a continuum of entrepreneurs means that although signal histories may differ across any two entrepeneurs at any point in time s, the economywide distribution of σ_s is a deterministic function of θ. Since only those with specific signal sequences suspend in equilibrium, observers can use the mass of initial suspensions to back out the value of θ consistent with observed suspensions. At this point beliefs concentrate (correctly) on a common point and further signals are uninformative.[6] Thus $f(\theta|\sigma) = f(\theta|\Sigma)$ before suspensions occur, and $f(\theta|\sigma) = \theta$ afterward.

Given this discussion, we can define the vector of beliefs at time t as $f_t = (f^e) = (f^0, f^1, ..., f^t)$, with the added restriction that if first suspensions occur at time s, f_{s+i} is such that $f^0 = f^1 = ... = f^{s+i}, i = 1, ..., T-s$. That is, all players share beliefs (priors) at time 0 and subsequent to suspensions, and in the interim, beliefs are formed by the application of Bayes rule to observed signals and behaviour.

Order of Play and Actions

Nature begins the game by choosing θ. The entrepreneur's action set is {*invest, suspend, liquidate*} = {*inv, sus, liq*}, subject to the proviso that once an entrepreneur liquidates the game ends for her. At time 0, an entrepreneurial choice of *inv* is interpreted as a decision to enter the industry, while

[6]This is a convenient construction borrowed from Caplin and Leahy. It greatly simplifes the characterisation of results. Otherwise (*i.e.* using a small number of entrepreneurs), the game might feature several rounds of partially informative suspensions, and open up the possibility (with some additional model adjustments) of enhanced strategic considerations. Both features would be useful in other contexts, but the work here is aimed at interpretation of macro crisis events rather than these issues.

a choice of either *sus* or *liq* is interpreted as a decision to not enter (and again, the game ends for those that do not enter). Moreover, for an entrepreneur with a suspended project, *inv* is interpreted as a project restart. At time T, *inv* is interpreted as a decision to produce and market one's output, while *sus* and *liq* are both treated as a decision to liquidate.

Strategies

Here, and in what follows, I will use the following notation: Let $\phi(\Sigma) = \phi^e(\Sigma^e)$ denote a strategy profile for the game. A superscript * denotes an equilibrium (see the section on Equilibrium below). The strategy space for the entrepreneur is $\Phi^e = \{inv_s|inv_{s-1}, sus_s|inv_{s-1}, liq_s|inv_{s-1}, inv_s|sus_{s-1}, liq_s|sus_{s-1}\}$. ϕ^e specifies, for every s and Σ^e_s, a a probability distribution over permissible elements in Φ^e.

Equilibrium

In general terms, I am searching for ϕ^{e*}, which is that strategy profile that specifies:

- entry by the appropriate mass of entrepreneurs (*i.e.*, such that the *ex ante* zero-profit condition is satisfied)
- continued investment by all entrants until some time $\hat{t}$, defined as the first time at which those entrepreneurs with only bad signals choose suspension with positive probability (all others continue to invest)
- from $\hat{t}+1$ onward, investment (and production) by the appropriate number of entrepreneurs (such that the $\hat{t}+1$ analogue to the zero-profit condition is satisfied), and liquidation by all others.

I look for symmetric (Bayesian) Nash equilibria featuring strategy profiles of type ϕ^*. I will use $U_s(\theta|\phi)$ to denote the expected net revenues, as viewed from time s, of using strategy profile ϕ.

Comment 1 This definition of equilibrium is consistent with equilibria that involve first supensions at $t \leq T$, and with the possibility that there are no suspensions (*i.e.*, all entrants simply invest through T).

Comment 2 I focus on equilibria in which, conditional on signal history, entrepreneurs play pure strategies at $\hat{t}$. Specifically, all entrepreneurs with the same signal history are restricted to playing the same pure strategy at $\hat{t}$, so *all* entrepreneurs with no good signals will suspend at $\hat{t}$. However, the model set up accomodates (indeed requires) the playing of mixed strategies in order to meet

various indifference conditions. For example, not all potential entrepreneurs will enter at time 0, and I assume that this is effected by entrepreneurs playing enter at time 0 with the 'right' probability (the one that ensures the zero expected profit condition will hold).

Comment 3 I look for equilibria in which entrepreneurs with the worst signal history (*i.e.*, the most pessimistic entrepreneurs) suspend first, and I look for the first time at which it is an equilibrium for them to do so. There may be equilibria in which

1. the most pessimistic entrepreneurs are joined by those not quite so pessimistic
2. first suspensions do not occur in the first period they can be supported as an equilibrium
3. asymmetric strategies are played

Restricting attention to the first possible time has focal qualities and I believe is quite reasonable. I check candidate equilibria to ensure that focus on the most pessimistic entrepreneurs is valid. Finally, although I cannot rule out asymmetric equilibria, some of the 'common' versions are not equilibria in this model. For example, it is not generally an equilibrium for all (or any subpart) of the entrepreneurs that see a bad signal in the first period to always suspend after one period. This would reveal information, but it would typically also be subject to free rider problems. Nor is it an equilibrium for some subgroup to always suspend based on some extrinsic factor – this will not reveal any information unless the extrinsic factor is related to the signals received (meaning it isn't really extrinsic).

To show that a candidate equilibrium is indeed an equilibrium, I demonstrate that no player will have an incentive to deviate (*i.e.*, ϕ^* specifies best responses). There are several possible types of deviations that need to be ruled out for a candidate equilibrium of the form ϕ^* to be valid. They are:

1. Type 1: An entrepreneur with one or more good signals prefers to suspend at $\hat{t}$ (rather than continuing as prescribed by ϕ^*).
2. Type 2: An entrepreneur with no good signals prefers not to suspend at $\hat{t}$.
3. Type 3: An entrepreneur with one or more good signals prefers to suspend at some time prior to $\hat{t}$ (rather than continuing).
4. Type 4: An entrepreneur with no good signals prefers to suspend at some time prior to $\hat{t}$ (rather than continuing).

Only two of these present practical problems. First, the solution method requires candidate equilibria to satisfy a relation that rules out Type 2 deviations. Also, Type 3 deviations are subsumed by Type 4 deviations (*i.e.*, if there are no Type 4 deviations then there will be no Type 3 deviations). Therefore checking candidate equilibria against deviations of Type 1 and Type 4 is all that is required. I discuss this in more detail later in the chapter.[7]

3.3 Approach to Solving the Model

Given that I am interested in equilibria of the form ϕ^*, time can be divided into three phases. First, there is an initial phase in which entry takes place, and all entrants subsequently invest and accumulate private signals. Next, there is a second phase – which lasts only one period – in which at least some of the entrepreneurs become pessimistic enough to shut down their projects, thereby revealing the 'true' state of demand. Finally, in the third phase all relevant information is known, so the size of the industry adjusts to the true state of demand, and those that carry on eventually produce and sell their goods. I use $\hat{t}$ to denote that decision point at which entrepreneurs first choose to suspend. Therefore, decisions characterising the 'evolution' of the industry take place at 0 (entry), $\hat{t}$ (first suspensions), and $\hat{t}+1$ (any reinitiations or further suspensions). In solving, it is convenient to work backwards, characterising entrepreneur behaviour in each period.

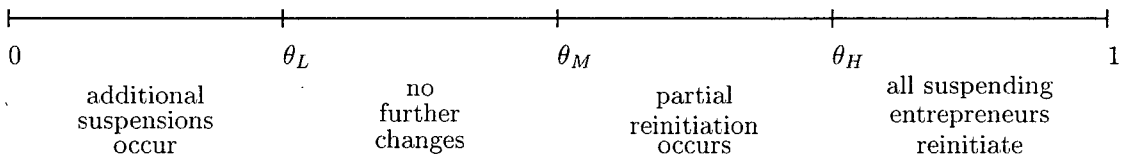
Subsequent to the revelation of θ, it may be that entrepreneurs that initially suspended want to restart their projects. Alternatively, some of the entrepreneurs that carried on while others suspended may wish to subsequently suspend themselves. Finally, it may be that the number of entrepreneurs that suspended was 'just right' – that is, there are no further suspensions and no restarts. To deal with this it is helpful to partition the range of possible θ realisations into distinct regions[8] where these different behaviours will occur, as indicated in Figure 3.1. A useful indifference condition defines each of $\{\theta_L, \theta_M, \theta_H\}$.

The indifference conditions that characterise $\{\theta_L, \theta_M, \theta_H\}$ are developed below. These conditions

[7]The list of deviations does not contain possible deviations relating to decisions taken at entry, or subsequent to the revelation of θ at $\hat{t}+1$. The magnitude of initial entry, and the industry adjustments subsequent to $\hat{t}$, must by construction satisfy specific indifference relations (discussed in detail later in the text). Therefore I specify that at $t=0$ (entry) and at $\hat{t}+1$ (post-realisation industry adjustment) entrepreneurs choose entry and continuation / reinitiation / liquidation respectively with probabilites calibrated to ensure these indifference conditions hold. I do not consider further the possibility of deviations at these decision points.

[8]I show that these regions are indeed distinct.

Figure 3.1: Change in Industry Size at $\hat{t}+1$



characterise regions of behaviour that will occur subsequent to the realisation of θ (*i.e.*, from $\hat{t}+1$ forward). Note that for a given firm, these conditions hold only in expectation, since the interim private benefits that will accumulate between $\hat{t}+1$ and T are not deterministic even after θ is known. However, expected interim private benefits (given by $c\theta I_{\hat{t}+1}$) is all that is required to determine behaviour at $\hat{t}+1$.[9] Two further observations facilitate the analysis:

Observation 1 (Outcome Equivalence) *Conditional on θ, decisions taken at $\hat{t}$ determine expected outcomes.*

In equilibrium, entrepreneurs that follow the same strategy at $\hat{t}$ receive the same expected outcome, whether or not they subsequently produce. For example, if suspensions at $\hat{t}$ reveal $\theta < \theta_L$, some that continued at $\hat{t}$ subsequently choose to liquidate their projects. Those that do so nonetheless receive the same outcome as those that do not. The specific identity of those that carry on and those that do not is irrelevant.[10]

Observation 2 (Regions are Distinct) *There are no values of θ that, once revealed, will motivate suspenders to restart and continuers to suspend.*

At most one of these things will occur. For example, suppose that θ has been revealed to be high enough that at least one entrepreneur is willing to return ($\theta \in (\theta_M, 1]$). This entrepreneur must expect to receive interim private benefits and production receipts sufficient to compensate not only for the remaining investment requirements (including the skipped investment), but also for the

[9]Given the continuum assumption, all possible patterns of private benefits between $\hat{t}+1$ and T will occur. The 'unlucky' ones will receive no private benefits at all while the luckiest will enjoy private benefits each period. On an industry wide basis, however, θ% of the remaining firms will receive the cash flow each period.

[10]Self-financed entrepreneurs fully internalise the costs and benefits of the private benefits in their decision-making process. This will not necessarily be true once debt is added.

restart costs. Since all producing entrepreneurs get the same price, those that continued at $\hat{t}$ will strictly prefer the elevated production receipts (high enough to compensate them for restart costs they aren't required to pay) to liquidation proceeds. Similarly, if at least some of those that have remained in are ready to shut down ($\theta \in [0, \theta_L)$), then it must be that the market outcome will compensate only the expected net costs of further investment, and then only if the industry shrinks. No entrepreneur will be willing to pay restart costs to participate, since these cannot be recouped.

θ_H

If the news is good enough, entrepreneurs that suspend at $\hat{t}$ may find it profitable to pay the restart costs and the missed investment, as well as all remaining investment costs, and carry on to production at T, rather than liquidating their projects. θ_H is the θ such that all entrepreneurs that suspended at $\hat{t}$ are just willing to reinitiate at $\hat{t}+1$, conditional on *all* entrepreneurs doing so and given that the entrepreneurs that invested at $\hat{t}$ remain in the industry. Thus all entrepreneurs that initially entered at 0 will produce, so industry production ($Q(\theta_H)$) is given by N. Remaining investment requriements are $I_{\hat{t}+1} = \kappa + T + 1 - (\kappa + \hat{t} + 1) = (T - \hat{t})$ so, net of expected interim private benefits, the entrepreneur expects to contribute $(T - \hat{t})(1 - c\theta_H)$. Entrepreneurs that suspended must also pay the reinitiation cost of μ and the skipped unit of investment. Liquidation by those that suspended would generate $\alpha(\kappa + \hat{t})$. Therefore the indifference condition can be written:

$$P(\theta_H, Q(\theta_H)) - I_{\hat{t}+1}(1 - c\theta_H) - 1 - \mu = \alpha(I_0 - I_{\hat{t}})$$

or, using the specific assumptions,

$$\theta_H A - N - (T - \hat{t})(1 - c\theta_H) - 1 - \mu = \alpha(\kappa + \hat{t}) \tag{3.2}$$

Production revenues plus expected interim private benefits (*i.e.*, total project revenues) will be $(T - \hat{t}) + 1 + \mu + \alpha(\kappa + \hat{t})$, so reinitiating entrepreneurs expect to net $\alpha(\kappa + \hat{t})$ after the remaining investments and reinitiation payments are made. Note that at θ_H, entrepreneurs that did *not* suspend at $\hat{t}$ and that carry on to produce at T generate the same production revenues and expected interim private benefits, but these entrepreneurs need pay only $(T - \hat{t})$ to generate them. Therefore if $1 + \mu + \alpha(\kappa + \hat{t}) \geq \alpha(\kappa + \hat{t} + 1)$ – which it must be – then no entrepreneurs that continued at $\hat{t}$ will find it optimal to suspend for any $\theta \in (\theta_H, 1]$. To summarise, for $\theta > \theta_H$ all entrepreneurs produce, and outcomes increase with θ.

θ_M

θ_M is the highest θ at which *none* of those that suspend at $\hat{t}$ are willing to reinitiate their projects, given that all who continued at $\hat{t}$ remain in the industry. For any $\theta > \theta_M$ at least some entrepreneurs

will reinitiate their projects. On the other hand, for all $\theta \in [0, \theta_M)$ there will be no reinitiation. Given that those that suspend are those that have received no good signals after $\hat{t}$ periods, we can compute the mass of suspending entrepreneurs as $N(1-\theta_M)^{\hat{t}}$. The relevant indifference condition is then

$$\theta_M A - [1-(1-\theta_M)^{\hat{t}}]N - (T-\hat{t})(1-c\theta_M) - 1 - \mu = \alpha(\kappa + \hat{t}) \tag{3.3}$$

The conclusions drawn above regarding entrepreneurs that continued at $\hat{t}$ are also true on the interval (θ_M, θ_H). In particular, they will not suspend, since remaining generates expected net receipts (in excess of liquidation) of $\mu + 1 - \alpha > 0$. The implication is that on this interval the size of the industry adjusts to the realisation of θ with higher θ prompting more reinitiation. Therefore, expected outcomes do not vary with θ.

θ_L

We know that below θ_M there will be no reinitiation behaviour, but because of the 'wedge' introduced by the reinitiation costs we would expect that conditions would have to be even less favourable to induce any of those entrepreneurs that invested at $\hat{t}$ to suspend (liquidate) at $\hat{t}+1$. θ_L helps to formalise this notion, and is defined as the highest θ such that some entrepreneur that continued at $\hat{t}$ would just be willing to liquidate at $\hat{t}+1$ (conditional on no other entrepreneurs doing so). The indifference condition is given by:

$$\theta_L A - [1-(1-\theta_L)^{\hat{t}}]N - (T-\hat{t})(1-c\theta_L) = \alpha(\kappa + \hat{t} + 1) \tag{3.4}$$

Because the 'marginal' entrepreneur is now one that continued at $\hat{t}$ the right hand side of (3.4) reflects the additional unit of investment that has been made.

On the interval (θ_L, θ_M) outcomes accruing to suspended entrepreneurs are constant (given by the liquidation value of $\alpha(\kappa + \hat{t})$). However, this is not true for entrepreneurs that continued at $\hat{t}$, for whom outcomes vary with θ. At the top of the interval all continuing entrepreneurs enjoy positive profits (as viewed from $\hat{t}+1$) in the amount of $\mu + 1 - \alpha$. By the bottom of the interval, they are receiving the equivalent of liquidation. Inspection of (3.4) indicates that for $\theta < \theta_L$ equilibrium production revenues will not compensate the payment of reinititation costs, showing that no entrepreneur that suspended at $\hat{t}$ will want to reinitiate for any value of θ that also motivates a $\hat{t}$-continuer to suspend.

As θ moves below θ_L we expect to see even more suspensions. Is there a $\theta > 0$ such that no entrepreneurs produce? Yes, given the assumed demand curve, there is a θ below which no entrepreneurs produce. However, from the standpoint of the outcomes accruing to different strategy choices, this θ is irrelevant: below θ_L all entrepreneurs that suspended at $\hat{t}$ receive the outside option

of $\alpha(\kappa + \hat{t})$ and all those that continued at $\hat{t}$ get their outside option of $\alpha(\kappa + \hat{t} + 1)$ whether or not they go on to produce. Over the entire range of θ payoffs are weakly increasing in θ independent of whether entrepreneurs suspend.

These various 'cutoff' values of θ embed equilibrium behaviour and are used to compute expected payoffs to different strategies. From (3.2), (3.3), and (3.4) it is easy to show that $0 < \theta_L < \theta_M < \theta_H$ for any reasonable parameter set. There is no algebraic guarantee that $\theta_H < 1$ (or for that matter that $\theta_L < 1$) – but parameter restrictions suffice to ensure that this occurs.

3.4 Entry, Suspension, and Deviant Behaviour

In outlining the different cutoff levels of θ, the foregoing description characterised behaviour once θ is known. These results are summarised in Table 3.1. I now turn to the other two key decisions that entrepreneurs make. One characterises the first decision point at which the expected value of suspending exceeds the expected value of carrying on, as a function of beliefs (*i.e.,* as a function of signals received). The second is an *ex ante* zero-profit condition that determines the magnitude of initial market entry. Here common priors are used to form expectations. Both decisions can be characterised using the outcomes summarised in Table 3.1, together with the fact that prior to $\hat{t}$ each entrepreneur will have expended $I_0 - I_{\hat{t}} = \kappa + \hat{t}$ and have been eligible for private benefits in each of the preceding periods. I begin with discussion of the expression characterising first suspensions.

3.4.1 First Suspension Times

In this section I develop an expression defining the decision to suspend. Because a time T suspension is equivalent to liquidation, it is necessary to define two distinct expressions, one covering suspensions that take place for some $s \in [1, T-1]$ and a second for suspensions that occur at T.

Suspensions $\in [1, T-1]$

Recall that an entrepreneur with an active project can choose one of three actions: invest, suspend, liquidate. However, in any case in which reinitiation is feasible (*i.e.*, excluding extremely high values of μ) the analysis defining suspensions at $s \in [1, T-1]$ need only consider the relative merits of

Table 3.1: Expected Revenues and Costs Conditional on Strategy Followed at $\hat{t}$

	Suspend at $\hat{t}$				Continue at $\hat{t}$				Benefit of Suspending
	Revenue		Costs		Revenue		Costs		
	$\hat{t}$	Post $\hat{t}$	$\hat{t}$	Post $\hat{t}$	$\hat{t}$	Post $\hat{t}$	$\hat{t}$	Post $\hat{t}$	
$0-\theta_L$	0	$\alpha(\kappa+\hat{t})$	0	0	$c\theta$	$\alpha(\kappa+\hat{t}+1)$	1	0	$1-\alpha-c\theta$
$\theta_L-\theta_M$	0	$\alpha(\kappa+\hat{t})$	0	0	$c\theta$	$\theta A - (1-(1-\theta)^{\hat{t}})N + c\theta(T-\hat{t})$	1	$(T-\hat{t})$	$\alpha(\kappa+\hat{t}) - [\theta A - (1-(1-\theta)^{\hat{t}})N - (T+1-\hat{t})(1-c\theta)]$
$\theta_M-\theta_H$	0	$\alpha(\kappa+\hat{t})$	0	0	$c\theta$	$\alpha(\kappa+\hat{t})+1+\mu$	1	0	$-\mu-c\theta$
	or, equivalently								
	0	$\theta A - n + c\theta(T-\hat{t})$	0	$(T-\hat{t})+1+\mu$	$c\theta$	$\theta A - n + c\theta(T-\hat{t})$	1	$(T-\hat{t})$	
θ_H-1	0	$\theta A - N + c\theta(T-\hat{t})$	0	$(T-\hat{t})+1+\mu$	$c\theta$	$\theta A - N + c\theta(T-\hat{t})$	1	$(T-\hat{t})$	$-\mu-c\theta$

suspending and continuing because at any s at which θ is not yet known, suspension dominates immediate liquidation. The argument is very simple. In the absence of a time value for money, one can do no worse by waiting to liquidate tomorrow than by liquidating today. However, one can do better, should suspensions reveal that θ is very high. The informational assumptions ensure that any possible signal sequence will generate posteriors that place positive weight on all values of θ in the interval $[0,1]$. Thus the option to reinitiate will always have value when θ is not yet known, and therefore suspension dominates immediate liquidation.

The preceding section outlined the payoff profiles that entrepreneurs can expect to receive, conditional on θ and the operational decisions they make at $\hat{t}$. Given that the first suspensions reveal the true value of θ, the expected value of suspending, relative to continuing, can be calculated interval by interval. In other words, I am looking for:

$$\hat{t} = \min_s \{s \in [1,T] : U_s(\theta|\text{suspend at } s) > U_s(\theta|\text{continue at } s)\}$$

where expectations are taken with respect to the time s posteriors of the most pessimistic entrepreneurs and it is understood that entrepreneurs will behave according to ϕ^* subsequent to $\hat{t}$.

$[0, \theta_L)$

On this interval, all those that suspend at $\hat{t}$ pay nothing at $\hat{t}$, receive no cash flow at $\hat{t}$, and liquidate

at $\hat{t}+1$ receiving $\alpha(\kappa+\hat{t})$. Those that continue at $\hat{t}$ expect to pay $1-c\theta$ at $\hat{t}$ (*i.e.*, they pay 1 for sure, while expected private benefits are $c\theta$[11]). They may or may not liquidate at $\hat{t}+1$ but will in either case receive a net outcome of $\alpha(\kappa+\hat{t}+1)$.[12] Therefore, should θ be in this interval, the expected value of suspending less the expected value of continuing is $\alpha(\kappa+\hat{t})-[\alpha(\kappa+\hat{t}+1)-(1-c\theta)] = 1-\alpha-c\theta$.

(θ_L, θ_M)

Entrepreneurs that suspend at $\hat{t}$ will liquidate at $\hat{t}+1$ if θ is in (θ_L, θ_M), and will receive $\alpha(\kappa+\hat{t})$. On the other hand, outcomes experienced by those that invest at $\hat{t}$ vary with θ. On this interval there are no suspensions or reinitiations subsequent to $\hat{t}$ and therefore industry output (*i.e.*, the mass of entrepreneurs that carry on to production) does not adjust to ensure a constant outcome over the interval. Instead, output is constant and net production and cash flow revenues increase with θ. Outcomes (reflecting the expected net investment at $\hat{t}$) are $\theta A-(1-(1-\theta)^{\hat{t}})N-(T-\hat{t})(1-c\theta)-(1-c\theta)$.[13]

$(\theta_M, 1]$

Here the time $\hat{t}$ continuers remain in, and some or all of the suspenders return. Those that return must pay (and therefore be compensated for) the skipped investment (which the continuers have already paid), plus the reinitation cost of μ. Moreover, suspenders forgo the possibility of a $\hat{t}$ private benefit c. Thus the expected net cost of suspending is $\mu+c\theta$.

The decision to suspend is taken when the expected value of doing so (relative to continuing) is positive. An explicit representation of the condition determining $\hat{t}$ is the smallest s such that

$$\int_0^{\theta_L}(1-\alpha)\,f^s(\theta)\,d\theta+\int_{\theta_L}^{\theta_M}[\alpha(\kappa+s)-(\theta A-(1-(1-\theta)^s)N-(T-s)(1-c\theta)-1)]\,f^s(\theta)\,d\theta$$
$$-\int_{\theta_M}^{1}\mu\,f^s(\theta)\,d\theta-\int_0^1 c\theta\,f^s(\theta)\,d\theta \;\geq\; 0 \quad (3.5)$$

where $f^s(\theta)$ denotes the posterior beliefs of those agents that have received only bad signals up to time s. The left side of (3.5) is bounded below by $-(\mu+c)$ and above by $1-\alpha$.

[11] At this point θ is still unknown, so entrepreneurs will use their posterior beliefs to form expectations.

[12] That is, exit will occur until those that remain receive the same expected outcome as those that liquidate, and $\alpha(\kappa+\hat{t}+1)$ is the liquidation outcome.

[13] At the lower end of the interval, those that have continued at $\hat{t}$ will experience the same net outcome as they would on the interval $[0,\theta_L)$. That is, continuing entrepreneurs must net $\alpha(\kappa+\hat{t}+1)$. At the upper end of the interval, θ_M, suspending entrepreneurs are just begining to reinitiate, implying that the market price must compensate for not only the remaining investment costs but also reinitiation costs μ. Those that have carried on at $\hat{t}$ earn μ as well. These outcomes are assured by using (3.3) and (3.4) to define the interval (θ_L, θ_M).

Comment: Examination of (3.5) would appear to indicate that the LHS (and thus $\hat{t}$) will be quite sensitive to changes in any of α, μ, κ, or c. However, all of $\{\theta_L, \theta_M, \theta_H, N\}$ are endogenously determined. Changes in α, μ, κ and/or c change the levels of the endogenous variables without impacting the rate at which pessimism grows in those receiving bad signals. For example, recall that the outcome to a suspender is insensitive to θ for $\theta < \theta_H$. The higher is θ_H the smaller is the likelihood of θ exceeding it. This tempers the impact of increases in these parameters on suspension times.

Suspensions at T

Since reinitiation is not possible, entrepreneurs that suspend at T will receive the liquidation value of $\alpha(\kappa + T)$. On the other hand, if they continue (produce) they will receive production revenues with certainty, subject to a minimum of zero. Thus the decision to suspend at T is taken when the expected value of liquidating exceeds the expected value of continuing:

$$\alpha(\kappa + T) - \int_{\theta_b}^{1} [\theta A - (1 - (1-\theta)^T)N] f^T(\theta)\, d\theta - \int_0^1 [1 - c\theta]\, f^T(\theta)\, d\theta \geq 0 \tag{3.6}$$

where $A\theta_b - (1 - (1-\theta_b)^T)N = 0$ defines θ_b, below which production generates zero revenue.[14] In the event that neither of (3.5) and (3.6) hold then there is no equilibrium featuring suspensions. In this case, all entrepreneurs continue to invest through to T and then produce (again, subject to a minimum price of 0).[15]

3.4.2 Entry

There are three possible suspension outcomes (suspensions prior to T, suspensions at T, and no suspensions). Each has a distinct entry condition.

[14] I suppose I am implicitly assuming free disposal, something I thought I'd never have to do...

[15] There is a second case in which no suspensions will be observed, though in this case it will come as a surprise. If $\theta = 1$, no entrepreneurs will suspend and all will carry on until T (and produce) despite everyone having expected interim suspensions at $\hat{t}$. This outcome clearly involves positive profits for all, since it means private benefits in every period in addition to end of period profits. I do not discuss this possibility further, except to note that it is formally a zero-probability event.

Entry Given Suspensions $\in [1, T-1]$

The mass of entrepreneurs entering at 0 adjusts to ensure that expected profits are zero *ex ante*, so we are looking for N such that $U_0(\theta|\,\phi^*) = 0$. Entry occurs prior to the receipt of any private signals so priors are used in forming expectations. The essential considerations have already been outlined. We must only account for the likelihood of finding oneself at time $\hat{t}$ with a signal history containing only bad signals, in which case one suspends.

On the interval $(\theta_H, 1]$ all entrepreneurs produce, and profits increase with θ. The profit earned by an entrepreneur that does not suspend investment at $\hat{t}$ is given by $\theta A - N - (\kappa + T + 1)(1 - c\theta)$. This expression is simply the total revenue (interim private benefits plus production receipts) net of investments. For an entrepreneur that suspends at $\hat{t}$, expected profit is given by $\theta A - N - (T + 1)(1 - c\theta) - \mu - c\theta$, since these entrepreneurs pay reinitiation costs and forgo the possibility of a cash flow at $\hat{t}$.

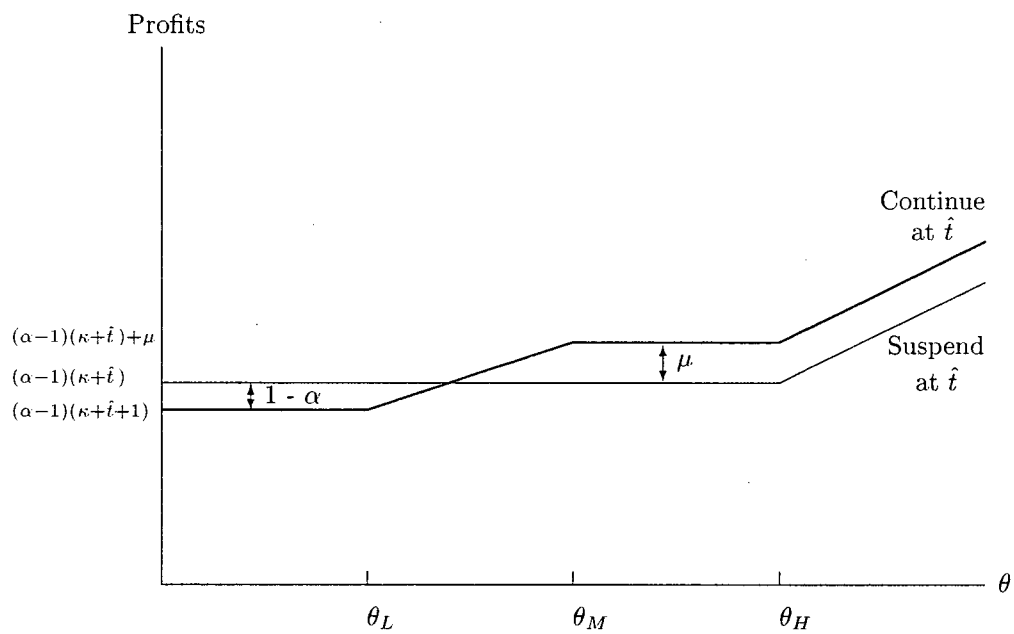
For all $\theta < \theta_H$, we know that the entrepreneurs that suspend end up with the equivalent of the liquidation value plus private benefits accrued to $\hat{t}$, implying expected profits of $(\kappa + \hat{t})(\alpha - 1) + c\theta\hat{t}$. Figure 3.2 illustrates the *ex ante* profit profiles for entrepreneurs that suspend at $\hat{t}$ vs. entrepreneurs that invest at $\hat{t}$ as a function of θ, for the special case of $c = 0$ and $\hat{t} = 1$, given that entrepreneurs behave according to ϕ^*. The bold line is the profit profile for entrepreneurs that continue at $\hat{t}$. Note the option-like features of the profiles, which reflect the assumption that α is constant.

Below θ_H, the profit situation for those entrepreneurs that do not suspend at $\hat{t}$ is a bit more varied. On (θ_M, θ_H), adjustments to industry output take place through the reinitiation behaviour of the suspending entrepreneurs, and in order for any entrepreneurs to reinitiate the eventual revenue earned must offset the reinitiation costs they pay. Those that do not suspend will receive the same profits for any θ in this interval, given by $\mu + (\kappa + \hat{t})(\alpha - 1) + c\theta(\hat{t} + 1)$. On the bottom interval, $[0, \theta_L)$, some or all of the $\hat{t}$-continuers themselves suspend until the net revenues received by remaining are just equal to their liqudation value of $(\kappa + \hat{t} + 1)(\alpha - 1) + c\theta(\hat{t} + 1)$. Finally, for $\theta \in (\theta_L, \theta_M)$, there is no reinititation or further exit after $\hat{t}$ and the profits accruing to entrepreneurs that produce therefore are rising with θ.

Using all of this, an explicit representation of the zero-profit condition determining N is

$$\left[\int_0^1 (1-\theta)^{\hat{t}} f^0(\theta)\, d\theta\right] \times \left\{\int_0^{\theta_H} [(\alpha - 1)(\kappa + \hat{t}) + c\theta\hat{t}]\, f^0(\theta)\, d\theta \; + \right.$$
$$\left. \int_{\theta_H}^1 [\theta A - N - \kappa - (T+1)(1 - c\theta) - \mu - c\theta]\, f^0(\theta)\, d\theta \right\} +$$

Figure 3.2: *Ex Ante* Expected Profits



$$\begin{aligned}\left[1-\int_0^1 (1-\theta)^{\hat{t}} f^0(\theta)\,d\theta\right] \quad \times \quad & \left\{\int_0^{\theta_L} [(\alpha-1)(\kappa+\hat{t}+1)+c\theta(\hat{t}+1)]\, f^0(\theta)\,d\theta \;+\right. \\ & \int_{\theta_L}^{\theta_M} [\theta A-(1-(1-\theta)^{\hat{t}})N-\kappa-(T+1)(1-c\theta)]\, f^0(\theta)\,d\theta \;+ \\ & \int_{\theta_M}^{\theta_H} [(\alpha-1)(\kappa+\hat{t})+c\theta(\hat{t}+1)+\mu]\, f^0(\theta)\,d\theta \;+ \\ & \left.\int_{\theta_H}^{1} [\theta A-N-\kappa-(T+1)(1-c\theta)]\, f^0(\theta)\,d\theta\right\} \\ = \; & 0 \end{aligned} \tag{3.7}$$

where $f^0(\theta)$ denotes the prior distribution of θ. The first term (top left) is the *ex ante* likelihood of receiving all bad signals up to $\hat{t}$, and the second term on the left the likelihood of receiving any other set of signals.

Entry Given Suspensions at T

Any entrepreneurs that suspend at T get the liquidation value. Those that remain get the proceeds from production, subject to a minimum of zero. Entry is determined by

$$\begin{aligned}
\left[\int_0^1 (1-\theta)^T f^0(\theta)\, d\theta\right] &\times \int_0^1 [(\alpha-1)(\kappa+T)+c\,\theta\, T]\, f^0(\theta)\, d\theta \;+ \\
\left[1-\int_0^1 (1-\theta)^T f^0(\theta)\, d\theta\right] &\times \left\{\int_{\theta_b}^1 [\theta A-(1-(1-\theta)^T)N]\, f^0(\theta)\, d\theta \;- \right. \\
&\quad \left. \int_0^1 [(\kappa+T+1)+c\,\theta(T+1)]\, f^0(\theta)\, d\theta\right\} \\
&= 0
\end{aligned} \tag{3.8}$$

Entry Given No Suspensions

It is possible that there will be no $t \in [1, T]$ such that even the most pessimistic entrepreneurs find it in their interests to suspend. In this case, all initial entrants remain in the industry through T, and subsequent to the realisation of θ, produce. For $\theta > \theta_b = N/A$ entrepreneurs earn at least some revenue from their production; below this, they get nothing.

In this case, entry is determined by the condition

$$\int_{\theta_b}^1 [\theta A - N]\, f^0(\theta)\, d\theta - \int_0^1 [(\kappa+T+1)+c\,\theta(T+1)]\, f^0(\theta)\, d\theta = 0 \tag{3.9}$$

3.4.3 Deviations

I now return to the two forms of deviations outlined earlier.

Type 4 Deviations: Existence Issues

Suppose that I am able to find a $\hat{t} < T$ such that (3.5) is satisfied (or a $\hat{t} = T$ such that (3.6) is satisfied). By construction this means that $\hat{t}$ is the first time at which the most pessimistic entrepreneurs perceive that the expected value of suspending exceeds the expected value of continuing, conditional on the equilibrium being played. But is it possible that at some $s < \hat{t}$ some entrepreneur will have become so pessimistic that she is willing to throw in the towel and suspend (*i.e.,* deviate) even though doing so is effectively an abandonment of the project before θ is known? In order to

answer this question, all potential equilibria are checked to ensure that a condition of the following form holds for all $s \in [1, \hat{t} - 1]$:

$$U_s(\theta \mid \phi^*(\sigma)) - \alpha(\kappa + s) \geq 0 \tag{3.10}$$

The first term in (3.10) represents the net revenues expected at time s, as perceived by the most pessimistic entrepreneurs, of continuing to play equilibrium strategies, while $\alpha(\kappa + s)$ is the value of the project in liquidation. If this entrepreneur chooses an off-equilibrium-path suspension she is certain to receive the liquidation value, since her suspension will reveal no information (and the entrepreneur will not decide to reinitiate).[16]

Comment: As far as I have been able to determine, the problem arises only in relatively extreme circumstances (something I will illustrate with a numerical example). Following similar arguments made by Caplin and Leahy themselves, and echoed in Schivardi (2000)[17], I suggest that the existence problem is related to the continuum assumption that ensures that the first suspensions reveal all relevant information. This makes behaviour easy to characterise, but also exacerbates incentives to delay (in hopes others will undertake the costly revelatory actions) and may push $\hat{t}$ far enough into the future that entrepreneurs aren't willing to wait. In a model with a discrete number of entrepreneurs, information could be revealed gradually by early suspenders. This would alter the strategic incentives, and the nature of the equilibrium, but would not create existence issues.

Type 1 Deviations: Semi-Pooling Incentives

Recall that Type 1 deviations are characterised by a desire to mimic on the part of entrepreneurs with one or more good signals.[18] If Type 1 deviations are to occur, it must be that case that an entrepreneur with no good signals at time $\hat{t} - 1$ is willing to invest once more *knowing* that she

[16]Off equilibrium path suspensions do not reveal θ. An entrepreneur that suspends and then reinitiates is simply paying μ for the privilege of being right where she would have been by continuing to play the equilibrium at no additional cost. Therefore those that engage in an off-equilibrium-path suspension will subsequently liquidate.

[17]Schivardi (2000) uses the Caplin and Leahy model to investigate the relationship between aggregate economic shocks and industry (job) restructuring.

[18]I use the expression 'semi-pooling' somewhat loosely. Equilibria of the form ϕ^* can be thought of as separating in the sense that they stipulate different strategies for those with the most pessimistic beliefs, and all the rest (hence separating the entrepreneurs into two groups). Only in the case of equilibria with $\hat{t} = 1$ would complete separation occur. Semi-pooling incentives thus refers to the possibility that other 'types' of entrepreneurs might wish to mimic the pessimists.

will suspend at $\hat{t}$ independent of the final signal she receives.[19] Given risk neutrality, the receipt of a good signal must improve one's outlook regarding demand. Thus Type 1 deviations imply that between $\hat{t}-1$ and $\hat{t}$ some entrepreneurs with no good signals at $\hat{t}-1$ become more upbeat about θ and yet sufficiently less upbeat about the returns to remaining in the industry that they are unwilling to pay the $\hat{t}$ investment and allow those even more pessimistic than themselves to incur the (expected) reinitiation costs. This sounds unlikely, and as noted the numerical work indicates that it is indeed unlikely. However, it is difficult to make analytical comparisons across time periods because $\{\theta_L, \theta_M, \theta_H, N\}$ are all endogenous and therefore vary with the time conjecture.

Therefore candidate equilibria are checked to ensure that a condition of the following form holds at $\hat{t}$:

$$U_{\hat{t}'}(\theta \mid \phi^*(\sigma)) - U_{\hat{t}'}(\theta \mid \text{suspend at } \hat{t}) \geq 0 \tag{3.11}$$

Here $\hat{t}'$ designates expectations taken with respect to the posterior beliefs of an entrepreneur that has, at $\hat{t}$, received one good signal and $\hat{t}-1$ bad signals.

In the event that Type 1 deviations are indicated, I must then search for an equilibrium featuring suspensions by those entrepreneurs with no good signals and those with one good signal, starting with the same $\hat{t}$ conjecture.[20] Any candidate thus found would then also have to be checked to ensure that deviations analogous to those described above do not occur.

3.5 Solving the Model

A solution to the model is a set $\{\theta_L, \theta_M, \theta_H, \hat{t}, N\}$ that satisfy (3.2) through (3.11).[21] In order to solve the model, I suppose that $\hat{t}=1$, and look for $\{\theta_L, \theta_M, \theta_H, N\}$ satisfying (3.2)–(3.4) and (3.7). Then I use these results in (3.5) to check that the inequality holds. If (3.5) holds, there is a candidate equilibrium with suspension at time $\hat{t}=1$. If it does not hold, I increment the guess for $\hat{t}$ by 1 and

[19] Given the assumptions made about the signal process, the pair (m, n) – the total number of signals, and the number of 'successes' – is a sufficient statistic for the signal history. The specific pattern of signals is irrelevant. This justifies framing the discussion in terms of those receiving their single good signal at $\hat{t}-1$.

[20] To justify this latter point regarding timing, I note that in originally searching for the candidate equilibrium we have shown that those with no good signals at $\hat{t}-1$ (including some of those that will subsequently have an incentive to deviate from candidate equilibrium at $\hat{t}$) do not wish to suspend at $\hat{t}-1$. If these most pessimistic entrepreneurs do not wish to suspend at $\hat{t}-1$ then neither would more optimistic entrepreneurs.

[21] Here I concentrate on equilibria with suspensions prior to T.

continue repeating the process until I find a $\hat{t}$ conjecture that works. Finally, once $\hat{t}$ is identified, I check (3.10) $\forall s \in [1, \hat{t}-1]$ and (3.11) at $\hat{t}$. Unfortunately, most of the relevant conditions and expressions are quite non-linear, and in most cases only numerical solutions are feasible.[22]

3.5.1 Numerical Results

Here I look at the properties of the model in more depth using a parameterised example. I start with a 'base case' using as a prior distribution for θ a $\beta e(6,6)$ (which is bell-shaped on $[0,1]$ with a mean of 1/2). The parameters are as above except that I set $c = 0.2$ and $\kappa = 3$. That is, $\{\alpha, \mu, T, \kappa, c, A\} = \{0.4, 3, 12, 3, 0.2, 100\}$.

Table 3.2: Base Case

	θ_L	θ_M	θ_H	N	LHS of (3.5)
$\hat{t}=1$	0.252	0.322	0.659	50.7	-2.73
$\hat{t}=2$	0.434	0.502	0.616	46.8	-0.85
$\hat{t}=3$	0.494	0.545	0.589	44.2	-0.10
$\hat{t}=4$	0.508	0.551	0.569	43.0	0.15

Table 3.2 reports results using $\beta e(6,6)$ priors and the parameter set described above. In this case we need go no further than $\hat{t} = 4$. Entrepreneurs become sufficiently pessimistic to motivate suspension after four bad signals (and no good ones). If Nature has drawn a θ larger than 0.508, we will see no further suspensions, and if it is in excess of 0.569 all of the suspending entrepreneurs will reinitiate.

It is useful to flesh out this numerical example somewhat, by considering various possible realisations of θ. First, it is straighforward to verify that (3.2), (3.3), and (3.4) hold (this is imposed in the solution procedure). More specifically, given the postulated full-information industry adjustments, at $\theta = \{0.508, 0.551, 0.569\}$ the expected revenue net of remaining required investment ($I_{\hat{t}+1}$) is, respectively, $\{3.2, 6.8, 6.8\}$. The first of these is the liquidation value of the project to an entrepreneur that continued at $\hat{t}$, while the second and third reflect the liquidation value to an entrepreneur that suspended at $\hat{t}$, plus the skipped investment cost and the reinititation cost.

More importantly, realisations of θ within the various intervals generate conditions consistent with those postulated in the discussion of the model solution. For example, suppose that Nature has

[22] In Appendix B I partially characterise analytical results for the case of an externally financed entrepreneur. The structure of the analysis is very similar to what would obtain in the self-financing case and therefore I omit it.

drawn $\theta = 0.5$. We know first of all that the mass of entrepreneurs that suspends will be $(1-\theta)^4 N = 0.5^4 \times 43.0 \approx 2.7$, or one-sixteenth of the industry. Everyone observes that precisely 6.25% of the entrepreneurs have suspended, and can therefore infer that $\theta = 0.5$. If no further suspensions took place, and no one reinitiated, those remaining in the industry would expect to pay out a further 8 units in investments. In return, they would generate revenues of $\theta A - (43.0 - 2.7) + (0.2 \times 0.5 \times 8) \approx 10.5$ – clearly, sufficient to recoup the eight units of investment that remain, with 2.5 units left over. But immediate liquidation would generate $\alpha(\kappa + \hat{t} + 1) = 3.2$, which is of course preferable to 2.5. The industry must shrink further. Subsequent to these adjustments, the size of the industry (call it N^*) will satisfy $A\theta - N^* - (T - \hat{t})(1 - c\theta) = 100 \times 0.5 - N^* - (12 - 4)(1 - 0.1) = 3.2$. Solving yields $N^* = 39.6 < (43.0 - 2.7)$, implying that there will indeed be further reductions in the size of the industry. In the event the realised θ is equal to the mean of the prior distribution, there will be some industry shrinkage along the way.

On the other hand, suppose Nature has drawn $\theta = 0.6$, which sits near the top of the interval (θ_L, θ_M). Given the implied suspension behaviour at $\hat{t}$, and the remaining investment requirements, no further industry size adjustments would result in continuing entrepreneurs receiving net revenues of about 6.7 units. This is high enough to ensure that no entrepreneurs that continued at $\hat{t}$ are willing to suspend, yet not large enough to motivate even marginal reinitiations. Similar calculations show that realisations of θ in (θ_M, θ_H) and $(\theta_H, 1]$ motivate partial and complete reinitiations, respectively. I now turn to consider how changes in the prior specification, and the various parameters, impact the outcomes.

Priors

To help illustrate the importance of the choice of priors, consider Table 3.3. This table contains the upper tail values (*i.e.,* the probability assigned to values of $\theta > 0.6$) for several different candidate prior distributions. Each of these distributions is symmetric about the (same) mean, and each is positive over its entire support $[0, 1]$. It is only the variability (precision) that changes from one to the next.

As evident in Table 3.3, the change in the distribution after receipt of a single signal is substantial in the case of the $\beta e(1, 1)$ (*i.e.*, the Uniform distribution) but not nearly so drastic in the case of the $\beta e(4, 4)$. After several bad signals have been received, the distributions become more similar in their behaviour. This is important to the analysis because the $\beta e(1, 1)$ assigns significant probablility to very good realisations of θ but a single bad signal causes a large decrease in the likelihood of good realisations. Therefore suspensions occur very rapidly in the case of $\beta e(1, 1)$ priors.

Table 3.3: Posteriors After Bad Signals Received

Probablity $\theta > 0.6$ given priors of...

Bad Signals	$\beta e(1,1)$	$\beta e(4,4)$	$\beta e(6,6)$	$\beta e(9,9)$	$\beta e(11,11)$
0	0.40	0.29	0.25	0.20	0.17
1	0.16	0.17	0.16	0.13	0.12
2	0.06	0.10	0.10	0.09	0.08
3	0.03	0.06	0.06	0.06	0.05
4	0.01	0.03	0.03	0.04	0.03
5	0.00	0.02	0.02	0.02	0.02
6	0.00	0.01	0.01	0.01	0.01
8	0.00	0.00	0.00	0.00	0.00

Concerns associated with the use of $\beta e(1,1)$ priors are well-known and it is often suggested (see, for a discussion, Hays and Winkler (1970)) that its use be avoided unless one is drawing a relatively large sample before decisions are made.[23] In the problem at hand, decisions are made after each draw, rather than after a large sample has been drawn. On the other hand, switching to a $\beta e(4,4)$ or even a $\beta e(11,11)$ is obviously not an innocuous switch to make. In particular, it suggests a much greater degree of pre-game consensus about the probability of various outcomes. The $\beta e(1,1)$ says that the most 'extreme' outcomes are as likely as the mean; the $\beta e(11,11)$ says that the mean is very likely and the 'extreme' cases are just that.

Table 3.4: Impact of Changing Priors on Suspension Times

Priors	$\hat{t}$	θ_L	θ_M	θ_H	N
$\beta e(1,1)$	2	0.683	0.739	0.781	63.7
$\beta e(4,4)$	3	0.531	0.579	0.614	47.1
$\beta e(6,6)$	4	0.508	0.551	0.569	43.0
$\beta e(9,9)$	5	0.485	0.526	0.535	40.1
$\beta e(11,11)$	6	0.473	0.512	0.517	38.7

Table 3.4 illustrates the impact that varying the assumed prior distribution can have on the

[23] One alternative sometimes suggested is a $\beta e(0,0)$. The suggestion is somewhat controversial, in part because it has the unfortunate disadvantage of not actually being a distribution. This rules out its use in this model, since I use priors to compute expected profits and determine entry levels.

solution of the model.[24] Other parameters remain as outlined earlier. It isn't surprising that the flat priors generate relatively quick suspensions. In equilibrium, everyone gets the liquidation outcome for $\theta < 0.683$ but after two bad signals, those with flat priors assign only about a 6% chance of θ being in excess of 0.6. As one moves from top to bottom in Table 3.4, the prior distributions become more concentrated around the mean of 1/2 – and therefore are impacted less by a short run of bad signals.[25] The other information in Table 3.4 is also revealing. First, there is a steady decline in the initial size of the industry (*i.e.,* measured by entry) as priors become more concentrated around the mean. Recall from Figure 3.2 that profit profiles have significant option-like charateristics. Therefore, since flatter priors assign greater *ex ante* likelihood to 'tail' events potential entrants expect the industry to be capable of generating greater profits for a given entry level. The option analogy is simply that from top to bottom in Table 3.4, the variability of θ declines, and so with it, the value of entry. Also, changes in priors also impact the levels of θ_L, θ_M, and θ_H. Specifically, the level of each declines, the interval between θ_L and θ_H shrinks, and θ_H moves closer to θ_M.

As a modelling issue, I think that the economic content of different priors, and the fact that this does have important implications for the behaviour within the model, is of interest for two reasons. The first is that, other things equal, suspensions will occur later the greater is the pre-game consensus about the state of demand. This may border on the completely obvious, but the model at least provides the result as well as a relatively flexible approach to examining the impact of different pre-game beliefs. Moreover, it helps to add empirical content to the model, to the extent that one can identify proxies for the extent of consensus in the early stages of an industry. The second is that one might think more carefully about where these priors come from – that is, given that investment decisions are in the hands of the entrepreneurs, are there circumstances under which banks and/or regulators have an incentive to try to shape entrepreneurs' priors? What are the social costs of consensus? To the extent that priors are impacted by the information available to entrepreneurs, there is a transparency interpretation here (which will be of particular relevance in the Asian case).

In the sections that follow, I allow the parameters of the model to vary in order to assess their impact on the base case outcome discussed previously. Throughout the priors used are $\beta e(6,6)$ and, and except where explicitly noted otherwise, all parameters (save the one being varied, of course)

[24] Each of the rows in Table 3.4 represents an equilibrium. That is, there are no incentives for deviations of either type.

[25] Table 3.4 contains results only for those priors at which the suspension times change. For example, for $\beta e(3,3)$ priors, and the assumed parameter values of $\{0.4, 3, 12, 3, 0.2, 100\}$, suspensions take place after two bad signals, so $\hat{t} = 2$ as is the case with the $\beta e(1,1)$ priors. Of course the values for N and the various cutoff levels for θ are different; the table is designed to illustrate the variation in suspension time that occurs as priors become less diffuse.

are fixed at their usual values. I present the results in tabular format. Unless explicitly noted to the contrary, each row in each table is an equilibrium of the form ϕ^*, checked against conditions (3.10) and (3.11) to ensure there are no incentives for either of the deviations described earlier.

Reinitiation Costs (μ)

Those that do not suspend avoid any chance of paying reinitiation costs in the event θ is high. Alternatively, for lower reinitiation costs, the 'penalty' for earlier suspensions is smaller and therefore entrepreneurs may be willing to suspend earlier, and simply pay μ if their pessimism is unwarranted. In the limit, when the cost gets very small, immediate suspension by all with bad signals would quickly solve the information problem. These ideas both suggest that the higher are the reinitiation costs the greater is the incentive to postpone suspensions a bit longer.

Table 3.5: Impact of Changes in μ

	θ_L	θ_M	θ_H	N	$\hat{t}$
$\mu = 2$	0.497	0.530	0.575	44.1	3
$\mu = 3$	0.508	0.551	0.569	43.0	4
$\mu = 5$	0.509	0.575	0.589	43.0	4
$\mu = 9$	0.507	0.610	0.614	42.1	5

The numerical results in Table 3.5 bear out this intuition. For small μ the inequality in (3.5) holds more quickly, and equilibrium suspensions occur earlier (at $t = 3$ in this case). However, for larger μ suspensions will take at least one extra period to occur, and perhaps more. For equilibria with a given first suspension time, there is relatively little change in the initial size of the industry, but each of θ_L, θ_M, and θ_H increase and θ_M moves closer to θ_H. The intuition is straightforward – higher reinitiation costs lead fewer entrepreneurs to reinitiate, other things being equal, and increase the distance from θ_L to θ_M, which is the region within which those that remain do not wish to leave but none of those that left can afford to return. Since investment costs are rising (in expectation) so must profits, implying that the level of entry must decline.

Project Maturity (T)

Shorter projects imply smaller investment requirements and therefore suggest that other things equal entry should be higher. They also imply that reinitiation costs are larger relative to the overall project investment requirements, suggesting that entrepreneurs will have to become even

more pessimistic before they are willing to suspend. That is, only when reinitiation is sufficiently unlikely (given beliefs) will it be less costly (in expectation) than continuing. Table 3.6 illustrates this. For $T = 16$ there is an equilibrium with $\hat{t} = 3$, one period earlier than the base case in which $T = 12$.

Table 3.6: Impact of Changes in T

	θ_L	θ_M	θ_H	N	$\hat{t}$
$T = 8$	0.487	0.541	0.587	47.9	4
$T = 12$	0.508	0.551	0.569	43.0	4
$T = 16$	0.501	0.549	0.585	40.6	3

Initial Investment(κ)

Other things being equal, higher initial investments will lead to smaller entry (from the time 0 perspective higher production revenues are required to compensate for greater expected investments made during the life of the project). Once paid, these costs are sunk (at least $1 - \alpha$ of them are) and no longer impact behaviour. However, since revenues to those remaining in the industry are higher than they would have been had κ been smaller, entrepreneurs are willing to wait a bit longer before suspending.

Table 3.7: Impact of Changes in κ

	θ_L	θ_M	θ_H	N	$\hat{t}$
$\kappa = 0$	0.536	0.602	0.688	55.4	2
$\kappa = 1$	0.539	0.587	0.621	48.6	3
$\kappa = 3$	0.508	0.551	0.569	43.0	4
$\kappa = 5$	0.478	0.522	0.542	39.5	4
$\kappa = 10$	0.425	0.465	0.472	31.4	6

Irreversibility (α) and Private Benefits (c)

I have left discussion of the cash flow and liquidation (irreversibility) parameters until last, in part because there are some interactions between the two that must be accounted for. In particular, if liquidation and private benefits are jointly 'too generous' the problem may become misspecified.

The restriction $\alpha < 1$ is sufficient to avoid this problem when $c = 0$.[26]

Things are less clear for c, since one receives expected private benefits rather than deterministic ones. This means that one can find equilibria in cases where c is chosen such that *ex ante* expected private benefits each period will exceed required investments.[27] In such cases the entrepreneurs' behaviour is being driven not by the terminal production revenues but by the prospects of very high interim private benefits. Although consistent with equilibrium this is some distance from the intent of this research. Thus, outside of the discussion in this section of the thesis, I restrict c as follows: $0 \leq c \leq 1$. This ensures that only in the best scenario ($\theta = 1$, a zero-probability event), and then only if $\kappa = 0$, can the value of the private benefits fully offset an entrepreneur's investment.

These two parameters also 'interact' in the sense that even for relatively small c, when α gets very high the impact on the problem is the same as would be an α in excess of 1. The two parameter conditions noted above do not address this possibility, to which I return shortly.

Table 3.8: Impact of Changes in c

	θ_L	θ_M	θ_H	N	$\hat{t}$
$c = 0$	0.493	0.538	0.556	40.8	4
$c = 0.2$	0.508	0.551	0.569	43.0	4
$c = 0.5$	0.532	0.574	0.588	46.4	4
$c = 1$	0.578	0.617	0.627	52.9	4

Table 3.8, as usual, maintains the priors and other parameters of the base case, varies c, and looks for a new equilibrium. As c rises both N and θ_H increase in equilibrium. This implies that for any given sequence of cash flow signals, the best states become relatively less likely, and suspensions therefore more appealing. On the other hand, the larger private benefits are that much harder to part with (even for those that haven't actually received one!). These two impacts net out over the permitted range of c.

Table 3.9 illustrates an interesting feature of the model – a non-monotonic impact on the delay

[26] For example, setting $c = 0$ and $\alpha = 0.99$ and otherwise using the base case parameters and priors, there is an equilibrium with $\hat{t} = 2$ and, not surprisingly, a relatively high entry level. $\alpha \geq 1$ is not only inconsistent with the motivation and structure of the problem (it becomes an interest rate rather than an index of irreversibility) it also causes the numerical routines some real headaches.

[27] Setting $\alpha = 0$ and $c = 4$, which implies *ex ante* expected private benefits of 2 per period, generates an equilibrium with unsustainably high entry levels and suspensions after only one signal is received. By unsustainable I mean that in the event that all entrepreneurs were to produce, price would be zero even in the best case ($\theta = 1$).

Table 3.9: Impact of Changes in α

	θ_L	θ_M	θ_H	N	$\hat{t}$
$\alpha = 0$	0.430	0.483	0.511	39.9	4
$\alpha = 0.25$	0.477	0.523	0.545	41.6	4
$\alpha = 0.5$	0.520	0.567	0.603	45.4	3
$\alpha = 0.75$	0.602	0.643	0.665	50.2	3
$\alpha = 0.9$	0.704	0.739	0.749	57.9	3
$\alpha = 0.925$	0.775	0.805	0.805	63.3	5
$\alpha = 0.99$	–	–	–	–	–

before first suspensions. For 'extreme' values (very small or very large) of α delay is longer than it is for intermediate values. Table 3.10 indicates that at least part of this result – the longer delay when α is large – stems from its interaction with the cash flow parameter c. In the former table, $c = 0.2$ and in the latter $c = 0$. The problem is the generosity issue referred to above – the combination of what you get back in liquidation plus expected interim private benefits is so enticing entrepreneurs will continue investing, despite not receiving a cash flow, until finally suspending in period 5. To see why, recall the first row of Table 3.1. The outcome given $\theta \in [0, \theta_L)$ is $1 - \alpha - c\theta$. There will be no suspensions if this term is negative. When α and c are jointly 'too high', one must wait for the most pessimistic entrepreneurs expectation of θ to fall far enough that $1 - \alpha - c\theta$ becomes positive.[28] When $c = 0.2$ and $\alpha = 0.925$ positivity requires $\theta < 0.375$. Given $\beta e(6, 6)$ priors, $E[\theta\,|\sigma] \approx 0.353$ if σ contains 5 bad signals and no good ones. Table 3.10 makes clear that the results in the last two rows of Table 3.9 are driven by this interaction rather than the increase in α *per se*.

It remains to explain why delay should *decline* with increases in α, as illustrated in Table 3.10. As α increases, the cost of bad demand realisations falls since liquidation yields more and more of the value of capital in place. One might therefore expect that the delay before first suspensions should *increase*. However, the relatively small expected losses in even the worst state of demand also implies a relatively large degree of entry. With a high entry level, profits will be modest in even the best states (the natural analogue to the small losses in the worst states). This magnifies the impact of bad signals – although the losses associated with sticking around too long are very small, it takes only a few bad signals to convince entrepreneurs that the very good states are very unlikely

[28] This is a necessary, but not sufficient, condition for suspensions to occur. At a given time, negativity of the expression is sufficient for suspensions to *not* occur. Imposing $\alpha < 1 - c/2$ would imply positivity at any t (in the eyes of the most pessimistic entrepreneurs), and hence ensure that delay does not result from the generosity 'problem'.

Table 3.10: Impact of Changes in α with zero private benefits ($c = 0$)

	θ_L	θ_M	θ_H	N	$\hat{t}$
$\alpha = 0$	0.419	0.468	0.484	37.4	5
$\alpha = 0.25$	0.463	0.511	0.534	39.6	4
$\alpha = 0.5$	0.516	0.558	0.574	41.9	4
$\alpha = 0.9$	0.652	0.689	0.705	52.1	3
$\alpha = 0.925$	0.671	0.708	0.721	53.6	3
$\alpha = 0.99$	0.759	0.801	0.826	63.7	2

and therefore they exit.

Comment 1 In the two-state demand problem, higher α makes delay more, rather than less, likely. In that formulation, the interaction between the realisation of demand uncertainty and operational decisions is much simpler – when demand is high, all entrepreneurs produce, and when it is low, none of them do. The only issue is whether a reinitiation payment will be incurred in the event of high demand, or whether one might invest one period too long in the event of low demand. Here, the richer interaction generates the opposite result. This is relevant because one can attach other interpretations to this parameter. For example, in a model of crony capitalism, it might represent an expected 'bailout' parameter. Interestingly, the greater the perceived guarantee, the greater the industry participation and the shorter the delay before information is aggregated. That doesn't necessarily imply that a government would choose to set α very high because of credibility (time consistency) issues. In particular, it would be necessary to determine the credibility that could be attached to any particular α since entrepreneurs would see through government guarantees that could not be made good on.

Comment 2 Specifying liquidation values as a constant proportion of capital in place neglects the impact of industry conditions. One can think of a number of reasons that liquidation values might fall when the state of the industry is very bad, including the simple idea that the demand curve for 'capital in place' is downward sloping. For example, suppose liquidation is given by $\alpha\theta$ times capital in place, where α is still a positive constant less than one.[29] Under this specification, the behaviour is qualitatively similar to the case of the simple parametric α. In particular, delay is declining in α

[29] Of course, θ isn't known at all times (and hence one may be concerned about a physical inconsistency should an entrepreneur choose early liquidation). In equilibrium, this isn't an issue since the actual value of θ becomes known just as it is needed (and expectations will do prior to that point). However, out-of-equilibrium early liquidations are more problematic since these actions do not reveal θ. I can avoid this technical issue by assuming that any entrepreneur engaging in an out-of-equilibrium liquidation must wait until T to collect. In the absence of a time

when $c = 0$, but when $c > 0$ one recovers the pattern evident in Table 3.9 – very small and very large values for α generate longer delay than do intermediate values of α.

Comment 3 This discussion has centred on very high α in conjucntion with modest private benefits, primarily because the restrictions on α seem more natural, and given that they are deterministic, easier to work with. Nonetheless, it may seem odd to be talking about situations in which liquidation yields such generous payouts. Flipping roles – choosing modest liquidation parameters but letting c grow larger – generates qualitatively similar results.

3.5.2 Deviations

As noted, Tables 3.4 through 3.10 describe equilibrium variations with parameter changes. All have been checked to ensure that no deviations (as reflected in (3.10) and (3.11)) will occur. Hopefully, these tables suggest that (pure strategy) equilibrium is consistent with a relatively broad parameter space. That said, one can find examples of deviations.

Existence

Free rider pressures, which generate incentive for delay, may endanger equilibrium existence if some entrepreneurs become so pessimistic that they find the option of immediate liquidation to be more palatable than playing out the equilibrium. There are two ways of looking at a single dynamic: first, it may be that entrepreneurs receiving bad signals become 'too pessimistic too fast'. Alternatively, candidate equilibrium suspension times may be 'too far' in the future for a pessimistic entrepreneur to be willing to make the investments necessary to get there. The numerical work I have done indicates that existence issues only arise in relatively extreme conditions.

Example Using the numerical results together with the intuition that this problem is more likely to arise for later suspension times, select the parameter set $\{\alpha, \mu, T, \kappa, c, A\} = \{0, 5, 12, 5, 0, 100\}$. Relative to the base set of parameters, this parameter set features a more substantial initial investment, higher reinitiation costs and zero private benefits. As well, entrepreneurs expect nothing in liquidation. Using the $\beta e(6,6)$ priors, the first $\hat{t}$ conjecture satisfying (3.5) is $\hat{t} = 9$ – considerably later than is the case using the base parameters. Unfortunately, given the outcomes implied by the $\hat{t} = 9$ conjecture, entrepreneurs with no good signals have by period 5 become sufficiently pessimistic that they prefer to simply walk away. Liquidation generates a certain payment of 0. Using

value for money, this assumption resolves the inconsistency without altering the conditions describing equilibrium behaviour.

the posterior beliefs of someone that has received five bad signals, the expected value of the revenues received from playing the $\hat{t} = 9$ candidate equilibrium, net of the 4 additional investments needed to get there, is -0.237. This destroys the candidate $\hat{t} = 9$ equilibrium.

Obviously, this is unfortunate. I think it reasonable to suggest that no possibility of interim private benefits, liquidation values of zero, and reinitiation costs of nearly half the original project costs, are a relatively extreme combination. What sorts of changes are sufficient to restore the viability of this equilibrium? If I use *either* $c = 0.1$ (instead of zero) *or* $\mu = 4.5$ (instead of 5) then I do end up in both cases with viable equilibria. The key is that either of these changes is sufficient to bring $\hat{t}$ from 9 to 8, implying one less unit of investment is required to reach $\hat{t}$. As it turns out, allowing entrepreneurs to play mixed strategies (given these parameters) there is also a mixed strategy equilibrium with $\hat{t} = 8$ that resolves the existence issue, at least in this particular case.

Semi-Pooling Deviations

When I first described the possibility that continuation at $\hat{t}$ would *not* be a best response for an entrepreneur with at least one good signal, I noted that it seemed a relatively unlikely prospect. To this point, I have been unable to find an appropriate example.

3.5.3 Equilibrium with Suspensions at T

The non-existence example above suggests that the easiest way to find an equilibrium with suspensions at T is to shorten project maturity. I use the usual parameters and priors, with the exception that I set $T = 4$ and $\alpha = 0.1$. In this case, there is an equilibrium with suspensions at T. The mass of initial entry is about 47.5, and most will go on to produce at T (only $(1-\theta)^T N$ will suspend). Production will generate positive revenues for $\theta > 0.431$.

3.5.4 Equilibrium with No Suspensions

If, in the previous example, we set $\alpha = 0$, we get an equilibrium with no suspensions. All entrepreneurs produce, and positive revenues will be received if $\theta > 0.466$. The mass of initial entry is about 46.6, slightly smaller than in the case of suspensions at T.

3.6 Mixed Strategy Equilibria

The previous sections have focused on characterising pure strategy equilibria. Are there (nondegenerate) mixed strategy equilibria that involve quicker suspension times? The answer, typically, is yes. From a welfare perspective, these equilibria are clearly important for in them, information is aggregated more quickly, and potentially inefficient investments are avoided. Moreover, it may be that very few entrepreneurs actually suspend, in principle reducing wasteful reinitiation costs. Table 3.11 is the mixed strategy equilibrium analogue to Table 3.4. The only structural change in the table is that another column has been added. This column lists the probability with which the entrepreneur suspends as part of her mixing strategy.[30]

Table 3.11: Impact of Changing Priors on Suspension Times: Mixed Strategy Equilibrium

Priors	$\hat{t}$	θ_L	θ_M	θ_H	N	Prob(Suspend)
$\beta e(1,1)$	1	0.582	0.649	0.816	66.8	0.727
$\beta e(5,5)$	2	0.549	0.589	0.610	46.2	0.276
$\beta e(7,7)$	3	0.520	0.559	0.571	42.7	0.340
$\beta e(9,9)$	4	0.503	0.540	0.545	40.5	0.275
$\beta e(10,10)$	5	0.473	0.512	0.517	38.7	0.662
$\beta e(11,11)$	no (nondegenerate) mixed strategy equilibrium exists					

Should we expect these entrepreneurs to play mixed strategies? The literature appears somewhat divided on the appropriate interpretation of mixed strategy equilibria.[31] My prejudice is that a restriction to pure strategies (as described here) is more natural given the rest of the analysis but that the *earliest* equilibrium – mixed strategy or otherwise – seems to be focal in nature, and since the mixed strategy equilibria occur earlier than the pure strategy equilibria, it is probably inappropriate to rule them out. I will simply note that although allowing entrepreneurs to play mixed strategies helps with the information aggregation problem, Table 3.11 makes clear that the problem is by no means resolved.

[30] To find these equilbria, I proceed as described in the case of pure strategy equilibria save for the addition of the mixing probability term where indicated, and the requirement that (3.5) hold with equality. I also check to ensure that the mixed strategy analogue to (3.10) – the Type 4 deviation condition – is not violated.

[31] Indeed, even co-authors sometimes disagree on this topic. Osborne and Rubenstein (1994) contains a discussion of mixed strategy interpretations in which various paragraphs are prefaced with one or the other of the authors' initials, representing opinions not shared by both.

3.7 Chapter Summary

In this chapter I have developed a model of self-financed entrepreneurial investment in projects that involve long-gestation periods prior to any revenues being realised. I have drawn upon the basic structure of the model of Caplin and Leahy (1994), and to this added non-zero liquidation outcomes, private benefits of project operation, and most importantly, an interval of possible demand outcomes (rather than a binary structure). The last of these changes complicates the solution process, and requires a much more extensive use of numerical solutions, but the outcomes are considerably more varied, and are more consistent with what is observed in the development of new industries.

In the model, entrepreneurs make sequential investments in a project, and each time they do so, receive a signal (in the form of receipt or non-receipt of a private benefit) regarding the realisation of a parameter in the demand function. Entrepreneurs are free to abandon their projects, or to halt investment for one period, with subsequent project reinitiation possible at some cost. Such changes in investment behaviour are observeable and permit industry-wide inference regarding terminal demand, after which the size of the industry adjusts to what has been learned.

This adjustment can be quite varied. For example, some or all of the intital suspenders may choose to return to the industry, or some or all of those that remained may choose to leave. As well, there is generally a substantial region of demand realisations for which the initial suspension levels are 'just right' in that subsequently there are no further suspensions, and no reinitations. The incidence of these different outcomes can be related to the paramters of the model. The model generates outcomes that are in principle consistent with the empirically observed 'shakeouts' documented by Klepper and Graddy (1990), Klepper and Simons (1997), and others, though for different reasons than this literature generally suggests.

These varied outcomes stand in contrast to what emerges from a model with a binary demand structure, in which (using equal *ex ante* probabilities) the model predicts significant real side adjustments during the life of the industry approximately half the time (the degree of the adjustment is determined by the difference between High and Low demand). With the demand interval, this sort of sharp adjustment is much rarer.[32] Despite the smoother structure, however, one can still

[32]Consider the numerical example described in Section 3.5.1. In the event that Nature draws $\theta = 0.5$ (the mean of the prior distribution) then a little over 90% of the original market entrants remain in the industry until T. Viewed from the perspective of time 0, all entrants end up with negative profits (either 4.2 or 4.8 units of investment, depending upon whether they suspend at $\hat{t}$) but this outcome is difficult to interpret as a crisis event (unless perhaps you are one of these entrepreneurs!). Moreover, for $\theta \approx 0.575$ and higher, all initial entrants go on to produce at T and more than 90% of them earn postive profits as viewed from time 0.

talk about 'crisis' as a model outcome.

How does something that might be identified as a crisis occur? Very bad outcomes require an unfavourable θ but the depth of the problem is determined by the length of time it takes for this information to be revealed. For example, suppose the parameters of the problem are such that there are no suspensions, and hence no information aggregation, prior to T. In this event, θ is revealed only when production takes place, and this may lead to significant over-capacity, even for θ that are not particularly 'extreme'. In these cases, the liquidation option again helps to limit the losses that entrepreneurs experience, but the losses are larger because the investment carried on much longer.

As I have illustrated in this chapter, suspensions equilibria are the norm rather than the exception. Given the standard parameter set adopted in this chapter, the earliest suspensions equilibrium has suspensions taking place in the fourth period. These suspensions may occur more quickly or more slowly, however, for different parameterisations. Parameter changes will generally imply changes in both industry size and in the expected profitability of a given θ, but have no impact on the way that beliefs are revised. For example, consider two extreme values for the liquidation parameter: 0, and 0.99. In the latter case the entrepreneur will lose only 1 cent from every dollar invested in the event of liquidation. Since losses are so modest in liquidation, profits must also be modest, and this implies a relatively high level of entry, and thus of θ_H, the threshold value beyond which the highest profits will be earned. Under these conditions, it takes very few bad signals to convince entrepreneurs that they are very likely to end up with the liquidation payoff, and therefore they suspend. Although continuing costs very little, the expected payoff to doing so is even smaller. On the other hand, when the liquidation parameter is zero, the entry condition requires significant profits in good times to counter the heavy losses in liquidation. That means relatively low entry levels, so that large profits are earned over a larger range of demand states. But in this case, it takes several signals to convince an entrepreneur that the high-profit states are so unlikely that she should suspend. Very similar arguments can be made for changes in startup costs and restart costs. This leads to a final interesting influence on suspension behaviour: the prior distribution. As illustrated, flatter priors lead to faster suspensions, other things being equal, because flatter priors place a relatively large weight on high profit states, but after only a few bad signals the likelihood of these good states ocurring has become extremely small.

To recap then, the changes in the modeling approach have generated a model of industry evolution that will typically feature a 'shakeout', and that may lead to crisis-like events (but that in general will not do so). Next I will investigate whether the financial sector exerts an important influence on the likelihood of these crisis events. Does debt finance exacerbate or attenuate the underlying real sector information problem?

Chapter 4

Debt-Funded Entrepreneurs

Adding external finance to the model adds a crucial additional consideration to the model, which turns on a divergence in interests between entrepreneurs and credit providers. Entrepreneurs begin with some amount of own capital invested in the project. Once this is exhausted the only source of finance is the bank. Entrepreneurs enjoy limited liability, control over operational decisions when not in default, and private benefits from project operation. So long as the entrepreneur has access to funds (whether own capital or borrowed) she will make operational decisions in her own interests. Entrepreneurs may stop investing in a project for two reasons: their access to credit is restricted, or they voluntarily decide to stop (in order to salvage something from what they will have come to regard as a failed venture). The latter course of action will require that entrepreneurs become pessimistic enough.

These are all familiar tensions but embedding these concerns within an industry evolution model does generate some interesting results. I develop the model assuming that all loans are priced competitively at all times. By this I mean that the bank always stands ready to provide a dollar of financing on terms such that, given publicly available information, it expects to receive a dollar back. Therefore, the entrepreneur will enjoy all the surplus in the event that the demand realisation is a good one.[1] In effect I am assuming that the deposit supply curve is infinitely elastic at the riskless rate of zero. The results of this modelling exercise differ from those in the previous chapter because of the limited liability constraints which prevent the entrepreneurs from fully internalizing the costs of private benefits when making continuation decisions. This induces entrepreneurs to carry on at

[1] By surplus I mean production revenues net of inputs.

lower demand levels (alternatively, in greater measure for a given demand level) than in the self-financing case. If private benefits are too large, entrepreneurs may never find it in their interest to suspend: despite becoming very pessimistic about the prospects of the industry, entrepreneurs will have no incentive to stop borrowing once the limited liability constraints bind.

After considering the case of a credit market that is competitive at all times, I consider the case of a monopoly bank. The bank's credit allocation decision determines the level of aggregate activity in the industry, and is chosen to maximise expected surplus (subject to satisfying entrepreneurial participation constraints). It uses debt contracts in order to extract any surplus (via choice of lending rate) that favourable demand states and its own restrictions on industry size might generate. To make things concrete, I assume that at time 0, the bank cannot commit to sharing more of the surplus than is required to satisfy post-realisation entrepreneurial participation constraints. This impacts the likelihood that entrepreneurs will see it in their interests to suspend (or liquidate) and reveal information; by remaining, the entrepreneur has access to private benefits. Those that suspend will, at best, receive some residual after the debt is paid off.

Consideration of these different environments permits some intermediate conclusions to be drawn. Relative to the situation with self-financed entrepreneurs, external finance restricts (in some cases quite severely) the parameter sets for which an equilibrium that features early information aggregation can be found. However, it also expands the set of parameters for which *some* equilibrium exists, helping to mitigate the existence problem discussed in the previous chapter.

Finally, I consider the implications of endowing the bank with some additional choice variables. First, I will allow the bank to reduce the amount of capital that the entrepreneur contributes (subject to an exogenously specified maximum). As well, I will allow the bank to choose negative lending rates (in effect, subsidising the entrepreneur). Finally, I allow the bank to make lump sum payments to entrepreneurs, conditional on the operational decisions the entrepreneur makes. These additional tools may satisfy entrepreneurial participation and incentive constraints when the parameters of the problem and the restriction to credit allocation and non-negative lending rates dictate otherwise.

Once again I begin with a description of the model. Much of what follows is identical to that appearing in the previous chapter, but it is reproduced here for convenience. Those sections that are identical to the material in Chapter 3 have been italicised.

4.1 The Model

- *Time is discrete and runs from* 0 *to* T.

- *All market participants are risk neutral and the time value of money is assumed to be zero.*

- *At time* 0 *a continuum of possible entrepreneurs with finite mass* $\geq A$ *(a positive constant) decides whether to undertake identical investment projects. Project initiation occurs only at time* 0. *There is no entry subsequent to time* 0 *but entrepreneurs can exit at any time.*

- Entrepreneurs have (contractible) initial wealth of $C \geq 0$, insufficient to fund the development of the entire project. Entrepreneurial contributions are made up front, before any lending takes place.[2]

- The credit market is modeled as a representative bank that has access to a limitless supply of deposits at the riskless rate of zero. The baseline assumption for the credit market is that it is competitive at all points in time, and therefore prices its loans (*i.e.*, sets the lending rate) to earn zero profits. Alternatively, one can think of contestable credit markets, and I use both terms.[3]

- *Project scale is fixed, and each entrepreneur operates a single project.*

- *Project completion requires investment each period, plus a one-time project initiation fee of* κ. *Define* I_t *as the total investment required from time* t *forward to complete a project that is active at* t. *For simplicity, the periodic investment requirement is assumed constant through time and equal to 1 per period. Thus* $I_0 = \kappa + T + 1$ *and at any time* t, *active projects are such that:* $I_t = T + 1 - t$ *and capital in place is* $I_0 - I_t = \kappa + t$.

- *At* T, *completed projects produce an infinitesimal amount of homogeneous output and revenue is received. Demand is represented by the inverse demand function* $P(Q(\theta), \theta)$, *where* $Q(\theta)$ *is aggregate industry output.* θ *is chosen by Nature at time* 0 *from the interval* $[0, 1]$ *but the draw is not observeable until the final investment decisions have been made at* T. *This draw is the only source of uncertainty about the operation of the project and is common to all entrepreneurs. I use a very simple demand function:* $P(Q(\theta), \theta) = A\theta - Q(\theta)$, *where* A *is a fixed constant. The dependence of* Q *on* θ *is not specified but rather results from equilibrium exit behaviour.*

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[2]In a richer model, and with a fundamentally different setup, it would be interesting to explore the way in which C could be used by banks to aggregate information through some mechanism design. I thank Paolo Fulghieri for this suggestion.

[3]Competition and contestability are not synonymous, but the pricing implications are the same and it is this which is important. See (for example) Mas-Colell *et al* (1995, pp 410-411) for a discussion of competition, Bertrand competition, and contestability.

- *At any $s \in [1, T-1]$, entrepreneurs with active investment projects choose between continuing the project, suspending the project for one period, or liquidating the project (exit). At T there are no subsequent periods in which to reinitiate so a choice of suspension is taken to be equivalent to liquidation. Entrepreneurs with suspended projects choose between liquidation and reinitiation. Any entrepreneur that chooses continue or reinitiate at T produces and receives revenue. I use $\hat{t}$ to denote the first period in which suspensions occur.*

- *Suspension is identified as skipping a required investment, and involves no additional costs. However, resumption of a suspended project requires payment of the skipped investment plus additional restart costs denoted by $\mu \geq 1$.*

- *Liquidation proceeds are an increasing function of capital in place, denoted $\alpha(I_0 - I_t)$. $\alpha(I_0 - I_t)$ indexes the degree to which investments are irreversible (the lower the liquidation value the greater the irreversibility) and is specified to ensure that it lies in $[0, 1)$. Restart costs μ do not contribute to capital in place (they are sunk once paid) and production at T entirely consumes an entrepreneur's capital in place (there is no salvage). α is initially treated as a constant (i.e, $\alpha(I_0 - I_t) = \alpha \times (I_0 - I_t)$).*

- *Projects generate private benefits as follows: each period, with probability θ an entrepreneur with an active project receives a one-time private benefit of $c \in [0, 1]$ and with probability $1 - \theta$ she does not. Receipt is observeable only to the entrepreneur. Private benefits do not cause any dimunition of the project's value in production or in liquidation. Entrepreneurs with suspended projects receive no private benefit while in this state. Private benefits thus serve as the signal process. Conditional on θ, signals are independent through time and across entrepreneurs.*[4]

- Entrepreneurs and banks begin the game with the same information. Banks do not see the private signals that their clients see (although banks do know the value of c).[5] Thus as time passes, banks have access to only two information sources: the priors, and the observed actions of the entrepreneurs in the industry.

- The mass of initial entrants is determined by an *ex ante* expected zero-profit condition (*i.e.*, the

[4] An alternative modelling strategy would be to turn these private benefits into non-observeable interim cash flows. This would introduce a need to formally consider entrepreneurs' use of accumulated cash flows to replace bank lending, which adds another layer of detail and is somewhat inconsistent with the initial premise that projects with long lead times and small revenues prior to completion might have a role to play in crisis severity.

[5] This allows the bank to make the inference regarding θ – otherwise there would be some ambiguity about suspension times and no way of making precise inferences about θ once suspensions occur.

entrepreneur's participation constraint) and is denoted by N. In the event no entrepreneurs exit the industry, $Q = N$.

- In each period $t < T$ the following events occur in the following order:

  1. The bank makes simultaneous credit offers to all entrepreneurs it is willing to fund for period t.
  2. Entrepreneurs make operational decisions, and invest / suspend / liquidate according to the decisions they have made.
  3. If the entrepreneur invests, a new signal (receipt / non-receipt of private benefit) is received.
  4. If the entrepreneur liquidates, proceeds are used to retire debt, and any residual accrues to the entrepreneur. Debt thus retired incurs no debt service charges for period t.
  5. All players observe the choices made by all other players, and update beliefs based on their signal and their observations of others.

  Therefore, including the signal received upon payment of the initial investment payment at time 0, at the beginning of period t investors with active projects are making decisions based upon priors, a total of t signals, and their t-period historical observations of other entrepreneurs' behaviour.

- A debt contract Δ specifies a maturity date, an upper bound on borrowing, and a vector of lending rates $\boldsymbol{\delta}$, one for each period from the inception date through maturity, all taking as given the parameter set Γ. If the maturity date is before T, a new contract may be offered in the period immediately following the previous contract's maturity. In this case, outstanding debt must be 'rolled over' as part of the new contract. In principle this allows for many different debt contract profiles, but I impose further restrictions (described momentarily). I adopt several conventions:

  - Entrepreneurs remain in control of operational decisions as long as they are not in default.
  - The bank is under no obligation to extend credit to an entrepreneur unless there is a contract in place. In particular, the bank is permitted to refuse further credit upon maturity of an existing contract.
  - Between a contract's inception and its maturity, renegotiation *per se* occurs only in the event that both parties to the contract agree to it. However, the entrepreneur is under no obligation to draw down the entirety of the credit line; she may switch banks at any

time. In this event, the entrepreneur takes her debt with her (*i.e.*, she refinances existing obligations through the new bank – otherwise the first bank would force liquidation).

– The lending rate δ is constant over the life of a contract (but may change when new contracts are negotiated).

- $D_t(\Delta)$ denotes the total debt owing at the beginning of period t by an entrepreneur that has negotiated debt contract Δ and who has a project that has never been suspended. The expression for $D_t(\Delta)$ can be somewhat cumbersome and is contained in Appendix D.1. Denote the total amount that has been borrowed, as of the beginning of period t, by an entrepreneur that has never suspended, net of accrued debt service charges, as PR_t.

- e_t^{ϕ} denotes the entrepreneur's payoff *in the event of liquidation at time* $t+1$. For an entrepreneur that suspends at t, $e_t^{sus} = \max[0, \alpha(\kappa + t) - D_t(\Delta)(1 + \delta_t)]$ while the entrepreneur that continues investing at t *and liquidates at* $t + 1$ is entitled to $e_t^{inv} = \max[0, \alpha(\kappa + t + 1) - D_t(\Delta)(1 + \delta_t) - 1 - \delta_t]$, so $(e_t^{sus} - e_t^{inv}) \in [0, 1 + \delta_t - \alpha], (1 + \delta_t - \alpha) > 0$.

- As debt accumulates, the value of net liquidation proceeds (*i.e.*, net of debt repayment) declines. Denote by $\bar{t}(\Delta, \Gamma) = \max_s\{s \in [1, T] : e_s^{sus} > 0\}$ the last period such that an entrepreneur suspending at $\bar{t}$ and liquidating at $\bar{t} + 1$ will receive liquidation proceeds in excess of her bank indebtedness.[6]

- Define the exogenous parameter set $\Gamma = \{\alpha, \mu, \kappa, c, T, A, C\}$, which represents the data of the model: the index of irreversibility, the reinitiation cost, the initial investment in the project, the magnitude of the cash flow, the number of periods a project takes to complete, a demand function parameter, and the entrepreneurs' initial wealth level. Each of these parameters is common knowledge.

- The endogenous variables in the model are the mass of entrepreneurs that are active in the industry at any time, the timing of changes in this level, the various 'cutoff' values of θ that distinguish different regions of post-revelation industry adjustments, and the details (lending rates and renegotiation points) of the debt contract.

- The following items are assumed contractible: C (entrepreneur's contribution), the fact of investment and the use of borrowed funds for such (entrepreneurs can't pocket the borrowed

[6]This variable is useful in thinking about default rates in the competitive case. For example, if suspensions take place early enough ($\bar{t} - 1$ or earlier – see Lemma 2) then the bank is assured of receiving payment in full on any loans it makes (this is an assertion about an equilibrium I haven't yet described). The key implication is that the lending rate will be zero.

money and then default), and the fact of (and proceeds from) liquidation (so entrepreneurs can't use liquidation proceeds for their own uses if debt is still owing). On the other hand, θ is not contractible.

Comment The debt contracts as described above are reasonably general, and are analogous to the commonly used approach of modelling a debt contract (with a fixed maturity structure) as two numbers (X_1, X_2) where X_1 is the amount borrowed and X_2 is the amount promised in return. I am primarily interested in the impact of debt finance on the likelihood and timing of suspensions (*i.e.*, information aggregation) and therefore I have made assumptions in order to rule out other considerations. For example, I do not focus on issues relating to switching of borrowers and / or debt seniority, and hence effectively rule them out by assuming that a borrower that switches lenders takes her debt with her. One paper in which this issue is carefully discussed is Diamond (1993). In assuming that banks always meet the commitments they make I am abstracting from some interesting reputational considerations. Dinç (2000) and several references discussed therein study a bank's decision to renege on implicit or explicit financing commitments. More generally, the structure of the problem imposes some restrictions on the analysis. For example, the only source of uncertainty is at the industry level, so there is no need to consider issues relating to (costly) state verification. Because the periodic investment requirement is fixed, and the entrepreneurial capital is assumed to be used first, loan size is ruled out as a choice variable. Since all projects and entrepreneurs are *ex ante* identical and only beliefs change with time, signalling and traditional screening tensions are not present.[7] Finally, the assumption that debt contracts feature a constant within-contract lending rate is made for simplicity. I will argue that in most cases it is irrelevant, but there may be cases in which the assumption restricts bank behaviour. However, I also consider the bank's ability to make investment policy-specific payments to the entrepreneur, which should allow the bank to accomplish the same tasks. Additionally, Shockley and Thakor (1997) note that the vast majority of the loan commitments in their sample (just over 2500 contracts) stipulate a fixed premium over a floating reference rate like prime or LIBOR, which is equivalent to what I assume.

[7]The bank may wish to motivate entrepreneurs with different beliefs to behave differently. However, there is no screening based on type or ability.

4.2 The Game

In this section I describe only the important differences between the game in this chapter and that in the last chapter. Much of the setup is identical. The formal description in this section corresponds to the model with credit markets that are competitive at each point in time (or contestable). The game described here is a Bayesian extensive game with observeable actions, and I look for a perfect Bayesian equilibrium.

The Players

In addition to the continuum of possible entrepreneurs, and Nature, there is a representative bank. Variables with a b superscript refer to the bank while the superscript e_i continues to denote an entrepreneur of "type" i.

Information Structure

All players share beliefs at time 0 (priors) and subsequent to suspensions, and in the interim, beliefs are formed by the application of Bayes rule to observed signals and behaviour. The structure of the game is common knowledge. The bank sees no private signals, so σ_s^b is empty (and in the context of (3.1), $m = n = 0$). Like the entrepreneurs, the bank uses observed behaviour of others to form beliefs. Let Σ_s^b denote the time s information set of the bank.

Order of Play

Nature begins the game by choosing θ. Following this there are up to $T + 1$ repetitions of the following game:

1. The bank offers credit (on new terms, if there is no contract in place covering the current period, and on previously contracted terms otherwise).

2. Entrepreneurs choose whether or not to accept the credit as offered, and make operational decisions. If the entrepreneur chooses not to accept the credit as offered, she may approach another bank (or the same one again) and receive a new offer; this is assumed to take no time and involve no cost.

I assume that debt contracts contain commitment features. In particular, banks must honour any multi-period commitments they agree to (entrepreneurs are not assumed to be able to make such commitments). Therefore 'new' contract terms are offered only at time 0, or at the maturity of an existing contract. Note that once a contract matures, the bank may choose to offer fewer entrepreneurs credit (or, alternatively, may reduce the probability that a given entrepreneur receives further credit).

Actions

The bank's action set is $\{lend,\ don't\ lend\} = \{l,\ dl\}$ and the entrepreneur's action set is as in Chapter Three. Not all of the actions apply in each repetition of the component games. For example, the bank can only choose dl in a period in which it has no contractual commitment to the contrary. When the bank plays l it takes the form of (δ, t') where $\delta > 0$ is the lending rate and t' the maturity of the contract. I don't explicitly model the entrepreneur's choice regarding contract acceptance; those responses are taken to be implicit in the operational decisions.

Strategies

Here, and in what follows, I will use the following notation: Let $\phi(\Sigma) = (\phi^e(\Sigma^e), \phi^b(\Sigma^b))$ denote a strategy profile for the game. A superscript * denotes a specific strategy profile of the sort I am looking for (see section on Equilibrium). Strategy spaces for the bank and the entrepreneur, respectively, are: $\Phi^b = \{l, dl\}$ and $\Phi^e = \{inv_s|(l, inv_{s-1}), sus_s|(l, inv_{s-1}), liq|(l, inv_{s-1}), liq|(dl, sus_{s-1})\}$.

ϕ^e specifies, for every s and Σ^e_s, a choice from Φ^e, and ϕ^b specifies, for every s and Σ^b_s, a probability with which an entrepreneur is offered credit, and the terms thereof. Since there may be more entrepreneurs requesting credit than the bank wishes to finance the bank may use a mixing strategy (*i.e.*, randomisation) to make this allocation. This has no strategic implications and is permitted solely to allow marginal conditions to be satisfied. Entrepreneurs play pure strategies.

Equilibrium

I look for a symmetric perfect Bayesian equilibrium. The equilibrium is symmetric in the sense that the bank offers the same contracts to all entrepreneurs of type i (always respecting informational constraints) and all entrepreneurs of type i play the same strategy. Equilibrium can be loosely described as consisting of one or more debt contracts offered by the bank, and a sequence of operational

decisions by the entrepreneurs, such that each debt contract earns zero-profits in expectation at the time of inception, and entrepreneurs earn time-0 expected profits of zero, and both make full use of all available information at all times. I look for equilibrium with ϕ^* generating play with the following characteristics:

- N firms enter the industry and begin project development, with N determined by a zero profit condition.
- Project development is financed with a combination of borrowing and own capital.
- If there exists a $\hat{t}$ (*i.e.*, there exists a $t \leq T$ such that some firms have become pessimistic enough to suspend project development):
  - All entrants continue investing until $\hat{t}$, when those entrepreneurs with only bad signals choose liquidation or suspension (all others continue to invest).
  - From $\hat{t}+1$ onward, industry size adjusts to reflect the information that has been revealed about demand.
  - Time 0 debt contracts offer funding to time $\hat{t}$ and mature at $\hat{t}+1$, at which time the bank offers some entrepreneurs new contracts that mature at T.
- If no $\hat{t}$ exists, all entrants invest through T, and then produce. Debt contracts mature at T.

Formally, equilibrium is defined as follows:

Definition *Equilibrium* is a set of beliefs f and a strategy profile ϕ such that at each node of the game:

(a) $\phi^e(\Sigma^e|f^e)$ and $\phi^b(\Sigma^b|f^b)$ are Nash (*i.e.*, specify best responses) given that entrepreneurs use ϕ^e and that the bank uses ϕ^b

(b) debt contracts Δ earn zero expected profits, conditional on the information contained in Σ_s^e and Σ_s^b, and given that N entrepreneurs enter and use ϕ^e and the bank uses ϕ^b

(c) ϕ^e implies time 0 expected profits of zero, conditional on the information contained in Σ_s^e and Σ_s^b, and given that N entrepreneurs enter and use ϕ^e and the bank uses ϕ^b

I use $U_s^{e_i}(\theta|\phi^{e_i^*})$ to denote the expected outcome (net revenue) for an entrepreneur of type i, as viewed from time s, of using strategy profile ϕ, given that all other players play ϕ^*.

Comment The new element that is of particular note is that first round debt contracts mature at $\hat{t}+1$. I will not argue in favour of this aspect of the equilibrium until late in the chapter, and therefore highlight it now. Given this, and given that the within-contract lending rate is constant, I will use the notation δ_1 and $\delta_2(f)$ to denote the lending rates included in the pre- and post-suspension contracts respectively. I may write $\delta_2(f)$ as $\delta_2(\theta)$ when the post-realisation context is clear.

As in the previous chapter, I must ensure that there is no incentive for deviation from play prescribed by ϕ^*. I deal with this issue in more detail later, and here briefly summarise. With regard to the entrepreneur, the deviations of interest are analogous to those that appeared in the previous chapter. The assumptions regarding the contractual negotiations with the bank, and the environment within which the bank operates, remove any incentive for the entrepreneur to switch banks, renege on debt, use borrowed funds for other purposes and so forth. In principle, the bank could engage in a variety of deviations. Assumptions made about the structure of the credit market place considerable limitations on the scope for such deviations. For example, the bank cannot arbitrarily adjust lending rates in an attempt to alter entrepreneurial behaviour.[8] I devote specific attention to the form of the debt contracts later. With regard to possible deviations at entry, or to the industry adjustments that take place at $\hat{t}+1$ subsequent to the revelation of θ, the continuum assumption is quite handy. A strategy change by a single entrepreneur, or by the bank with respect to a single entrepreneur, will have no impact on the equilibrium outcome. The magnitude of initial entry, and the industry adjustments subsequent to $\hat{t}$, must satisfy specific indifference relations. If an entrepreneur should, for example, choose to not enter despite being offered credit at time 0, this (out-of-equilibrium) choice will neither do her any good, nor would the knowledge of it impact the decisions of any other agents.

4.3 Contestable Credit Market

There are three basic cases that I analyse. One is the case of no suspensions or liquidations: all entrepreneurs simply invest through to T, when the value of the demand parameter θ is revealed by entrepreneurs marketing their output. The second is the case in which some proportion of the entrepreneurs choose to suspend their investments before the projects are completed, and the third is that some entrepreneurs may opt for immediate liquidation (instead of suspension). The distinction

[8] This statement is not true of the bank with monopoly power, however.

between the latter two is that suspensions can be undone at a cost, while liquidation is irreversible.[9] I start with analysis of the case of equilibrium with suspensions (or liquidations), which is considerably more involved than the no suspensions (or liquidation) equilibrium.

4.3.1 Equilbrium With Suspensions

Given that I am interested in equilibria of the form ϕ^*, and that suspensions occur in equilibrium, time can again be divided into three phases. The key question is the timing of the second phase, which can occur in any period from 1 through T. The next section characterises this decision; for the moment, I simply define $\hat{t}$. It is nearly identical to the definition used in the previous chapter, but here the prospect of immediate liquidation being preferred to suspension cannot be ruled out:

Definition $\hat{t}$ is defined as that decision point at which entrepreneurs first choose to suspend or liquidate, and can be represented in the following way:

$$\hat{t}(\Delta, \Gamma) = \min_s \{s \in [1, T] : \max[U_s(\theta|liq \text{ at } s), U_s(\theta|sus \text{ at } s)] > U_s(\theta|con \text{ at } s)\}$$

where expectations are taken with respect to the time s posteriors of the most pessimistic entrepreneurs and it is understood that entrepreneurs will behave according to ϕ^* subsequent to $\hat{t}$.

Post-Revelation Industry Adjustments

Again I must identify the 'cutoff' values of θ that partition the range of possible values of θ into different regions. The identification is complicated somewhat by the introduction of external finance. There are two issues that must be considered: the willingness of the bank to extend credit, and the interest of the entrepreneur in carrying on with the project. Because I assume that entrepreneurs are not able to divert borrowing for their own purposes and that there is no idiosyncratic uncertainty, the scope for conflict between bank and entrepreneur is limited to the (non-transferable) private benefits. When these are large enough, the bank and the entrepreneur may disagree over the bank's demand-state contingent credit policies. Below, I develop the indifference conditions that define each of $\{\theta_B, \theta_L, \theta_M, \theta_H\}$, under the assumption that an equilibrium of the form ϕ^* is being played. The addition here, relative to the notation developed in Chapter Three, is θ_B, which is the θ such that the first unit of production, net of the investments required, generates zero profit. Below this point

[9] There is a partial exception to this statement – the case of a suspension at T, which is effectively a liquidation since no further operational decisions can be made. This particular outcome does not arise with 'reasonable' parameterisations and therefore I devote limited attention to it.

there will be no production.[10] Knowing these cutoff levels is important because the entrepreneur and bank payoff functions differ across the regions and therefore I must be able to specify the location of the payoff function changes.

$\boldsymbol{\theta_H}$ is defined as the *lowest* θ such that in equilibrium, *all* entrepreneurs that suspended at $\hat{t}$ are granted further credit, reinitiate at $\hat{t}+1$, and go on to produce. Two participation constraints must hold at θ_H: the bank must expect demand to be good enough to support the granting of credit to all entrepreneurs (*i.e.*, debt contracts negotiated at $\hat{t}+1$ must generate weakly positive profits for the bank), and entrepreneurs must (weakly) prefer undertaking this course of action to the alternative, which is immediate liquidation. In general, only one of these constraints will be binding. Note that by definition of θ_H, all initial entrants will go on to production so $Q(\theta_H) = N$.

Suppose that the entrepreneur has already borrowed at least some funds from the bank, and that $\hat{t}+1$ is designated in the original contract as the maturity date of the contract. The worst case scenario for the bank will be defined by their ability to force liquidation on any firms that owe money and that are unable to find funding. From the banks' perspective, in order for it to be willing to fund project completions, it must be the case that

$$\underbrace{P(\theta_H, N)}_{\substack{\text{Production}\\ \text{Revenue}}} - \underbrace{TD}_{\substack{\text{Time T}\\ \text{Debt}}} \geq 0 \tag{4.1}$$

where $TD = D_{T+1}(\Delta) + (\mu - \delta_1)(1+\delta_2(\theta))^{T-\hat{t}}$ includes the investment required from $\hat{t}+1$ forward, plus the skipped investment, restart costs, and any debt already owing at $\hat{t}+1$ rolled forward.[11] The $-\delta_1$ term reflects the fact that firms that suspend at $\hat{t}$ and then return must ultimately make the missed investment but do save the debt service charge on that single unit of investment (*i.e.*, that would have accrued between $\hat{t}$ and $\hat{t}+1$).

Now consider the case of an entrepreneur that suspended at $\hat{t}$. Liquidation at $\hat{t}+1$ – which leaves the entrepreneur with the greater of zero and the difference between the liquidation proceeds and debt outstanding at $\hat{t}+1$ – defines the worst case scenario (outside option) for this entrepreneur. Continuation, with all of its attendant costs, must generate at least as favourable an outcome.

[10] This possibility is a reflection of linear demand.

[11] No, there is no period $T+1$, but I have defined D_t as the debt outstanding at the *beginning* of period t (for a firm that has never suspended) and this notational abuse is convenient. $D_{T+1}(\Delta) = D_T(\Delta)(1+\delta_2(\theta)) + (1+\delta_2(\theta))$.

Therefore if all entrepreneurs are to carry on, it must be that:[12]

$$\max\left[0, P(\theta_H, N) - TD\right] \quad + \quad \underbrace{c\,\theta_H\, I_{\hat{t}+1}}_{\substack{\text{Expected}\\ \text{Private Benefits}}} \quad \geq \quad \underbrace{e_{\hat{t}}^{sus}}_{\substack{\text{Net Liquidation}\\ \text{Proceeds}}} \tag{4.2}$$

Which of (4.1) and (4.2) binds depends upon a tradeoff between private benefits and net liquidation value. For example, suppose that (4.1) binds (defining θ_H). In this case, the first term in (4.2) is zero, and the constraint can only be satisfied if $c\,\theta_H I_{\hat{t}+1} \geq e_{\hat{t}}^{sus}$, which is more likely to be true when private benefits are relatively large.[13] This is telling us that the bank will require better demand conditions to fund all suspending entrepreneurs than the entrepreneurs would like (alternatively, (4.2) could be satisfied at a lower θ_H than (4.1)). In this case, should θ fall in the interval between θ_H and the θ that would cause (4.2) to hold with equality, an analogue to credit rationing will exist – the bank will be unwilling to fund all suspending entrepreneurs but those entrepreneurs that do not get further financing would have wanted it.[14] On the other hand, when $c\,\theta_H I_{\hat{t}+1} < e_{\hat{t}}^{sus}$ (as it is sure to be if private benefits are assumed to be zero) then (4.2) binds. The implication is that in equilibrium, banks are willing to lend at some demand levels for which entrepreneurs are not interested in borrowing.

The next step is to examine the same sorts of conditions for θ_M, θ_L, and θ_B where these entities are defined as follows:

$\boldsymbol{\theta_M}$ is defined as the *highest* θ such that in equilibrium, *no* entrepreneur that suspended at $\hat{t}$ is funded and chooses to reinitiate at $\hat{t}+1$, and goes on to produce.

$\boldsymbol{\theta_L}$ is defined as the *lowest* θ such that in equilibrium, *all* entrepreneurs that *continued* at $\hat{t}$ are funded and choose to carry on to production.

$\boldsymbol{\theta_B}$ is defined as the *highest* θ such that in equilibrium, *no* entrepreneur that *continued* at $\hat{t}$ is funded and chooses to carry on to production.

Arguments similar to those above generate the following conditions:

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[12] If borrowing has not yet begun, she will also account for the use of any remaining capital.

[13] The notation $c\,\theta_H I_{\hat{t}+1}$ is simply expected private benefits accruing to project operation from $\hat{t}+1$ to T (recall that $I_{\hat{t}+1} = T - \hat{t}$).

[14] Note that while entrepreneurs might complain about restricted access to credit under these circumstances, we are not talking about credit rationing, since the bank would lose money if it were to lend to all suspending entrepreneurs at some $\theta < \theta_H$.

$$P(\theta_M, [1-(1-\theta_M)^{\hat{t}}]N) - TD \geq 0 \tag{4.3}$$

$$\max[0, P(\theta_M, [1-(1-\theta_M)^{\hat{t}}]N) - TD] + c\,\theta_M\, I_{\hat{t}+1} \geq e_{\hat{t}}^{sus} \tag{4.4}$$

$$P(\theta_L, [1-(1-\theta_L)^{\hat{t}}]N) - TD' \geq 0 \tag{4.5}$$

$$\max[0, P(\theta_L, [1-(1-\theta_L)^{\hat{t}}]N) - TD'] + c\,\theta_L\, I_{\hat{t}+1} \geq e_{\hat{t}}^{inv} \tag{4.6}$$

$$P(\theta_B, 0) - TD' \geq 0 \tag{4.7}$$

$$\max[0, P(\theta_B, 0) - TD'] + c\,\theta_B\, I_{\hat{t}+1} \geq e_{\hat{t}}^{inv} \tag{4.8}$$

where $TD' = TD - (\mu - \delta_1)(1+\delta_2(\theta))^{T-\hat{t}}$. The key differences from (4.1) and (4.2) are the changes in industry size, and the fact that the 'marginal' entrepreneur in (4.5) and (4.6) is one that continued at $\hat{t}$ rather than one that suspended. Thus in the case of θ_M, the condition determining which of the constraints binds is the sign of $e_{\hat{t}}^{sus} - c\,\theta_M I_{\hat{t}+1}$; if this term is positive, (4.4) binds and again, over some range of θ the bank is willing to fund entrepreneurs that have little interest in borrowing. Likewise, when private benefits are large, there will be a range in which some entrepreneurs would like access to credit but don't get it. Finally, in the case of θ_L it is the sign of $e_{\hat{t}}^{inv} - c\,\theta_L I_{\hat{t}+1}$ that determines the binding constraint, and again there is a small region of θ in which access to credit is restricted. To further aid in the interpretation of these constraints, note that they are dynamic in the following sense: early in the project's life, the entrepreneur constraints are likely to bind. Once the entrepreneur is deep enough in debt that $e^{sus} = 0$ the bank constraints must bind, and in the special case that private benefits are zero, the entrepreneurs constraint would bind as well – but only as an artifact of limited liability, because under those circumstances the entrepreneur would be quite indifferent to remaining or departing.

Given that $\theta_B \leq \theta_L \leq \theta_M \leq \theta_H$[15] it is also possible to make some statements about the relationship between the various expressions that determine which constraints are binding. For

[15] Again, for reasonable parameter sets Γ, this is evident from (4.1) - (4.8).

example, $e_{\hat{t}}^{sus} - c\theta_H I_{\hat{t}+1} \geq 0 \Rightarrow e_{\hat{t}}^{sus} - c\theta_M I_{\hat{t}+1} > 0$ (so $e_{\hat{t}}^{sus} - c\theta_M I_{\hat{t}+1} \leq 0 \Rightarrow e_{\hat{t}}^{sus} - c\theta_H I_{\hat{t}+1} < 0$). Also, if private benefits are assumed to be zero, then since $e_{\hat{t}}^{sus} \geq 0$ and $e_{\hat{t}}^{inv} \geq 0$, it must be that (4.2), (4.4), (4.6), and (4.8) hold with equality.

Observation 3 (Regions are Distinct) *There are no values of θ that, once revealed, will simultaneously motivate suspenders to restart and continuers to suspend. At most one of these things will occur.*

For example, suppose that θ has been revealed to be high enough that at least one entrepreneur is willing to return ($\theta > \theta_M$). This entrepreneur must expect to receive interim private benefits and production receipts sufficient to compensate not only for the remaining investment requirements (including the skipped investment), but also for the restart costs. Since all producing entrepreneurs get the same price, those that continued at $\hat{t}$ will strictly prefer the elevated production receipts (high enough to compensate them for restart costs they aren't required to pay) to liquidation proceeds. Similarly, if at least some of those that have remained in are ready to shut down ($\theta < \theta_L$), then it must be that the market outcome will compensate only the expected net costs of further investment, and then only if the industry shrinks. No entrepreneur will be willing to pay restart costs to participate, since these cannot be recouped.

To summarise, one of each of these pairs of equations will determine $\{\theta_B, \theta_L, \theta_M, \theta_H\}$, with the magnitude of private benefits playing an important role in determining which. I conclude this section with a preliminary result relating to equilibrium lending rates.

Lemma 1 (Post-Suspension Lending Rates) *If credit markets are competitive at all points in time (contestable), debt contracts negotiated after suspensions occur will carry a lending rate of zero (independent of θ).*

The simplest motivation for Lemma 1 is that all post-suspension lending is riskless and should therefore specify the riskless rate. A more careful discussion appears in Appendix A.1.

Timing of First Suspensions / Liquidations

Implicit in the expressions that determine the location of $\{\theta_B, \theta_L, \theta_M, \theta_H\}$ are the outcomes that entrepreneurs will experience in each of these ranges. The analysis here proceeds as follows: under the assumptions that the current decision point is $\hat{t}$, that access to credit for this current period is contracutally assured, and that in all following periods all players use ϕ^*, I outline the costs and

benefits to a given entrepreneur of each the possible actions available to her. I begin with a second result that will prove useful in the exposition. Recall that $\bar{t}$ is defined as the last period in which an entrepreneur can suspend, liquidate in the subsequent period, and still expect something back after using liquidation proceeds to pay off debts.

Lemma 2 (Pre-Suspension Lending Rates) *If $\hat{t}$ is in the range $[1, \bar{t}-1]$, all debt is riskless and therefore the lending rate δ must be zero where banks price loans competitively (Case 1). If $\hat{t} = \bar{t}$, then debt is risky and therefore δ will be positive (Case 2). Finally, if there is no $\hat{t} \in [1, \bar{t}]$ then there will be no suspensions or liquidations (Case 3).*

Proof See Appendix A.2

The first implication of Lemma 2 (in conjuction with Lemma 1) is that where first suspensions occur early enough, all observed debt contracts will be written at the riskless rate.

The second important implication relates to the possibility that pessimistic entrepreneurs will choose immediate liquidation (rather than suspensions) at $\hat{t}$. A choice of liquidation at $\hat{t}$ generates $e_{\hat{t}}^{sus} + \delta_1 D_{\hat{t}}$ immediately, with no further costs or subsequent revenues. If this expression looks a bit odd, recall that the definition of $e_{\hat{t}}^{sus}$ nets out the debt service charges $\delta_1 D_{\hat{t}}$ that accrue between $\hat{t}$ and $\hat{t}+1$ and which are not applicable in the case of liquidation.[16] Thus the benefit of liquidation relative to suspension is that one period of debt service is avoided; the cost is that the entrepreneur no longer has the option of reinitiating the project if demand turns out to be very strong. In the event that $\delta = 0$, as it will be if $\hat{t} < \bar{t}$, then liquidation will not be observed in equilibrium – doing so amounts to throwing away the (real) option to reinitiate with no corresponding benefit.

The outcomes accruing to an entrepreneur that suspends or invests at $\hat{t}$ are much more detailed, but the essentials are easy to describe. For those that suspend at $\hat{t}$, any θ below θ_M leads to liquidation, while any θ above θ_H leads to reinitiation. For θ between θ_M and θ_H, some will reinitiate while others will liquidate; whether that is left entirely to the entrepreneurs's discretion or dictated by credit availability was characterised in the previous section. For those that invest at $\hat{t}$, any θ above θ_L will mean they carry on to production, while for lower θ some (or all, if θ is below θ_B) will liquidate.

[16] Note that $e_{\hat{t}}^{sus} > 0$ (otherwise there would be no possibility of either suspensions or liquidations) so there is no problem bringing $\delta_1 D_{\hat{t}}$ out of the max operator defined by $e_{\hat{t}}^{sus}$.

Table 4.1 summarises the (demand) state contingent expected revenues and costs of liquidating, suspending, or investing at $\hat{t}$, given that an equilibrium of the form ϕ^* being played.[17] The rightmost column presents the net benefit of suspending, relative to continuation.

Table 4.1: Expected Revenues and Costs Conditional on Strategy Followed at $\hat{t}$

	Liquidate	Suspend		Invest		Suspend -
	Outcome	Revenue	Costs	Revenue	Costs	Invest
$0-\theta_B$	$e_t^{sus}+\delta_1 D_t$	e_t^{sus}	0	$c\theta+e_t^{inv}$	0^*	$e_t^{sus}-e_t^{inv}-c\theta$
$\theta_B-\theta_L$	$e_t^{sus}+\delta_1 D_t$	e_t^{sus}	0	$c\theta+e_t^{inv}$	0^*	$e_t^{sus}-e_t^{inv}-c\theta$
				or		or
				$P(\theta,n)+c\theta I_t$	$I_{t+1}+D_{t+1}$	$e_t^{sus}-[P(\theta,n)-(1-c\theta)I_{t+1}-D_{t+1}+c\theta]$
$\theta_L-\theta_M$	$e_t^{sus}+\delta_1 D_t$	e_t^{sus}	0	$P(\theta,n')+c\theta I_t$	$I_{t+1}+D_{t+1}$	$e_t^{sus}-[P(\theta,n')-(1-c\theta)I_{t+1}-D_{t+1}+c\theta]$
$\theta_M-\theta_H$	$e_t^{sus}+\delta_1 D_t$	e_t^{sus}	0	$P(\theta,n'')+c\theta I_t$	$I_{t+1}+D_{t+1}$	$e_t^{sus}-[P(\theta,n'')-(1-c\theta)I_{t+1}-D_{t+1}+c\theta]$
		or				or
		$P(\theta,n'')+c\theta I_{t+1}$	$I_t+\mu+D_t(1+\delta_1)$			$\delta_1-\mu-c\theta$
θ_H-1	$e_t^{sus}+\delta_1 D_t$	$P(\theta,N)+c\theta I_{t+1}$	$I_t+\mu+D_t(1+\delta_1)$	$P(\theta,N)+c\theta I_t$	$I_{t+1}+D_{t+1}$	$\delta_1-\mu-c\theta$

Table 4.1 includes three notational shortcuts, made for expositional convenience: I use $n\in[0,n')$, n', and $n''\in(n',N)$ to denote the post-adjustment size of the industry in the three bottom intervals. Of these three, only $n'=(1-(1-\theta)^{\hat{t}})N$ is constant over the interval to which it applies; the other

[17]The expressions in Table 4.1 reflect the following specific case: $\hat{t}<\bar{t}$ is late enough in the game that borrowing has already begun. In other words, I am considering Case 1 of Lemma 2, but where there is some outstanding debt. This can, of course, be relaxed. Also, I include expected private benefits in the revenue column although it is not properly a revenue; call it *pro forma* notation.

two vary with θ depending upon the magnitude of reinitiation when θ falls in the relevant intervals. When necessary to characterise this value explicitly, I substitute from the appropriate (binding) constraint.[18]

Each row in Table 4.1 describes the outcomes of the three possible action choices, given that θ falls in the indicated range and that θ will be revealed in the current period. Complicating the exposition somewhat is the result from the previous discussion. In particular, if there is post-realisation credit rationing, it may be that some entrepreneurs that would prefer to continue given θ are refused credit and forced to liquidate. These entrepreneurs will receive different outcomes than those that are not forced to liquidate. On the other hand, if there is no credit rationing, entrepreneurs will be indifferent at the margin between continuing and liquidating, as each will expect the same outcome. In other words, if (4.2), (4.4), (4.6), and (4.8) hold with equality, then what appears above and below the "or" entries in Table 4.1 will be the same. A sufficient condition for this to be the case is that private benefits be small enough.

Consider the case of the interval from θ_B to θ_L. As noted, immediate liquidation is simple to characterise as it affords no subsequent operational flexibility. Those that suspend at t will liquidate at $t+1$, so there are no costs incurred, and revenues are given by e_t^{sus}. Finally, some of those that invest at t will liquidate, with the implied *net* revenue stream of $c\theta + e_t^{inv}$ (in this case, the costs associated with the t-period are incorporated in e_t^{inv}. Those that carry on to production will earn production revenues of $P(\theta, n)$ and receive expected private benefits $c\theta I_t$ (as at t there are $I_t = T + 1 - t$ periods remaining in which to possibly receive private benefits), and must make further investments of I_{t+1} as well as being responsible for the debt incurred to $t+1$. The table presents the cost and revenue streams for both cases; given the assumption that private benefits are small enough, the net streams in both cases will be identical in equilibrium.

The remaining rows in the table are developed in the same manner. Given the implication of Lemma 2 that liquidation is dominated by suspension whenever $\hat{t} < \bar{t}$, the rightmost column in the table is of particular interest. It gives the interval by interval net benefits of suspending over continuing to invest. Taking expectations over θ allows one to determine whether the expected value of suspension exceeds that of continuation – and the first time at which it does so is $\hat{t}$. More generally, one can simply take expectations over θ for each action choice and compare them; if for the most pessimistic firms t is the first time that either liquidation or suspension have the highest expectation then $t = \hat{t}$.

[18]See Appendix A.3 for a more careful discussion of this point.

Given the analysis captured by the entries in the table, one can also construct expressions governing the other two important decisions not yet addressed: entry, and the details of the debt contracts negotiated at time 0. I do this on a case by case basis, covering in turn the cases of suspensions at $\hat{t} < \bar{t}$ and $\hat{t} = \bar{t}$, and no suspensions.[19]

Riskless Debt (Voluntary Suspensions Prior to $\bar{t}$)

If entrepreneurs become pessimistic enough, early enough, they may suspend early in order to recoup what they can of their original investment. Suspensions take place at the first time s (given $s \in [1, \bar{t}-1]$) such that (4.9) holds:

$$\int_0^{\theta_L} (e_s^{sus} - e_s^{inv})\, f_s^{e_0}(\theta)\, d\theta \; + \\ \int_{\theta_L}^{\theta_M} [e_s^{sus} - (P(\theta, n') - (T-s)(1-c\theta) - 1 - \delta - D_s(1+\delta))]\, f_s^{e_0}(\theta)\, d\theta \; + \\ \int_{\theta_M}^{1} (\delta - \mu)\, f_s^{e_0}(\theta)\, d\theta - \int_0^1 c\,\theta\, f_s^{e_0}(\theta)\, d\theta \;\geq\; 0 \qquad (4.9)$$

Because θ is revealed early enough, there is no default risk. In the event that some entrepreneurs liquidate at $\hat{t}+1$ owing to a poor θ realisation, there will be sufficient liquidation proceeds to pay off their debt completely.[20] This means that $\delta_0 = \delta_1 = ... = \delta_{\hat{t}} = 0$, that $e_s^{sus} = \max[0, \alpha(\kappa + \hat{t}) - D_s] = \alpha(\kappa + \hat{t}) - D_s$ and that $e_s^{inv} = e_s^{sus} + \alpha - 1$. Making these replacements yields

$$\int_0^{\theta_L} (1-\alpha)\, f_s^{e_0}(\theta)\, d\theta \; + \\ \int_{\theta_L}^{\theta_M} [\alpha(\kappa + s) - (\theta A - (1-(1-\theta)^s)N - (T-s)(1-c\theta) - 1)]\, f_s^{e_0}(\theta)\, d\theta \; - \\ \int_{\theta_M}^{1} \mu\, f_s^{e_0}(\theta)\, d\theta \; - \; c\int_0^1 \theta\, f_s^{e_0}(\theta)\, d\theta \;\geq\; 0 \qquad (4.10)$$

The tradeoffs are quite apparent here. On one hand, when demand is low, the suspending entrepreneur winds up having 'saved' that part of one period's investment that is lost in liquidation $(1-\alpha)$. Against this she must weigh the surplus earned if demand is high (μ), and single period of control benefits that are surely lost by choosing to suspend. Between θ_L and θ_M the savings transit from $1-\alpha > 0$ to $-\mu < 0$.

[19] The details of the case $\hat{t} = \bar{t}$ are similar to the $\hat{t} < \bar{t}$ case and are contained in Appendix A.4.

[20] This statement also holds in the case of forced liquidations by the bank – that is, when (4.5) is binding, rather than (4.6), as I earlier assumed.

Next I characterise the magnitude of initial entry N, which is determined by a zero-profit expression. The general form of the expression is

$$\text{Prob}_0(\sigma_{\hat{t}} = 0) \times U_0(\theta|\phi^*(\sigma_{\hat{t}})) \quad + \quad \text{Prob}(\sigma_{\hat{t}} > 0) \times U_0(\theta|\phi^*(\sigma_{\hat{t}}))$$

which is simply the *ex ante* probability of receiving only bad signals until $\hat{t}$ multiplied by the expected outcome given that one plays according to ϕ^* throughout the game (and thus suspends at $\hat{t}$) plus the probability of all other $\hat{t}$-signal histories multiplied by the expected outcome given optimal play under this circumstance. The expression is quite cumbersome, and appears in the footnote.[21] The key addition is the entrepreneurial contribution term C.

The final issue that must be addressed is that of the profits accruing to the bank. However, Lemmas 1 and 2 imply that there is little need to formalise an expression characterising the bank's profits since in this case under consideration the bank always receives back what it lends.

4.3.2 Equilibrium Without Suspensions

Where entrepreneurs derive little benefit from suspending (for example, because private benefits are very high, or C is small, or because α is very small) then entrepreneurs cannot be expected to

[21] Following is the full expression characterising N, assuming that the entrepreneur's constraints bind in equilibrium and that by $\hat{t}$, the entrepreneur will have commenced borrowing.

$$\begin{aligned}
\left[\int_0^1 (1-\theta)^{\hat{t}} f^0(\theta)\, d\theta\right] \quad \times \quad & \left\{\int_0^{\theta_H} [\, e_{\hat{t}}^{sus} + c\,\theta\hat{t} - \min[C,\, \kappa + \hat{t}]\,]\, f^0(\theta)\, d\theta \;+\right. \\
& \left.\int_{\theta_H}^1 [\,\theta A - N + c\,\theta T - C - TD]\, f^0(\theta)\, d\theta\right\} + \\
\left[1 - \int_0^1 (1-\theta)^{\hat{t}} f^0(\theta)\, d\theta\right] \quad \times \quad & \left\{\int_0^{\theta_L} [\, e_{\hat{t}}^{inv} + c\,\theta(\hat{t}+1) - \min[C,\, \kappa + \hat{t} + 1]\,]\, f^0(\theta)\, d\theta \;+\right. \\
& \int_{\theta_L}^{\theta_M} [\,\theta A - (1-(1-\theta)^{\hat{t}})N + c\,\theta(T+1) - C - TD']\, f^0(\theta)\, d\theta \;+ \\
& \int_{\theta_M}^{\theta_H} [\,\theta A - n'' + c\,\theta(T+1) - C - TD']\, f^0(\theta)\, d\theta \;+ \\
& \left.\int_{\theta_H}^1 [\,\theta A - N + c\,\theta(T+1) - C - TD']\, f^0(\theta)\, d\theta\right\} \\
= \quad & 0
\end{aligned} \tag{4.11}$$

where $n'' = \theta A + c\,\theta(T+1) - TD - e_{\hat{t}}^{sus}$. This expression for n'' is based on the assumption that the entrepreneur's constraints bind. In the event that the bank constraints bind at equilibrium, $n'' = \theta A - TD$. These are simply the relevant incentive constraints applied to some $\theta \in (\theta_M, \theta_H)$. See Appendix A.3 for a detailed discussion of this issue.

suspend at all. In this case, all entrepreneurs invest through to T, and produce, and the 'payoff profile' for the bank and entrepreneurs is very standard. When θ is small (below θ_B) the price will be zero (a simple implication of the linear demand curve). Between θ_B and θ_E, all sales proceeds accrue to the bank (with θ_E defined as the θ above which all entrepreneurs can produce, pay their debts, and leave some surplus to be enjoyed). The default rate and the entry level, together with θ_B and θ_E, comprise the endogenous variables, which are determined simultaneously. The default rate is determined by the bank's *ex ante* zero-profit condition. Thus the important equations describing the equilibrium are:

Entry:

$$\int_{\theta^E}^{1} [\theta A - N - D_{T+1}]\, f^0(\theta)\, d\theta + \int_{0}^{1} [c\,\theta(T+1)]\, f^0(\theta)\, d\theta = C \tag{4.12}$$

Bank zero (expected) profit:

$$\int_{\theta^B}^{\theta^E} [\theta A - N]\, f^0(\theta)\, d\theta + \int_{\theta^E}^{1} [D_{T+1}]\, f^0(\theta)\, d\theta = PR_{T+1} \tag{4.13}$$

and the expressions determining the key values of θ:

$$\theta_B A - N = 0 \tag{4.14}$$

$$\theta^E A - N = D_{T+1} \tag{4.15}$$

I show in Appendix B.2 that in the special case of flat priors (so $f^0(\theta)$ is a uniform distribution on [0,1]) the solution to this set of four equations is given by[22]

$$\begin{aligned} N^* &= A - \sqrt{A(2(\kappa + T + 1) - c\,(T+1))} \\ \theta_B^* &= 1 - \frac{1}{\sqrt{A}} \sqrt{2(\kappa + T + 1) - c\,(T+1)} \\ \theta_E^* &= 1 - \sqrt{\frac{2C - c\,(T+1)}{A}} \\ \sum_{i=1}^{t'-1} (1+\delta^*)^{T-i} &= \sqrt{A}\left[\sqrt{2(\kappa + T + 1) - c\,(T+1)} - \sqrt{2C - c\,(T+1)}\right] \end{aligned} \tag{4.16}$$

[22]Note that this is not necessarily an equilibrium; one must check that there is no incentive for an entrant to deviate at any point during the investment process.

where t' denotes the first period in which borrowing is required, $PR_{T+1} = \kappa + T + 1 - C = T + 1 - t'$ is the total amount of money lent net of debt service charges, and (simply for notational convenience) I have assumed that $C \geq \kappa$ is an integer.

The properties exhibited by these solutions as the parameter set changes seem reasonable. The larger are private benefits, the larger will be the industry, and the smaller the set of demand realisations for which the entrepreneur must expect to share in the surplus in order for entry to be worthwhile. Indeed, so long as expected private benefits do not fully cover the wealth the entrepreneur brings to the table (*i.e.*, $C > \frac{c(T+1)}{2}$) then $\theta_E^* < 1$. Finally, as the share of total required investment that the bank contributes goes to zero, so too will the debt burden (of course).

4.3.3 Deviations

In order to show that I have indeed found an equilibrium, I need to show that there are no incentives for the bank or the entrepreneurs to deviate from the strategy profiles specified. Here, and in the corresponding discussion of the monopolistic credit market case (see 4.4.3), I first take debt contract structure as given and consider possible deviations within those confines. By structure I refer to the fact that contracts are negotiated at time 0 and time $\hat{t} + 1$, that they stipulate constant within-contract lending rates, that they take the entrepreneurial capital as given and do not specify any additional features, and that the same contracts are offered to all entrepreneurs. Later in the chapter (see 4.5) I discuss alternate contract structures.

Deviations by the Bank

There are many potential deviations that the bank could consider, but most of the non-obvious ones are ruled out by the assumption of contestability (as featured in the justification for Lemma 1). Any deviations that result in negative profits are unappealing, while those resulting in positive profits will be countered by entrepreneurs choosing not to accept the credit on those terms and to move on to another lender.

I begin with the suspension equilibrium case, and the decisions made at $\hat{t} + 1$.[23] The bank will allocate credit to that fraction of its existing customers (alternatively, to all its customers with the required probability) such that given θ and given that it charges a borrowing rate of zero, it earns

[23] Arguments for the no suspensions equilibrium are very similar and are not included.

zero expected profits. Given that all other banks are doing this, and that entrepreneurs are playing equilibrium strategies, would a bank have an incentive to deviate?

Fixing the loan rate, a deviation that involved offering credit to an additional entrepreneur would generate a profit of zero, hence there is no incentive to do so (and I assume they don't). Offering credit to some positive measure of additional entrepreneurs would imply losses, since the added production would mean that operating revenues would no longer cover the required borrowing.[24] Finally, restricting credit to a single entrepreneur would likewise generate no additional profits, as would restricting credit to some positive measure of entrepreneurs, since the lending rate is zero.[25]

Now fixing allocation, if the bank offered credit at a reduced (*i.e.*, negative) lending rate, it would earn negative profits, and therefore would not do so. Offering credit at an increased interest rate would imply positive profits on any loans made, but would also induce customers to move to another bank.

Finally, would a bank wish to deviate in both its lending rate and its allocation policy? No – any combination leading to positive profits will come at the expense of the entrepreneur, who would in turn choose to deal with a competing bank (contestability). And combinations leading to negative profits are clearly not worth pursuing.

Moving backward to time 0, again contestability means that deviations will not be undertaken by the banks. Any offer that would generate positive profits for the bank is also one that another bank can better, so the entrepreneur will refuse.

Deviations by the Entrepreneur

The primary concern is that entrepreneurs might decide that the first suspension time is simply too far in the future for them.

[24] This implies that all loans would be money losers, which implies some response by other banks, and so on. Even if I assume that the deviator can credibly commit to such deviations, and that these other banks simply 'give up' the appropriate number of customers (in the limit, all of them) all I need to ensure that the deviator cannot earn positive profits is to assume that the competing banks continue to exist. Note that too large an industry would also imply losses for the entrepreneurs under some circusmtances, but no single entrepreneur would recognise that she was 'excessive' and hence refuse the offered credit. While contestability is by no means an innocuous assumption, neither is allowing one bank to become a monopoly without some sort of regulatory intervention.

[25] That is, even if the those entrepreneurs did not find credit elsewhere, the zero lending rate means the higher profits that would result from a smaller industry would accrue to the entrepreneur rather than the bank.

Suppose that I am able to find a $\hat{t} < T$ such that (4.9) is satisfied. By construction this means that $\hat{t}$ is the first time at which the most pessimistic entrepreneurs perceive that the expected value of suspending exceeds the expected value of continuing, conditional on the equilibrium being played. But is it possible that at some $s < \hat{t}$ some entrepreneur will have become so pessimistic that she is willing to throw in the towel and liquidate immediately (*i.e.*, deviate) before θ is known?[26] In order to answer this question, all potential equilibria are checked to ensure that a condition of the following form holds for all $s \in [1, \hat{t} - 1]$:

$$U_s^{e_0}(\theta \mid \phi^*(\Sigma)) - e_s^{sus} + \delta_s D_s \geq 0 \tag{4.17}$$

The first term in (4.17) represents the net revenues expected at time s, as perceived by the most pessimistic entrepreneurs, of continuing to play equilibrium strategies, while $e_s^{sus} + \delta_s D_s$ is the value of the project to the entrepreneur in liquidation.

Comment: In the model without debt, this problem arises only in relatively extreme circumstances in which the first suspension times are 'too far' in the future. In the present model, Lemma 2 further restricts the parameter sets for which there will be such problems since it implies that there are no suspensions late in the going (*i.e.*, after $\bar{t}$). The potential problem with 'late' suspension equilibria is that a self-funded entrepreneur will have to spend a lot of her own money to get there. As one grows very pessimistic the merits of doing so may decline enough that the incentive to remain disappears. The use of external debt helps to solve that problem, because it opens up the possibility of a no suspension equilibrium funded by the bank. Obviously, the bank will require $\delta > 0$ to take on this risk, but the entrepreneurs most likely to destroy a candidate equilibrium have little incentive to do so when someone else is footing the bill. By way of example, using the parameters from the non-existence example in the previous chapter (augmented with an assumed entrepreneur wealth level $C = 5$) generates a no-suspension equilibrium in the model with debt.

Candidate equilibria are also checked to ensure that a condition of the following form holds at $\hat{t}$:

$$U_{\hat{t}}^{e_1}(\theta \mid \phi^*(\sigma)) - U_{\hat{t}}^{e_1}(\theta \mid \text{suspend at } \hat{t}) \geq 0 \tag{4.18}$$

If violated, it implies that entrepreneurs with one good signal would prefer to join their more pessimistic colleagues at $\hat{t}$ rather than continuing on as specified in ϕ^*.

Finally, the entrepreneur retains operational control of the project so long as he or she is funded, meaning that she has the ability to liquidate the project subsequent to $\hat{t} + 1$. Depending upon the

[26]The alternative deviation, suspension, will generate a (weakly) smaller payoff with no corresponding benefit since there will be no information revealed by the action. Thus, given that the entrepreneur is choosing an off-equilibrium path strategy, suspension is dominated by liquidation.

parameter set and the timing of the equilibrium the loss incurred by the bank (relative to what it was otherwise expecting) should the entrepreneur liquidate could be substantial. The entrepreneur may be able to use her ability to liquidate to squeeze the bank (and this would represent a deviation from the play described by ϕ^*). The issue, as one might expect, is whether she can credibly threaten to liquidate the project. The punchline, stated in the following lemma and developed in Appendix A.5, is that she cannot so long as her private benefits are small enough.

Lemma 3 (Post-Suspension Deviations) *The entrepreneur cannot credibly threaten to liquidate the project subsequent to $\hat{t}+1$ if $c \leq 1-\alpha$.*

The parameter restriction is sufficient but not necessary to avoid the deviations described. There are three interesting aspects to the lemma. First, the standard parameter set used in this paper satisfies the restriction. Second, one implication of the parameter restriction is that the entrepreneurs' ability to credibly make such threats relies on private benefits being *large*. It is precisely when they are large that the passage of time can erode the remaining stream of private benefits sufficiently far to make the threat credible. The final point to make is in the context of the 'generosity' problem of the self-financed entrepreneur. Imposition of the parameter restriction in Lemma 3 is sufficient but not necessary to rule out the generosity problem also.

4.3.4 Solving the Model

A solution to the model featuring early suspensions is a set $\{\theta_B, \theta_L, \theta_M, \theta_H, \hat{t}, N, \delta_1, \delta_2\}$ that satisfies (4.1) through (4.9), (4.11), and (4.17)-(4.18).[27] In order to solve the model, I first argue that when $\hat{t} < \bar{t}$, $\delta_1 = \delta_2 = 0$ (using Lemmas 1 and 2). Now suppose that is true, conjecture that $\hat{t} = 1$, and look for $\{\theta_B, \theta_L, \theta_M, \theta_H, N\}$ satisfying (4.1)–(4.8) and (4.11). Use these results in (4.9) to check that the inequality holds. If (4.9) holds, there is a candidate equilibrium with suspension at time $\hat{t} = 1$. If it does not hold, I increment the guess for $\hat{t}$ by 1 and continue repeating the process until I find a $\hat{t}$ conjecture that works. Finally, once $\hat{t}$ is identified, I check (4.17) $\forall s \in [1, \hat{t}-1]$ and (4.18) at $\hat{t}$. I must generally use numerical solution methods to characterise the model outcomes, but a partial characterisation of an analytical solution appears in Appendix B. I defer the remainder of this discussion to the end of this chapter in order to make the comparison with the monopoly case more explicit.

[27] A solution to the model without suspensions is a set $\{\theta_B, \theta_E, N, \delta\}$ that satisfies (4.12) through (4.15) and (4.17).

Numerical Examples

Here, I briefly outline examples of the equilibria that obtain using the standard parameter set from Chapter Three, augmented with a value for entrepreneurial wealth: $\{\alpha, \mu, T, \kappa, c, A, C\} = \{0.4, 3, 12, 3, 0.2, 100, 5\}$. This value of entrepreneurial wealth implies that the entrepreneur comes to the table with just under a third of the capital that will be required to develop the project fully. Given that $C = 5$, borrowing commences at $t = 2$, and $\bar{t} \leq 5$. That is, as the entrepreneur makes her operating decision at the beginning of $t = 6$, total borrowing amounts to 4 units (the face value of debt owing will be larger if the borrowing rate is positive) and the value of the project in liquidation is 3.6 (40% of the total capital in place, which is 9 units). However, at the beginning of period 5, liquidation proceeds exceed total borrowing by 0.2 units, making period 5 the last possible period in which an entrepreneur can suspend and expect to receive something back after liquidation.[28]

In Chapter Three, given this data set (except for the limit on entrepreneurial wealth) suspensions occured in period 4. In the case of the contestable credit market, we will observe suspensions in the third period given these parameters. But this result is quite sensitive to the value chosen for the entrepreneurial contribution. If C were lower – even by as small an amount as 0.25, meaning $C = 4.75$ instead of 5 – there would be no suspension equilibrium; from the entrepreneur's perspective, the expected value of carrying on with the investment project in period 3 becomes higher than the value of suspending, and the same is true for all other $t \leq \bar{t}$ as well. The 'culprit' here is the restricted entrepreneurial wealth and the limited liability feature of the debt finance that substitutes; the entrepreneur is contemplating buying private benefits with someone else's money. In the absence of a suspension equilibrium, we must look for a no-suspension equilibrium. Returning again to the case of the usual parameters, there is an equilibrium with $\{\theta_B, \theta_E, N, \delta\} = \{0.37, 0.54, 36.5, 0.08\}$. That is, for demand realisations above 0.54, the entrepreneurs share in the surplus, and the borrowing rate is about 8% per period.

4.4 Monopoly Bank

In this section I consider the case of a monopoly bank. One can think of this as a banking industry in which there is either only one lender, or in which there is more than one lender, but lenders are able to coordinate their actions (collude).

[28] If $\delta_1 > 0$ it may be that $\bar{t}$ is earlier than period 5.

4.4.1 Equilibrium With Suspensions

I assume that the bank is unable to commit to sharing the surplus that will arise in high demand states beyond that required to ensure continued entrepreneurial participation at and following $\hat{t}$. This means that if θ should become known, the bank will be able to choose a θ-contingent lending rate that ensures extraction of all possible surplus, and a credit allocation policy that maximises the surplus available for extraction. The bank behaves as a *de facto* product market monopolist. The key implication is that entrepreneurs that carry on to production will receive only private benefits and, when necessary, a modest amount of the production surplus. This constrains the set of parameters that are consistent with a suspensions equilibrium. The entrepreneurs know upfront that they will not share in the operating surplus in good states, so the primary motivation for entering the industry is the prospect of private benefits, which must be significant enough to compensate them for the capital they contribute to the project. But the larger is the private benefit, the smaller is the incentive to suspend (or liquidate) once the project is underway, even for those that become quite pessimistic after receiving several bad signals. And as was the case in the earlier versions of the model, while the entrepreneur's pessimism is growing, the net proceeds she can expect to receive in the event of liquidation grow smaller as debt accumulates, and soon, are gone. By that point, even the most pessimistic entrepreneur prefers to remain in the game collecting private benefits.

The bank has at its disposal (for the moment) two tools: it can choose the amount of credit it allocates, and the rate at which it is allocated. Subsequent to the realisation of θ the bank will choose industry size to maximise expected industry surplus and credit pricing to extract surplus. Therefore, within the current contract structure, the bank effectively has only a single tool (the lending rate that applies during the time period(s) leading up to suspensions). However, there are several constraints that must be satisfied. In particular, entrepreneurs must enter, and the most pessimistic among them must find it in their interest to suspend at the t specified by the candidate suspensions equilibrium. Moreover, akin to earlier discussions, an entrepreneur must not have any incentive to deviate at any time. Depending upon the parameter set, there may be no way to satisfy all of these constraints with a single tool.

I have placed the bulk of setup details in Appendix C, and here provide a description of the problem, some results, and a few examples. The problem being solved is as follows: the bank is maximising expected profits by choice of credit allocation (*i.e.*, industry size) and lending rates, subject to entrepreneurial participation and to entrepreneurs having an incentive to suspend in equilibrium.[29] The standard parameter set that I use throughout the paper does not generate a

[29](4.17) implies $\hat{t} - 1$ additional conditions that must be met in equilibrium. I solve the problem ignoring these

suspension equilibrium in this set up. The private benefits are simply not sufficiently attractive to motivate entry. To illustrate further, the entrepreneurs' expected private benefit stream will, *ex ante*, be worth $c/2(T+1)$, or using the usual parameters, about 1.3. Against this, the entrepreneur is assumed to be contributing $C = 5$. Given this parameter set and the hypothesised equilibrium it will involve, the entrepreneur is simply unwilling to enter. Therefore I consider not only variation in elements of the parameter set Γ but also augmenting the tools available to the bank. I focus on the capacity of the monopolistic bank to engineer early suspensions.[30]

The Problem, and the New Tools

When private benefits are small enough, the entrepreneurial commitment to the project must also be made quite small to induce entry. However, the smaller the entrepreneurial commitment, the more difficult it will be to induce suspensions even with a very high lending rate. In the limit, when entrepreneurs commit little or no wealth, they have no reason to ever suspend. This latter problem will be particularly acute when the liquidation parameter α is very low. In this case, entrepreneurs make the transition from self-funded entrepreneur to insolvent project manager very quickly, and therefore the bank's ability to motivate suspensions with lending rates is very limited. On the other hand, if the parameter set features private benefits and liqudation values that are 'high enough', and a wealth level that is not too high, the bank will not need to worry about entrepreneurial participation, and can use the lending rate to motivate suspensions. Finally, if the bank is endowed with additional tools, it may be able to deal with less favourable parameter sets. This is particularly interesting because it shows that under some circumstances a bank with monopoly power can (and will wish to) 'engineer' early equilibria. Other things equal, there are clearly social benefits to early adjustment, as this reduces unnecessary investment when demand is low. I consider the following:

- Bank chooses a non-negative δ_1: As already noted, if the bank is restricted to using a non-negative lending rate, then it is essentially helpless when private benefits are 'too low' relative to entrepreneurial contribution. In other words, the bank is not able to do anything to ensure that the time-0 participation (*i.e.*, entry) constraint is satisfied. On the other hand, if parameters are such that the entry constraint is not binding, then the bank can generally motivate a suspension via choice of lending rate, since it applies only to those that continue.

conditions, and then check to ensure that they are satisfied.

[30]This is distinct from the question of whether it *will* engineer these suspensions, which will (in the absence of regulatory barriers to the contrary) depend solely upon whether profits increase.

- The bank is allowed to reduce entrepreneurial captial commitments C: When expected private benefits are small, reducing the entrepreneurial contribution to the project makes entry more attractive. However, the smaller the entrepreneurial contribution the more rapidly debt builds up, reducing the attractiveness of suspensions. Therefore, this additional tool alone may be insufficient.

- Bank permitted a negative δ_1: Given that the riskless rate is assumed to be 0, δ_1 less than zero implies lending below riskless rates.[31] In this case, the bank can impact the entry constraint by subsidising borrowing for entrepreneurs that might not otherwise wish to enter the industry. When δ_1 is negative enough, the entrepreneur's initial stake can be maintained for many periods. That is, when $\delta_1 < 0$ each period of borrowed investment contributes $\alpha - (1 - \delta_1)$ to the net-of-debt liqudation value of the project, and in addition, reduces any outstanding debt by a factor of $1 - \delta_1$. Thus a lending subsidy can be used to ensure that the entrepreneur retains an interest in the project in liquidation even when her initial contribution is very small.

- Finally, the bank may be permitted to offer action-contingent lump sum payments to entrepreneurs: Assuming that banks can commit to doing so, a lump sum payment offered to those that suspend can help motivate suspensions.

The key question in this portion of the thesis is whether the bank can induce early suspensions and in so doing, expect to earn greater profits than can expect in the absence of suspensions. That a bank with sufficient pricing power and additional tools should be able to generate early suspensions is not particularly surprising. What is of more interest is that these early suspensions will involve greater profits for the bank than would the case of no suspensions.

4.4.2 Equilibrium Without Suspensions

In the absence of an equilibrium featuring suspensions, the alternative is equilibrium in which all entrants invest to project completion, and then learn the demand parameter via the marketing of their production. The bank still maximises profits by choosing the amount of entrepreneurs to fund, and the rate at which they will provide the funding, in order to do two things: maximise the (expected) available surplus, and make the entrepreneurs just indifferent to entry at the surplus maximising

[31] The assumptions that credit ceilings are part of the contracts, and that the borrowed proceeds must be used for the purposes intended, rule out arbitrage.

level. Basically, in this equilibrium, the bank's monopoly power permits surplus extraction subject to the contstraint that the entrepreneurs participate.[32] The bank solves:

$$\max_{N,\delta} \quad N\left[\int_{\theta^B}^{\theta^E}[\theta A - N]\, f^0(\theta)\, d\theta + \int_{\theta^E}^{1} D_{T+1}\, f^0(\theta)\, d\theta - (\kappa + T + 1 - C)\right] \tag{4.19}$$

subject to:

$$\int_{\theta^E}^{1}[\theta A - N - D_{T+1}]\, f^0(\theta)\, d\theta + \int_{0}^{1}[\, c\,\theta(T+1) - C\,]\, f^0(\theta)\, d\theta = 0 \tag{4.20}$$

$$\theta_B A - N = 0 \tag{4.21}$$

$$\theta^E A - N = D_{T+1} \tag{4.22}$$

Again, (4.21) and (4.22) define three regions over which the bank collects nothing, the entirety of the operating proceeds, and the face value of debt only. In the top region, the entrepreneur collects some of the operating surplus. (4.20) defines the entrepreneur's participation constraint. The problem can be separated into one of a simple maximisation over N by using (4.20) and (4.21) to substitute for the terms involving δ in (4.19). This helps to reinforce the notion of the bank choosing aggregate production (*i.e.* credit allocation) to maximise the surplus and using the lending rate to ensure that entrepreneurs participate. A solution to the model with a monopoly bank that does not feature early suspensions is a set $\{\theta_B, \theta_E, N, \delta\}$ that satisfies (4.19) through (4.22) and (4.17).

Once again resorting to the special case of flat priors the solution to this set of four equations is given by (see Appendix B.3):[33]

$$N^* \quad = \quad \frac{2A}{3} - \frac{\sqrt{A}}{3}\sqrt{A + 3[2(\kappa + T + 1) - c\,(T+1)]} \tag{4.23}$$

[32] When parameters are such that anticipated private benefits exceed the entrepreneurial contribution, the interest rate can be set such that the bank does in fact acquire all of the surplus. To do so it sets the interest rate to equate the debt level with the operating revenues in the best state of the world – $\theta = 1$.

[33] As in the contestable credit markets case, t' denotes the first period in which borrowing is required, and $C \geq \kappa$ is an integer. Also as before, this is not necessarily an equilibrium; one must also check that there is no incentive for deviations.

$$\begin{aligned}
\theta_B^* &= \frac{2}{3} - \frac{1}{3\sqrt{A}}\sqrt{A + 3[2(\kappa + T + 1) - c(T+1)]} \\
\theta_E^* &= 1 - \sqrt{\frac{2C - c(T+1)}{A}} \\
\sum_{i=1}^{t'-1}(1+\delta^*)^{T-i} &= \frac{A}{3} + \frac{\sqrt{A}}{3}\left[\sqrt{A + 3[2(\kappa + T + 1) - c(T+1)]} - 9\sqrt{2C - c(T+1)}\right]
\end{aligned}$$

4.4.3 Deviations

Deviations by the Bank

Equilibrium behaviour by the bank in a no suspension equilibrium involves allocating credit to that proportion of entrepreneurs that maximises the available surplus, and choosing a (constant) lending rate such that entrepreneurs ultimately receive just enough of the surplus that they are willing to enter. I show in Appendix B that these decisions are separable. Any other credit allocation decision, and any other interest rate decision, will not benefit the bank and therefore will not be chosen. Moreover, since it is the aggregate debt service that matters to the entrepreneurs' entry decision in a no suspensions equilibrium, choosing another lending rate policy (one that varies the lending rate through time but that maintains the same total debt service level) will generate equivalent outcomes. An alternative lending rate policy that generates a different total debt service level will either fail to satisfy the entrepreneur's participation constraint, or it will permit the entrepreneur to enjoy too much of the surplus at the bank's expense. Therefore, the debt contracts as described are equilibrium contracts.

The no suspensions equilibrium is more complicated, but the argument is quite straightforward: given the structure of the problem, the bank is choosing the variables it has some control over to maximise profit. Again, the bank chooses initial credit allocation to maximise surplus, and at $\hat{t}+1$ may further restrict credit once θ is revealed.[34] Note that part of the $\hat{t}+1$ allocation decision might involve θ-dependent credit restrictions (as embodied in the conditions determining the important cutoff values of θ) that limit 'excessive continuation', though of course the bank is not concerned about this except insofar as it impacts bank profits.

[34] Given the structure of the problem the bank is unable to expand credit after θ is revealed, though it might wish to.

Deviations by the Entrepreneur

Possible entrepreneurial deviations are analogous to those in the case of contestable credit markets and I do not repeat that discussion here. Note though that as the bank is given additional tools, new avenues for entrepreneurial deviation open up. By way of example, when the bank is permitted to offer investment policy-contingent lump sum payments, I must be sure these payments do not motivate the 'wrong' entrepreneurs to suspend.

4.4.4 Numerical Examples

The problems already apparent in the contestable markets case are exacerbated by the monopolist bank's inability to commit to (setting a post-suspension lending rate that would permit) sharing surplus beyond that necessary to ensure post-suspension participation. In the event that there are no suspensions, one must investigate the case of no suspensions (in which the associated use of long-term debt does permit a commitment to sharing surplus). The specific details, given the standard parameter set, are $\{\theta_B, \theta_E, N, \delta\} = \{0.18, 0.54, 17.7, 0.19\}$. Relative to the contestable credit markets, no-suspensions outcome the industry is considerably smaller, and the interest rate considerably higher, under the monopolistic bank.

As suggested earlier, the bank cannot induce early suspensions given the standard parameter set unless endowed with additional tools. Reducing the entrepreneurial contribution, even to 0, is insufficient to generate early suspensions so long as interest subsidies and / or lump-sum payments for suspenders are ruled out. On the other hand, once endowed with these tools, the bank is able to implement early suspensions, even as early as the first period. For example, if the bank is endowed with the right to make such lump sum payments as well as lending rate subsidies, it can induce period-1 suspensions and in so doing earn higher profits than would be earned in the no-suspensions case of the previous paragraph. Suppose the bank reduces to 1.6 the original entrepreneurial contribution, and offers a lump-sum payment of 0.15 to all entrepreneurs that suspend at the beginning of the second period. In this case the bank can induce first-period suspensions with the following details: $\{\theta_B, \theta_L, \theta_M, \theta_H, N, \delta_1\} = \{0.13, 0.34, 0.44, 0.80, 32.2, -0.66\}$.

Are there parameter sets for which early suspensions can be motivated without additional tools being allocated to the bank? Suppose that we begin with the standard parameter set, with the following changes: $\alpha = 0.7$ (meaning that liquidation yields 70% of the original investment) and $c = 0.785$ (implying that the entrepreneur enjoys private benefits that she values as equivalent to almost 80% of the periodic investment requirement). The very high level of private benefits makes

entry worthwhile, and the high liquidation parameter helps entrepreneurs that don't last very long recoup much of their original investment. Given these parameters, the bank can induce suspensions in the second period without reducing the entrepreneurial contribution or resorting to the use of subsidies or lump-sum payments: $\{\theta_B, \theta_L, \theta_M, \theta_H, N, \delta_1\} = \{0.13, 0.48, 0.52, 0.63, 24.5, 1.134\}$. Here the bank charges approximately 113.4% interest per period. The interest rate is effectively a tax on continuation, which is sufficiently high to make those with bad signals prefer departure.[35] Bank profits are about 22% higher than they would be given a no-suspensions outcome with the same parameter set. Here, the bank is able to capture some of the value of the private benefits from the entrepreneur. If the private benefit parameter is increased from 0.785 to 0.8, bank profits increase further. This happens because the bank can set the lending rate even higher without compromising entrepreneur participation.

4.5 Equilibrium Debt Contracts

There are three key questions about the debt contracts that are used in this model. First, how do they relate to debt contracts found in the related literature, and to those that are empirically observed? Second, are they equilibrium contracts under these circumstances? Finally, are they optimal (relative to other possible debt contract structures)? Note that I am not asking if debt (relative to outside equity, bond finance etc) is optimal within this setting.

In answer to the first question, there are two ways of thinking about the debt contracts used in the paper. One might think of traditional debt contracts, with variable terms (including maturity). Then, in the usual suspension equilibrium, there are two distinct debt contracts. The first begins at time 0, and matures at $\hat{t} + 1$. Then new contracts are written to cover the time period from $\hat{t} + 1$ to T. Subject to the assumptions on pricing behaviour, credit allocation and pricing decisions can reflect public information as soon as it is available.

The alternative way of thinking about the contracts is as loan commitments, which come with fixed maturity T and an option (held by the bank) to renegotiate. Shockley and Thakor (1997) document that loan commitment contracts typically feature a clause giving the bank the right to reprice or even revoke its commitment in the event of a 'material adverse change' (MAC). The contracting structure in this paper is also consistent with financing via loan commitments with MAC

[35] However, the bank cannot effect *first*-period suspensions using a positive lending rate alone. Given entrepreneurial wealth of 5, period 2 is the first period in which borrowing will occur. Those (and only those) entrepreneurs that continue at $\hat{t}$ will accumulate debt on which δ_1 applies.

clauses. However, the following caveat is in order: typically, loan commitments generally also involve additional fees that the borrower pays out of pocket. These fees do not appear in the current model, and should in principle be priced as part of the equilibrium. However, they could likely be folded into the initial investment κ (noting that at time 0, when they are determined, all entrepreneurs are identical and hence there would be no basis for them to differ across entrepreneurs).

The second question is answered in the discussions of deviations earlier in this chapter. Within the context of the structural assumptions made, the contracts are equilibrium contracts.

Finally, I turn to the third question: are the structural assumptions restrictive? By structure I mean such things as the following:

- δ is constant within a contract
- contracts are negotiated at time 0 and time $\hat{t}+1$ (as opposed to negotiation each period)
- the same contract is offered to all entrepreneurs
- contracts are restricted to the specified variables (initially, maturity and lending rates, and subsequently, entrepreneurial capital contribution and investment policy-specific lump sum payments)
- entrepreneurial capital contributions are used first (in calendar time)

I will focus my comments on the second item in this list. Evidently, these structural features interact. For example, suppose contracts are negotiated every period. In this case, I might also wish to allow the bank to offer a menu of contracts. As it stands, there is no need to offer such a menu; entrepreneurs are functionally identical at the points at which these contracts are negotiated and therefore will choose the same contracts. If I restrict the contracts to lending rates, then the bank will not be able to separate the pessimists from the optimists even if contract negotiation takes place each period – all entrepreneurs will prefer the contract with the lower lending rate. Introducing entrepreneurial capital contribution as an additional variable, so that this separation might be effected, will not work in situations where the available entrepreneurial wealth is relatively small since it is likely to have been exhausted by the time at which new contracts are negotiated. In other words, even were I to arm the bank with menus of contracts and allow renegotiation each period, the bank might still require the use of an additional tool (like the investment-policy contingent lump sum payment) in order to engender rapid suspensions.

I also note that this list of concerns is relevant only to the case of equilibrium with suspensions. In the no suspension case, we simply have long-term debt. Since it is offered at time 0, when

all entrepreneurs are identical, there is no loss in assuming that all are offered the same contract. Moreover, nothing is lost by assuming a constant lending rate: the lending rate is determined solely by expected default considerations and there are an infinite number of outcome equivalent contracts featuring acceptable time series variation in lending rates but (ultimately) the same coverage for the bank (alternatively, the same debt service charges for the entrepreneur).[36]

4.6 Chapter Summary

In this Chapter I extend the model of Chapter Three to consider the impacts of the use of external finance on the entrepreneurs' decisions. I am particularly interested in exploring the impact of different degrees of lender pricing power. I consider two extreme cases: credit markets in which credit allocation and pricing are perfectly competitive at all points in time (contestable credit markets) and credit markets in which the lender exercises monopoly power over credit allocation and credit pricing.

In the case of the contestable credit market, the potential for suspensions equilibrium is determined by the entrepreneur's perceptions of the costs and benefits of suspension, and the limitations (stemming from the contestability of the market) faced by a bank that might like to use credit pricing and / or allocation to alter the entrepreneurs' cost-benefit structure. There is an upper bound $\bar{t}$ on possible suspensions times, determined primarily by the magnitude of the entrepreneurial contribution to the project and the liquidation parameter, beyond which the entrepreneur has grown so indebted that she can expect nothing in liquidation. Therefore, she will not voluntarily suspend or liquidate her project beyond this point in the investment process.

If suspensions do occur in equilibrium (*i.e.*, prior to, or at, $\bar{t}$), we can conclude two things. First, all lending subsequent to the suspensions must be riskless (since all uncertainty has been resolved). Moreover, by definition of $\bar{t}$ the bank is assured of receiving back all that it has lent to all entrepreneurs (independent of the realisation of the demand function parameter) and therefore pre-suspension debt must also be priced as riskless debt in equilibrium. On the other hand, in the event that no suspensions occur, debt will not be riskless, and the lending rate will be set to cover expected defaults (that is, to generate zero expected bank profits).

[36] Of course one must nonetheless be careful in making such statements – I cannot take the form of the equilibrium as given and then arbitrarily vary lending rates. Thus the use of the word 'acceptable', which is to say, subject to not compromising the viability of the no suspensions equilibrium.

Using the baseline parameters, there is a suspensions equilibrium at time 3. However, if the entrepreneurial contribution to the project and/or the liquidation parameter were lower, the equilibrium would be broken. As well, if the private benefits parameter is too high then entrepreneurs will prefer to remain in the industry rather than suspending. In that case, the 'earliest' equilibrium is one without suspensions.

When the entrepreneur is faced with a monopoly bank, the bank can use its additional pricing power to generate early suspensions. She knows that in the event that suspensions occur in equilibrium, the bank will set the terms of post-suspension debt so that she enjoys no more of the surplus than is necessary to motivate her participation beyond $\hat{t}$. Depending upon the toolkit with which the bank is endowed, this restriction (*i.e.* that the bank cannot commit at time 0 to 'excessive' sharing) will place limitations on the bank's ability to induce very early suspensions.

The tools I consider are reduced entrepreneurial contributions, lending subsidies, and action-specific lump sum subsidies. Other things equal, reductions in entrepreneurial contributions make entry more attractive, but may also make subsequent suspensions *less* attractive by reducing the net-of-debt liquidation outcome for the entrepreneur. A lump sum payment promised to those that suspend directly relaxes the $\hat{t}$ incentive constraint (*i.e.* suspension choice), and in improving the outcome to a suspending entrepreneur, also makes initial entry more attractive. Finally, the lending subsidy operates on both the entry and suspension conditions. The bank can choose the subsidy to ensure that a pessimistic entrepreneur retains just enough interest in suspending their projects.[37] However, because it is offered to all entrepreneurs, it also helps to relax the entry constraint.

By way of example, using the standard parameter set, the bank is unable to induce suspensions in the first period without resorting to the use of lump sum subsidies. Reductions in the entrepreneurial contribution and lending subsidies do not provide the bank enough flexibility; one of the entry or suspension conditions fails to be satisfied. However, with that additional tool, the bank is able to generate first-period suspensions in which it expects greater profits than the outcome with no suspensions. On the other hand, these additional tools are not always necessary for early suspensions. For example, when private benefits are large relative to the entrepreneurial commitment to the project, entrepreneurs do not need to be motivated to enter, and the bank needs no additional tools: it can choose a non-negative initial lending rate that will effectively act as a tax on those entrepreneurs that continue investing, and thereby encourage those with the most pessimistic beliefs to suspend.

[37] Throughout, I consider subsidies $\delta_1 > -1$. Subsidies larger than this would be more appropriately described as wages.

Chapter 5

Relevance to the East Asian Financial Crisis

"Truth is stranger than fiction because fiction has to make sense." Twain

In this chapter I explore two main themes. First, I consider the properties of the models developed in Chapter 4 in the context of the East Asian Crisis. Next, I look more carefully at the question of whether banking markets in East Asia featured competitive pricing. As the modelling results indicate, the properties of the equilibria can be quite different under these two different regimes. Finally I conclude with a discussion of some extensions and unresolved issues.

5.1 Does This Model Speak to the East Asian Crisis?

The model I have worked with is not a model of financial crisis. However, an obvious implication of the model is that in equilibria in which information aggregation takes place via suspensions both entrepreneurs and their creditors can adjust to that information. Therefore suppose, as I described at the end of Chapter Three, that 'crisis' is identified as the magnitude of (ultimately) unnecessary investment. Clearly there will be no crisis without a relatively poor demand realisation, but the magnitude of the impact of that poor realisation depends on how long the investment carries on before the available information is realised. As highlighted in the previous chapter, the structure

of credit markets is one crucial determinant. However, the basic parameters of the model can also have a significant influence, and I illustrate this now with reference to the East Asian crisis.

In the immediate aftermath of the East Asian crisis there were a number of ideas advanced regarding possible causes. Now, several years later, the matter is by no means resolved (although as noted early in the thesis most writers identify heavy corporate reliance on debt finance as an integral part of the explanation (for example, see Shirai (2001) or Alba *et al*, (1999)). Here I consider how the models of the previous chapter might fit with observations made about the crisis.[1] I focus on whether the model can deliver any insight into some common themes of the post-crisis discourses, both popular and academic. I address the following themes:

- overborrowing / overlending / overinvestment
- transparency
- crony capitalism
- weak institutional environment (*i.e.*, corporate governance, bankruptcy law)

5.1.1 Overinvestment

One of the very common suggestions about the East Asian crisis is that a primary cause was overinvestment. It is important to distinguish between *ex ante* and *ex post* conceptions of the term. That is, do we define the appropriate level of investment with respect to what is expected, or with respect to what obtains? Obviously, in hindsight, there was excess investment, at least in some sectors. Most of the popular press accounts of the crisis that discuss overinvestment implicitly or explicitly use this *ex post* concept. And the model can deliver such an overinvestment result. But the interesting question is whether *ex ante* overinvestment existed. This raises an alternative interpretation of the liquidation parameter α, already alluded to in the first Comment following the discussion of changes in α in Chapter Three. Higher α leads to higher N – but on the other hand may also make a suspension equilibrium more likely. Credible implicit or explicit guarantees may raise the value of α. If the impact of such an increase is higher N but the likelihood of suspension doesn't change, then one can argue that overinvestment arises, a result of induced moral hazard. On the other other hand, an increase in α may speed up the process of information aggregation, which can be socially beneficial even if the equilibrium involves higher entry than one would expect relative to the 'true' α.

[1] That is, I interpret the model with reference to the crisis, rather than the crisis with reference to the model.

5.1.2 Transparency

Despite the ubiquity of the term, it is not always clear what is meant by transparency, but the working definition I will use is that transparency relates to one's ability to access accurate and timely information necessary for use in making decisions. This may reflect anything from basic macroeconomic data useful in assessing the stability of the government and the strength of any contingent liabilities it might have to the cost one will have to pay in order to acquire regulatory permissions and licenses. Authorities in East Asian countries have long been targets for criticism on this score; Ramkishen Rajan provided a succinct statement of the problem, and hinted one of the reasons for it, when he wrote "Authorities in the region... have used economic data as a strategic tool rather than a public good" (Rajan, 2000).[2] Somewhat more benign, but no less relevant, is the question of data quality.

In the context of the model I build, at least some of the flavour of the transparency question can be imbedded in the question of the appropriate prior distribution to use. For example, relatively flat priors can be interpreted as resulting from a lack of transparency, thereby reducing the precision of beliefs. Given that this association is appropriate, the model generates an interesting result: crisis events may be less likely and less costly when the environment is *less* transparent, since the signals that investors are receiving have a greater influence on beliefs the flatter are the priors. The alternative interpretation would be that priors are unaffected by the state of information, and that the impact of reduced transparency is introduction of some noise into the signal process (so that investors place less weight on signals received). In this case, the argument made earlier would have to be reversed: greater transparency would facilitate earlier suspensions.

5.1.3 Crony Capitalism

Attention has been focused on the fact that in those countries where the crisis had a significant impact, there was a close relationship between government and elements of the business community. This could also be said of most other countries in the world, but particular attention was focused

[2] Hints of this kind of sentiment appeared in a number of personal interviews (completed in the context of Furtado and Storey (2001)). The clearest example was provided by the Head of Research at one of the regional central banks. When I asked if he any difficulty accessing data collected by officials at the Ministry of Finance, he replied that access was not an issue because "(he knew) everyone over at Treasury." Fully 70% of the officials interviewed indicated that there was a lack of information sharing between different government offices – though this is by no means a uniquely Asian phenomenon.

on Asia as the crisis occured, perhaps because the crisis-era leadership in Indonesia was so widely associated with such practices.[3]

The present model cannot address directly the tightness of the association between the entrepreneur and the government, but to the extent that association is reflected in wealth, there is a role to play in the model. Specifically, the higher the entrepreneurial wealth level, the earlier are the suspensions (within the contestable markets framework). For sufficiently high wealth levels, we move from a case of no suspension equilibrium to a suspension equilibrium. Given the tensions considered in this model, crises are less likely the richer are the market participants.

5.1.4 Institutional Environment

The institutional environment is taken to refer to such things as regular application of the rule of law, existence of a competent and impartial judiciary, consistent and effective bankruptcy proceedings, competent corporate governors, and so on. It is often argued that some or all of these things were lacking in the crisis countries. One consequence is that outside investors may choose to liquidate holdings at the first sign of trouble when they have little confidence in the institutional environment. This can lead to outcomes with self-fulfilling components – that is, the flight ensures that trouble will ensue, akin to the bank run model of Diamond and Dybvig (1983), for example. The model I have presented has little to say about such outcomes.

However, another way of thinking about this issue is with respect to the efficacy of corporate governance. In particular, effective corporate governance and/or regulatory mechanisms may constrain the entrepreneurs' ability to capture private benefits. In the model I build, the private benefits do not compromise the value of the project except insofar as they impact the entrepreneur's suspension decision. If private benefits are 'too high' it may be very unlikely that the entrepreneur will choose to suspend. Suppose that effective corporate governance can be interpreted as a reducing the private benefit parameter. Recall that in the contestable markets case, with a private benefit parameter of 0.2, the entrepreneur is willing to suspend investment in the third period. However, a higher private

[3]The Prime Minister of Malaysia, Dr. Mahathir, has candidly discussed allocating project development rights to friends and associates of the political organisation he leads. His justification for doing so: those who are rich and influential have become so because they are competent. More recent incarnations of these arguments have focused on the revenue and fees that government collects from businsess. Says Dr. Mahathir, "We believe that it is the duty of government to help out the private sector. That's what we are elected for. And when the private sector performs, 30 to 35 percent of their profit belongs to the government. We are working as a shareholder." (asia inc, May 2002, p. 28)

benefit parameter (say 0.4, for example) is sufficient to break the suspension equilibrium. On the other hand, in the monopolistic markets case, private benefits are crucial to motivating entry (conditional on playing a suspensions equilibrium) and, particularly when the bank has a limited toolkit, larger private benefits can be helpful in permitting the bank to engineer a suspensions equilibrium. From a social standpoint, it may thus be that monopolistic banks are better suited to environments in which private benefits are high and entrepreneurial wealth levels relatively low. On the other hand, contestable credit markets may well-suited to richer entrepreneurs who enjoy smaller private benefits.

5.2 Competition in East Asian Banking Markets

The popular press, quasi-regulatory institutions like the Bank for International Settlements, and academics (for example, Chang and Velasco (1998)), have attributed at least part of the problem that occured in Asia to liberalisation of local capital markets.[4] There is of course an important distinction between the level of competition in the credit market, and *changes* in that level. The model developed in the thesis directly addresses different levels of competition but does not deal with changes in that level. This raises the possibility of saying something about the transition from a monopoly bank to a competitive bank (interpreted as capital market opening), and comparing different cases to see whether something instructive can be learned about the crisis. Bank strategies in place when the market opens may be dashed once the competition removes the ability to prompt early suspensions – a concern discussed, for example, in Allen and Gale (1997) in a much different framework. Weinstein and Yafeh (1998) examine the consequenses of capital market opening on the Japanese banking industry and find that banks, which had enjoyed surpluses based on market power and close bank-firm relationships, lose this surplus after the market is opened.

The degree to which banks in East Asia can, or could, in the mid 1990s, exercise market power in their lending arrangements, is essentially an empirical one. There has been very little formal econometric work done on East Asian banking system market structure, with the possible exception of Japan. One obvious reason for this is the issue of data limitations. Here I outline the results of the single paper I am aware of that tackles this question, and outline a second paper that awaits writing.

[4]Financial liberalisation might be defined in many ways, but in empirical studies is commonly identified with a reduction in interest rate controls, removal of reserve requirements, and/or a reduction in restrictions placed on foreign banks or domestic banks' foreign transactions.

The traditional approach to assessments of market power is the structure-conduct-performance approach. In brief, this approach involves identification and testing of hypotheses built around the interrelationships between market structure, firm conduct, and the industry outcomes that ensue. Ultimately, though, they generally boil down to a search for a relationship between market concentration and profitability. In the banking context, there are a variety of difficulties with identifying and interpreting the results of such studies. One of the most basic difficulties is settling on a definition of what constitutes an input, and what an output, for a standard commercial bank which typically will be active in several markets simultaneously (loans, deposits, and securities). Moreover, as technology and regulations change, so too do the markets (input and output) in which the banks compete, further complicating the analysis. Neuberger (1999) presents a thorough review of this paradigm with respect to banking.

Somewhat more recently, other econometric testing procedures have been developed to measure the degree of competition within an industry. One, which has the virtue of being based solely on aggregate time series data, in its most basic form estimates a system of two equations, one representing a demand function, and one representing a supply function. The demand side is typically a standard formulation including price, income, the price of one or more substitutes, and so forth. The supply function is used to identify the degree of market power in the following sense: in perfect competition, price equals marginal revenue equals marginal cost. Where there is some market power, marginal revenue exceeds price. If one makes sufficient assumptions about the structure of the demand and marginal cost functions,[5] it is possible to express marginal revenue as a separable function of price and coefficients and exogenous variables from the demand function. One can therefore estimate a supply relation that explains market price as an additive function of marginal cost and a term representing the excess of marginal revenue over price. The parameter on the $MR - P$ term is interpreted as a measure of market power. If it is zero, price equals marginal cost (perfect competition), and if it is one, price is set as if by a monopolist.

This approach has been applied to banking (for example, see Shaffer (1989, 1993)) but there are some pitfalls. For example, one must consider the possibility that data are non-stationary, making traditional inference measures inappropriate.[6] A recent paper (Steen and Salvanes (1999)) develops

[5] A simple set of assumptions that leads to this outcome is that demand is a linear function of own price, the price of a subsitute, and an interaction variable (own price times substitute price). This last term (which implies that a change in the substitute price affects both slope and position of the demand curve) serves to identify the parameter on the $MR - P$ term in the supply relation. A more general statement of the conditions under which identification is possible can be found in Lau (1982).

[6] One indication that this may be an issue in the Shaffer papers is the extremely high R^2 values that Shaffer

an error-correction formulation of the model and applies it to the French market for salmon.[7] The Steen and Salvanes method would, with some minor adjustments, likely provide a useful approach to estimations in the Canadian banking context (Shaffer (1993) considered the Canadian banking market). However, I do not believe it would be the best approach for the East Asian crisis-affected banking systems. The crucial physical difficulty would lie in obtaining a sufficiently long and consistent time series for any of the crisis countries. At a conceptual level, although the error-correction methodology explicitly allows for short-run movements away from long-run equilibrium, it does assume a long-run equilibrium. It is by no means clear that these markets are (or were in the years preceding the crisis) in long-run equilbrium.

A third approach builds on the work of Panzar and Rosse (1987) who developed the H-statistic as a measure of market power. The core of the approach is an estimation of a reduced form revenue equation, in order to obtain revenue elasticity measures (with respect to changes in input prices). Panzar and Rosse show via comparative static results that the sum of these elasticities differs systematically with market structure assumptions. In particular, when prices are set under a monopolist (or under perfect collusion) this sum will be negative, because the increase in costs reduces output and revenue. On the other hand, under perfect competition (or in a contestable market), these elasticities sum to one (the increase in costs motivates a commensurate increase in price and revenue).[8] Finally, values between 0 and 1 are indicative of some form of monopolistic competition.[9] A representative regression line might look like

$$Y_{i,t} = \sum_{j=1}^{J} \alpha_j X_{i,t}^j + \sum_{k=1}^{K} \beta_k Z_{i,t}^k + \epsilon_{i,t} \tag{5.1}$$

for a panel of length T and breadth I where Y is some measure of revenues (in natural log form), X is a vector of input prices (also in natural logs), and Z is a vector of other exogenous variables representing scale factors and business mix. The H statistic is calculated as $\sum_{j=1}^{J} \alpha_j$.

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obtains in both. Moreover, given the financial variables he uses, it would be quite surprising if non-stationarity were *not* present.

[7]In the event you are burning with curiosity, it seems that Norway has some short-run market power in this market.

[8]Molyneux *et al* (1996) point out that there are additional conditions that must be met. In particular, one of the following three conditions must hold: the firm produces a single output, the production function is homothetic, or factor prices change by equal proportions for all sample firms.

[9]Shaffer (1983) shows that both of the Panzar-Rosse H statistic and the parameter on the $MR - P$ term in the second approach can be expressed as a function of the other and the industry-wide elasticity of demand.

Several of the results underlying the Panzar-Rosse calculations also require that the industry be in long-run equilibrium for them to be conceptually valid. As such, some authors (see Molyneux *et al* (1994)) have also developed a test for equilibrium, based on similar reasoning. In particular, they note that industry returns should not be correlated with input price changes in equilibrium, and therefore they calculate an analog to the H-statistic that comes from regressing (5.1) once again, where Y is a measure of return on assets or equity. Thus one can test the underlying equilibrium assumptions using this approach.

This approach uses firm-level panel data, although depending upon the number of firms, it can potentially be reliably estimated with a relatively short panel. The previously mentioned paper by Molyneux *et al* (1994), as well as papers by Nathan and Neave (1989) and De Bandt and Davis (2000) represent recent applications of the Panzar-Rosse approach to banking markets. Given the data, this methodology should be more appropriate for East Asian banking markets than the previous candidate, since one could more reasonably suggest that in a given year, or over a short number of years, the East Asian banking systems were in equilibrium. Such data – with some limitations – appears to now be present for the countries in question, beginning in the mid-1990s.

5.2.1 Existing Evidence

There is, as I noted, only one formal empirical paper addressing the issue of market structure in the East Asian banking systems that are of particular interest in this thesis. Chowdhury (1996) adopts the structure-conduct-performance approach and considers 500 banks in 18 Asia-Pacific countries, of which about 150 are in one of Indonesia, Korea, Malaysia, Philippines, or Thailand, using 1994 data. The specific form of the regressions he runs is

$$\Pi = a_0 + a_1 CR + a_2 MS + a_3 CRMS + \sum_{i=4}^{n} a_i Z_i \tag{5.2}$$

where Π is a measure of profitability, CR is a measure of market concentration, MS is a measure of market share, $CRMS$ is an interaction term, and Z is a vector of other exogenous variables thought to impact banking profits, including total deposits, government ownership, inflation, per capita GDP, and so forth. Chowdhury's primary focus is to distinguish between two competing explanations for positive correlations between profits and market concentration. The traditional explanation is simply that concentration leads to collusive pricing and hence profits. The alternative explanation reflects change in the industry, suggesting that banks that are more efficient and effective are both profitable, and likely to acquire business from the less efficient banks as time passes. Hence there will be a positive correlation between industry concentration and industry profitability that has nothing to do

with collusion – the market concentration variable is actually proxying for market share, according to this view.

Chowdhury's results indicate that both market concentration and market share are positively and significantly correlated with bank profitability when the other is excluded from the regression, but when both are included, only the concentration ration remains significant. Chowdhury argues that this indicates support for the collusion hypothesis, rather than the efficiency hypothesis. In other words, the banks he studies appear to have (and use) market power. The only subsample results that Chowdhury discusses are those excluding about 150 Japanese banks, with "marginal" changes to the results. Approximately 40% of the remaining sample is represented by the banks in the countries of interest here.

5.3 Conclusions and Further Work

In this thesis I have outlined a model motivated by some of the physical characteristics one observes in emerging markets like those in East Asia that have so recently been through crisis. The model analyses the suspension behaviour of self-interested entrepreneurs in the presence of bank financing and is able to make some predictions about the nature of the debt contracts we can expect to see, the importance of the level of wealth an entrepreneur brings to a project, aggregate expectations regarding terminal demand, the impact of limited liability, and so on. There are a number of extensions for which the model seems well-suited and which therefore represent future work.

5.3.1 Smaller N

All of the analysis in this thesis has proceeded under the assumption that the number of firms entering is large enough that demand is revealed by the first suspensions. This assumption made characterisation of the equilbrium easier and helped to focus attention on the impact of some of the model characteristics. Nonetheless, it would be interesting, and technically more appropriate, to suppose that the number of entrants is smaller, and to try to characterise the continuation/suspension decisions under these circumstances. This will be rather complicated, but doable. Such a model would likely involve a slower aggregation process or instances of reinitiations and subsequent exit (something that does not occur in the current version of the model). Such an exercise would be useful in generating empirical implications about the dynamics during the period of information aggregation.

A model with fewer participants and protracted information aggregation would also present a number of strategic incentives that do not arise in this thesis. As one example, consider the specification of the liquidation process in the proposed model. There are no feedback effects of liquidation; the market for used capital is assumed to be infinitely elastic at a price of α per unit. This is simple and easy to work with but it also chokes off the interesting interactions that might be possible if I were to incorporate the insights of Shleifer and Vishny (1992) or the more recent work of Kiyotaki and Moore (1997). Shleifer and Vishny are concerned with the capital structure implications of asset liquidation values. If assets are best used by the competitors of the distressed firm, and if distress is correlated across firms, then liquidation values will be low precisely when liquidations are most likely to occur. This constrains debt capacity (or more properly, it makes leverage more costly *ex ante*). In Kiyotaki and Moore, shocks to asset prices reduce collateral values and hence credit limits; the subsequent decline in investment hurts asset values even further and set up the credit cycles they analyse.

5.3.2 Two Industries

One extension of the model could consider the much-discussed issue of *contagion* in an inter-industry context. If sudden, substantial shifts in the viability of loans outstanding to one industry constrain the banks' ability to continue lending to other sectors (perhaps because of capital requirements and/or some restriction in the supply of aggregate liquidity), a clear channel for cross-sectoral contagion exists, providing 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 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 market development. Recent work in this area includes Kiyotaki and Moore (1997) and a specific application of the Kiyotaki/Moore model to the Asian crisis by Edison, Luangaram, and Miller (1998). As pointed out already, the Kiyotaki and Moore framework does not allow for analysis of how the financial sector might alter the timing of shocks.

5.3.3 Depositor Concerns

In the model, funds are supplied to the financial sector perfectly elastically at the riskless rate of zero. This is convenient but chokes off much of what is likely to be most interesting about the model.

There are a variety of ways to introduce some aspect of depositor concerns in a more meaningful way, ranging from an inelalstic funds supply curve that is assumed to one that is derived. One might also represent these concerns via a government or regulator with various considerations possible, including a deposit insurance premium. Such a governor might also weigh the impacts associated with the process of investing (perhaps the depositor is also employed by the entrepreneur) and the subsequent market conditions (perhaps the depositor is also the purchaser of the output). How much financing does she want to occur? Few banking models that do take into consideration both sides of the balance sheet in a meaningful way actually exploit the potential correlations between the liquidity shocks that hit borrowers (Holmstrom and Tirole (1998)) and lenders (Bryant (1980) and Diamond and Dybvig (1983)).

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Appendix A

Derivations and Proofs

A.1 Proof of Lemma 1

Lemma 1 [Post-Suspension Lending Rates] *If credit markets are competitive at all points in time (contestable), debt contracts negotiated after suspensions occur will carry a lending rate of zero (independent of θ).*

Proof I need to show that debt contracts negotiated post-suspension that earn zero profits must also feature a lending rate of zero. Consider debt contracts negotiated at $\hat{t}+1$ and maturing at T. In equilibrium these contracts will roll over existing debt ($D_{\hat{t}+1}$) to T as well as providing for the remaining investment requirements.[1] The existing debt has some value, defined by the smaller of the face value of outstanding debt and the liquidation value of the project. Profitability of the subsequent debt contract must therefore be considered relative to

- the value of the existing debt that is to be rolled over, plus
- any additional lending.

Now fix a lending rate. Based on this, and on the credit allocation / acceptance policies implied by (4.1) - (4.8), at $\hat{t}+1$ one can compute with certainty the ultimate time T debt load, and whether entrepreneurs so financed will earn sufficient operational revenues to cover the loan. I need to show

[1] Again, I assume borrowing has commenced at $\hat{t}$. Small modifications to the argument are required in the event that borrowing begins later.

that contracts specifying $\delta_2 > 0$ cannot be part of an equilibrium.[2] Suppose $\delta_2 > 0$. Given the implied credit allocation / acceptance policies, these contracts must earn zero profits to be part of an equilibrium. Since $\delta_2 > 0$ zero profits can be achieved only if some entrepreneurs repay and others do not, or if all entrepreneurs repay 'just enough' (but less than the face value). The former case is not applicable here – there is no uncertainty and no idiosyncratic element so all entrepreneurs can pay the same amount. The latter only makes sense in the special case where all operational revenues go to debt service, in which case the lending rate chosen is irrelevant and it is innocuous to assume that equilibrium features the lowest possible rate.

A.2 Proof of Lemma 2

Lemma 2 [Pre-Suspension Lending Rates] *If $\hat{t}$ is in the range $[1, \bar{t}-1]$, all debt is riskless and therefore the lending rate δ must be zero where banks price loans competitively (Case 1). If $\hat{t} = \bar{t}$, then debt is risky and therefore δ will be positive (Case 2). Finally, if there is no $\hat{t} \in [1, \bar{t}]$ then there will be no suspensions or liquidations (Case 3).*

Proof Case 1: By definition of $\bar{t}$, it must be the case that a strategy of continuation at $\bar{t}-1$ or earlier, and liquidation in the subsequent period ($\bar{t}$), would yield liquidation payments sufficient to cover outstanding debt. Clearly, a strategy of suspension at $\bar{t}-1$ or earlier, with liquidation in the subsequent period, would similarly generate enough proceeds to pay all debts. Therefore, suspensions (and of course immediate liquidations) at $\bar{t}-1$ or earlier imply that debt is riskless, and therefore that $\delta = 0$.

Case 2: I show (by contradiction) that it must be the case that $\delta > 0$ if first suspensions (or liquidations) take place at $\bar{t}$. The key is showing that an entrepreneur that *invests* at $\bar{t}$ will not be able to cover all outstanding debt in the event that she is forced (by a poor demand realisation) into liquidation in the subsequent period. Consider the liquidation payment net of debt given the following three strategy profiles:

1. Suspend at $\bar{t}$, liquidate at $\bar{t}+1$.
2. Continue at $\bar{t}$, suspend at $\bar{t}+1$, and liquidate at $\bar{t}+2$.
3. Continue at $\bar{t}$, liquidate at $\bar{t}+1$.

[2] Contracts specifying $\delta_2 < 0$ will surely earn negative profits and hence cannot be part of an equilibrium.

Liquidation minus debt for these three strategy profiles will be (respectively)

$$\begin{aligned} S1 &= \alpha(\kappa + \bar{t}) - D_{\bar{t}}(1+\delta) > 0 \\ S2 &= \alpha(\kappa + \bar{t} + 1) - D_{\bar{t}+1}(1+\delta) < 0 \\ S3 &= \alpha(\kappa + \bar{t} + 1) - D_{\bar{t}+1} \end{aligned}$$

The signs on the first two ($S1 > 0, S2 < 0$) follow directly from the definition of $\bar{t}$. Now, suppose that $S3 \geq 0$. $S3 \geq 0$ implies that independent of the strategy followed at $\bar{t}$, liquidation at $\bar{t}+1$ will generate enough to entirely cover debt obligations. This in turn implies that if suspensions occur at $\bar{t}$, all debt is riskless, so $\delta = 0$. But $\delta = 0$ implies that $S3 = S2$ which contradicts $S3 \geq 0$. Therefore $S3 < 0$ (*i.e.* $S1 > 0 > S3 > S2$), and it must be that lenders will face some chance of loss, so $\delta > 0$.

Case 3: By definition of $\bar{t}$, no entrepreneur can benefit by suspending later than $\bar{t}$, since all proceeds go to the lender. The argument behind Case 2 (in particular, the result that $S3 < 0$) shows that liquidation in a subsequent period will similarly leave the entrepreneur with nothing. Of course, such a strategy would also jeopardise the entrepreneur's ability to collect interim private benefits. Thus there will be no voluntary suspensions or liquidations after $\bar{t}$.

A.3 Determination of n and n'' in Table 4.1

In what follows I discuss the determination of n''. A similar discussion applies to n.

Consider a realised θ between θ_M and θ_H, in which case n'' entrepreneurs go on to produce. What is n''? Clearly, it is all those that invested at $\hat{t}$, plus the proportion of suspending entrepreneurs that eventually reinitiates. I use the constraint that will bind at θ to compute the total magnitude of producing entrepreneurs (as a function of θ).

There are several possible patterns. It may be the case that the bank constraints bind at each of θ_M and θ_H, in which case it must also be the bank constraint that will bind at any value of θ between these two. Alternatively, the entrepreneurs' constraints may bind at both end points, and again, this means the binding constraint at an intermediate θ would also be the entrepreneurs'. These, along with the special case in which the two sets of constraints are coincident (which can occur once the entrepreneur has no remaining capital, and if $\alpha = c = 0$, for example) are simple to deal with. For example, if the bank's constraint binds,

$$A\theta - n'' = TD, \qquad \theta_M < \theta < \theta_H$$

so $n'' = A\theta - TD$.

The trickier situation occurs when the bank constraint binds at one end of this interval and the entrepreneurs' at the other. In this case, one must find the single value of θ at which both constraints bind (the linearity ensures there is only one). This defines two subintervals, with each being governed by a different constraint. This also implies that there will be two rates of initiation. That is, on the lower sub-interval, for a given change in θ, the magnitude of additional reinitiation will exceed the magnitude of additional reinitiation that will occur on the upper interval for a change in θ of the same magnitude. Of course, by the time we get to θ_H it will still be the case that all entrepreneurs have reinitiated. The approach used in this situation is addressed in Appendix C in slightly different context.

A.4 Suspensions at $\hat{t} = \bar{t}$

This case is structurally very similar to the one in which $\hat{t} < \bar{t}$, except that here banks are not guaranteed of receiving back all the funds they lend out prior to the suspensions. When demand is low, some entrepreneurs may be liquidated at $\hat{t} + 1$. Therefore $\delta_1 > 0$ must be chosen in order to solve the bank's *ex ante* zero-profit equation. The only source of default risk is due to those that have continued at $\bar{t}$, and then only when $\theta < \theta_L$. By definition, those that suspend at $\bar{t}$ are able to pay in full independent of the realisation of θ; for $\theta > \theta_L$, those that continue at $\bar{t}$ can also pay in full, as can those the bank funds from $\bar{t} + 1$ onward when θ is between θ_B and θ_L. However, continuers that do not access credit after $\bar{t}$ may be unable to fully pay the bank out of liquidation proceeds (this follows from the definition of $\bar{t}$. Therefore $\delta_1 > 0$ will be required to ensure that the bank earn's zero expected profit. The appropriate condition follows.

$$\begin{aligned}
\left[\int_0^1 (1-\theta)^{\bar{t}} f^0(\theta)\, d\theta\right] &\times \left[D_{\bar{t}}(1+\delta_1) - PR_{\bar{t}}\right] + \\
\left[1 - \int_0^1 (1-\theta)^{\bar{t}} f^0(\theta)\, d\theta\right] &\times \left[\int_0^{\theta_L} \alpha(\kappa + \bar{t} + 1)\, f^0(\theta)\, d\theta + \int_{\theta_L}^1 [D_{\bar{t}+1}]\, f^0(\theta)\, d\theta - PR_{\bar{t}+1}\right] \\
&= 0 \qquad \text{(A.1)}
\end{aligned}$$

where $PR_{\bar{t}+1}$ denotes the principal outstanding at the beginning of time $\bar{t} + 1$ (*i.e.*, the total cost to the bank of the loan).

An additional possibility arises when $\delta_1 > 0$. Entrepreneurs may prefer immediate liquidation to suspension, since the debt service savings are no longer zero. The tradeoff is the value of the option

to reinitate against the value of the debt service. Because this aspect of the model is not central to the issues I focus on I do not pursue the analysis further here.

A.5 Proof of Lemma 3

Lemma 3 [Post-Suspension Deviations] *The entrepreneur cannot credibly threaten to liquidate the project subsequent to $\hat{t}+1$ if $c \leq 1-\alpha$.*

Proof The proof consists of showing that $c \leq 1-\alpha$ implies that entrepreneurs that have continued at $\hat{t}+1$ will continue to find it in their interest to do so at every subsequent decision point, and therefore cannot credibly threaten to liquidate.

Each of (4.2), (4.4), (4.6), and (4.8) has the following basic form: $\max[0, \bullet] + c\,\theta\, I_{\hat{t}+1} \geq e_{\hat{t}}$. Pick any other θ and a similar expression must hold – for all entrepreneurs that continue on at $\hat{t}+1$, the sum of net operating surplus and expected private benefits must weakly exceed the liquidation outcome, conditional on equilibrium play (so that the industry is the 'right' size). So long as this weak inequality is maintained through all following periods, the entrepreneur will never be able to credibly threaten liquidation. I will work with an equality; if the argument holds for an equality it will surely hold for an inequality.

How do the various components of this incentive condition vary through time? The anticipated operational surplus is constant and weakly positive. Expected private benefits decline linearly with time, at the rate of $c\theta$ per period, and are strictly positive at all decision points. Finally, the liquidation outcome term also declines linearly with time, at the rate of $1-\alpha$ per period, to a minimum of zero (which may or may not be reached depending upon the parameter set Γ).[3] Clearly then, in order for the entrepreneur to develop such bargaining power, it must be the case that the expected private benefits term declines more rapidly than does the liquidation outcome term (this is true independent of the value of the operating surplus term). In other words, it must be that $c\theta > 1-\alpha$. The worst case is $\theta = 1$; assuming this gives the condition in the lemma.

[3]The exception is the special case of $\alpha = 1$, in which case the liquidation outcome term is constant. But this also means that the bank gets back all it lends with certainty, so the problem disappears. Recall that α is restricted to be less than 1 throughout.

Appendix B

Analytical Results

Throughout this Appendix suppose that priors are given by a $\beta e(1,1)$ – the uniform distribution on $[0,1]$. I focus on three cases: contestable credit markets with suspensions, and the simpler cases of no suspensions in both contestable and monopolistic credit markets.

B.1 Equilibrium With Suspensions, Contestable Credit Market

Suppose also that $C = \kappa$ and $c = 0$.[1] This implies that the constraints determining $\{\theta_H, \theta_M, \theta_L, \theta_B\}$ will be (4.2), (4.4), (4.6), and (4.8), and that the entrepreneurial contribution of C will not be sufficient to fund the time 0 investment requirements; the firm will have to borrow 1 in order to fulfill the period 0 requirements. Now make the conjecture that $\hat{t} = 1$ and determine whether it can be supported as an equilibrium.

The first issue to address is the debt contracts that will be observed. Given the conjecture that $\hat{t} = 1$, ϕ^* implies that the debt contracts signed at time 0 will have a maturity of $\hat{t} + 1 = 2$. Now, note that if $\bar{t} > 2$ then debt maturing at $t = 2$ will surely be risk-free (and hence carry a lending rate of 0). This will surely be the case for α and κ sufficiently large (it i.e., $e^{sus} = \alpha(\kappa + 2) - 2 > 0$. There are many combinations that would generate such an outcome; assume that one of them holds.

[1] That is, assume that entrepreneurs receive signals only, with no accompanying private benefit.

Therefore debt is riskless. Given that $\hat{t} = 1$, (4.2), (4.4), and (4.6) can then be expressed[2]

$$\begin{aligned}
\theta_H &= \frac{1}{A}(N + TD + e^{sus}) \\
\theta_M &= \frac{1}{A-N}(TD + e^{sus}) \\
\theta_L &= \frac{1}{A-N}(TD' + e^{inv})
\end{aligned} \tag{B.1}$$

Direct integration of (4.11) and some algebra yields

$$\begin{aligned}
(1-\theta_H) &\times (A - N - TD + \frac{\mu}{2}) + \\
(1+\theta_H) &\times e^{sus} + \\
(\theta_M + \theta_L) &\times \frac{1}{2}(\mu + e^{sus} - e^{inv}) \\
&= 2C
\end{aligned} \tag{B.2}$$

Substituing (B.1) in (B.2) and manipulating generates a cubic expression in N:

$$aN^3 + bN^2 + cN + d = 0 \tag{B.3}$$

where

$$\begin{aligned}
a &= 1 \\
b &= 2(TD + e^{sus}) - 3A < 0 \\
c &= A[3(A - TD) - 2(C + e^{sus}) - TD'] + (e^{sus} + TD)^2 > 0 \\
d &= A\left[-A^2 + A(2C + TD + TD') - \frac{1}{2}\left\{(e^{inv} + TD')^2 + (e^{sus} + TD)^2\right\}\right] < 0
\end{aligned}$$

Given that there are three changes of sign in the four coefficients (assuming 'reasonable' parameterisations), the solution to the cubic will have either one or three positive, real roots. A sufficient (but not necessary) condition for (B.3) to feature a unique real valued solution is[3]

$$A \geq \frac{(TD + e^{sus})^2}{3(e^{sus} + \mu - C)} = \frac{T + \mu + \alpha(\kappa + 1)}{3(\mu - (1-\alpha)(\kappa + 1))} \tag{B.4}$$

[2]There is no need to characterise θ_B in this case. Because the binding constraints are those of the entrepreneur, exit will adjust so that all entrepreneurs receive the equivalent of immediate liquidation for any $\theta < \theta_L$.

[3]A cubic of the form $ax^3 + bx^2 + cx + d = 0$ can be transformed to a cubic of the form $x^3 + px + q = 0$ by substituting $x - b/(3a)$ in the original equation (see, for example, Berck and Sydsæter (1991)). The roots of this transformed cubic are determined by the sign of the expression $4p^3 + 27q^2$. If positive, there is a single real root. It is possible to express $4p^3 + 27q^2$ in terms only of the parameters of the problem – but this leads to an extremely cumbersome expression that cannot be reasonably manipulated or interpreted. However, since $27q^2$ is clearly always positive, if $p > 0$ then the whole expression *must* be positive. After making the substitutions the sign of p is the same as the sign of $3c - b^2$, and forcing this to be positive generates (B.4), which is therefore sufficient but not necessary.

and $e^{sus} + \mu - C = 3(\mu - (1-\alpha)(\kappa+1)) > 0$. The final transformation in (B.4) uses the definitions of e^{sus} and TD, the assumption that $\kappa = C$, and fact that debt is riskless in this example. The right hand side of this expression increases in κ and T and decreases in α and μ. Assume that both of these conditions are met. Then a single, real-valued solution for the magnitude of entry exists, though its algebraic expression is extremely cumbersome. We can therefore now consider whether the $\{\theta_H^*, \theta_M^*, \theta_L^*, N^*\}$ defined by the N^* that solves (B.3) is a candidate equilibrium.

The next step is determining whether the conjecture that $\hat{t} = 1$ is an appropriate one. Integrating (4.9), the expression for the net benefit of suspending relative to continuing, generates

$$\begin{aligned}
({\theta_M^*}^3 - {\theta_L^*}^3) &\times 2\,(A - N^*) + \\
({\theta_M^*}^2 - {\theta_L^*}^2) &\times 3\,(N^* - A - TD - e^{sus}) + \\
(\theta_M^* - \theta_L^*) &\times (TD + e^{sus}) + \\
\theta_L^* &\times 3(2 - \theta_L^*)(TD - TD' + 1 - \alpha) \\
&- 3\,(TD - TD')
\end{aligned} \tag{B.5}$$

Again substituting from (B.1) one gets a polynomial in the parameters of the problem, and N^*, which will take the same sign as

$$\begin{aligned}
&(TD' + e^{inv})^3 - (TD + e^{sus})^3 \\
&\qquad + \; 3(A - N^*)\left[(TD + e^{sus})^2 - (TD' + e^{inv})^2\right] \; + \\
&\qquad\qquad 3(A - N^*)^2(TD' - TD)
\end{aligned} \tag{B.6}$$

The sign of the expected net benefit of suspending (relative to continuing) at time 1 is given by (B.6).[4] If this is expression is positive, entrepreneurs that received a bad signal at time 0 will suspend. The first and third terms of (B.6) are unabmiguously negative, while the second term is unambiguously positive. Suppose for the moment that at N^*, (B.6) is in fact positive. Then the conjecture of $\hat{t} = 1$, together with (B.1) and the N defined by (B.3), is a candidate equilibrium of the form ϕ^*. It remains to check that there are no incentives for deviation.

Since the conjecture is that $\hat{t} = 1$ no entrepreneur can deviate by choosing liquidation in a preceding period. However, we do need to check that an entrepreneur with a good signal will not wish to mimic those with a bad signal and suspend along with them. Checking this amounts to checking an analogue to (3.5), only this time, from the perspective of an entrepreneur that has received a good signal. Note that this is not a check that all entrepreneurs will suspend in equilibrium. Instead,

[4] (B.6) must be divided by $3\,(A - N)^2$ to get the actual value of this benefit.

it asks whether a single entrepreneur with a good signal has an incentive to deviate given that all others play the equilibrium.

After integration and substitution one arrives at an expression similar to (B.6) given by[5]

$$(TD + e^{sus})^3 - (TD' + e^{inv})^3 + 3(A - N^*)^2(TD' - TD) \tag{B.7}$$

Referring back to (B.6) we see that (B.7) is the third term of (B.6) minus the first term of (B.6), so (B.7) can also take on either positive or negative values. If our candidate equilibrium is to be confirmed as an equilibrium, it must be the case that this expression is negative; if positive, it implies that an entrepreneur that received a good signal after entry would prefer to deviate by suspending along with those that that received a bad signal. Of course that sounds strange in this example – since there are no private benefits we surely wouldn't expect an entrepreneur to want to enter if she was expecting to find it in her interest to suspend no matter what signal she received.

The final step is to make some specific parametric assumptions in order to illustrate the characterisations described above. The parameters of the model are $\{\alpha, \mu, T, \kappa, c, A, C\}$. Consider the parameter set $\{0.4, 3, 12, 5, 0, 100, 5\}$.[6] This means, assuming that each period is a quarter and a unit of investment is \$1 million, that we are thinking of projects that take about three years from inception to completion and cost a total of \$13 million (not including any reinititation costs). Each dollar invested in the project returns 40 cents in liquidation, and should you shut down for one period, the cost to restart the project is \$3 million (increasing project costs by about 23%). Given these values, substitution into (B.1), (B.3), and (B.5) indicates that

$$\{\theta_L, \theta_M, \theta_H, \hat{t}, N\} = \{0.34, 0.42, 0.76, 1, 58.99\}$$

is *not* a candidate equilibrium, since the value of the expression in (B.5) is about $-0.784 < 0$ (rejecting the conjecture that $\hat{t} = 1$). After one bad signal, entrepreneurs are not yet willing to throw in the towel. Unlike the case in which entrepreneurs self-fund, flat priors do not induce immediate suspensions.

Comment The process outlined above becomes quite intractable once one moves beyond the $\hat{t} = 1$ conjecture. For example, consider how the problem changes once one moves to try $\hat{t} = 2$. The indifference conditions defining θ_M and θ_L both become quadratics. Moreover, even with flat priors,

[5] Again, this expression is the numerator in a fraction with denominator $3(A - N)^2$, so it is the sign of (B.7) rather than its magnitude that matters.

[6] Recall that I have forced $C = \kappa$ and $c = 0$ to ease the algebra, and so that we might be sure which constraints are binding.

the integrations that are required for N and checking the $\hat{t}$ conjecture both involve at least cubics – into which one is substituting quadratic roots. Solving the example outlined above for $\hat{t} = 2$ leaves one with a 5-th order polynomial to solve for N. The endogeneity of exit (*i.e.* the fact that the industry can adjust to the realisation of a continuous random variable) means that I must account accurately for the proportion of entrepreneurs that exit, and this implies higher order polynomials. This could be avoided by specifying exit as the result of an exogenous process (Schivardi (2000) uses this approach), or by decoupling the signal process from the demand parameter. This latter approach was implicitly what the Caplin and Leahy approach offered – though as noted, they also required the use of numerical solutions to characterise elements of their equilibrium existence conditions.[7] Making exit irrevocable would not entirely solve the problem since the proportion of suspending firms would still be a function of the signals received.

B.2 Equilibrium Without Suspensions, Contestable Credit Market

Begin with the four conditions that must hold in equilibrium.[8]

Entrepreneur zero profit:

$$\int_{\theta^E}^{1} [\theta A - N - D_{T+1}]\, d\theta + \int_{0}^{1} [c\,\theta(T+1)]\, d\theta = C \tag{B.8}$$

Bank zero profit:

$$\int_{\theta^B}^{\theta^E} [\theta A - N]\, d\theta + \int_{\theta^E}^{1} [D_{T+1}]\, d\theta = PR_{T+1} \tag{B.9}$$

and the expressions determining the key values of theta:

$$\theta_B A - N = 0 \tag{B.10}$$

$$\theta^E A - N = D_{T+1} \tag{B.11}$$

[7] That said, I am making much heavier use of numerics than did Caplin and Leahy.

[8] I have not made explicit some additional constraints imposed throughout. In particular, all values of θ are restricted to lie in [0,1] and I look for N such that $0 \leq N \leq A$. The non-negativity part is obvious. For the second part, note that if $N > A$ the implication is that price is zero in all states of the world (since, even at $\theta = 1$, $\theta A - N < 0$). This only becomes as issue for very extreme parameter sets.

where $PR_{T+1} = \kappa + T + 1 - C$ is the principal lent to each entrepreneur. It is convenient to begin by noting an implication of the structure of the entrepreneur zero-profit expression. Integrating (B.8) yields:

$$\frac{A}{2}(1-\theta_E^2) - (1-\theta_E)N - (1-\theta_E)D_{T+1} = C - \frac{c\,(T+1)}{2}$$

Focusing on the left side and using (B.11) note that:

$$\begin{aligned}\frac{A}{2}(1-\theta_E^2) - (1-\theta_E)N - (1-\theta_E)D_{T+1} &= (1-\theta_E)\left[\frac{A(1+\theta_E)}{2} - N - D_{T+1}\right] \\ &= (1-\theta_E)\left[\frac{A+N+D_{T+1}}{2} - N - D_{T+1}\right] \\ &= (1-\theta_E)\left[\frac{A-N-D_{T+1}}{2}\right] \\ &= \frac{A}{2}(1-\theta_E)^2\end{aligned} \tag{B.12}$$

which implies that

$$\theta_E^* = 1 - \sqrt{\frac{2C - c\,(T+1)}{A}}$$

Given the parameter set used throughout the paper, $\theta_E \approx 0.728$.[9] This expression tells us that as private benefits become larger, the region of θ over which the entrepreneur will need to share in the operating surplus ($\theta > \theta_E$) shrinks.

Next note that (B.8) implies that

$$\int_{\theta^E}^{1} D_{T+1}\,d\theta = \int_{\theta^E}^{1}[\theta A - N]\,d\theta + \int_{0}^{1}[c\,\theta(T+1)]\,d\theta - C$$

Substitute this and (B.10) into (B.9) and it becomes

$$\int_{\frac{N}{A}}^{1}[\theta A - N]\,d\theta = C + PR_{T+1} - \frac{c\,(T+1)}{2} \tag{B.13}$$

Integrating leads to a quadratic in N which solves to give

$$N^* = A - \sqrt{A(2(C + PR_{T+1}) - c\,(T+1))}$$

This in turn means that

$$\theta_B^* = 1 - \frac{1}{\sqrt{A}}\sqrt{2(C + PR_{T+1}) - c\,(T+1)}$$

[9]There is another solution that is larger than one and hence infeasible. Real solutions require that $2C \geq c\,(T+1)$ which – in the case of no suspensions, with flat priors – places some constraints on the parameters sets than can support an equilibrium. Given entrepreneur wealth, the projects cannot take too long to complete nor can the private benefits be too large.

Thus it must be the case (assuming that bank lending is positive in equilibrium) that $\theta_E^* > \theta_B^*$, and also note that the where $2C \geq c\,(T+1)$ (so that a real valued root to the θ_E quadratic can be found) then there will be real valued solutions for N^* and θ_B^* as well. Finally, we need to solve for δ. In the case of the parameter set at hand, borrowing commences in period 2, so $D_{T+1} = \sum_{i=1}^{11}(1+\delta)^i$. Thus solving for D_{T+1} in terms of the parameters of the model implicitly defines δ. Again using (B.11),

$$\sum_{i=1}^{11}(1+\delta^*)^i = \sqrt{A}\left[\sqrt{2(C+PR_{T+1}) - c\,(T+1)} - \sqrt{2C - c\,(T+1)}\right]$$

B.3 Equilibrium Without Suspensions, Monopoly Bank

Again, begin with the maximisation problem outlined in the text.

$$\max_{N,\delta} N\left[\int_{\theta^B}^{\theta^E}[\theta A - N]\,f^0(\theta)\,d\theta + \int_{\theta^E}^{1} D_{T+1}\,f^0(\theta)\,d\theta - (\kappa + T + 1 - C)\right] \tag{B.14}$$

subject to:

$$\int_{\theta^E}^{1}[\theta A - N - D_{T+1}]\,f^0(\theta)\,d\theta + \int_0^1[\,c\,\theta(T+1) - C\,]\,f^0(\theta)\,d\theta = 0 \tag{B.15}$$

$$\theta_B A - N = 0 \tag{B.16}$$

$$\theta^E A - N = D_{T+1} \tag{B.17}$$

Structurally, this problem is quite similar to that with the constestable markets, except that the bank is solving a maximisation problem here. First, the same result obtains regarding θ_E. That is,

$$\theta_E^* = 1 - \sqrt{\frac{2C - c\,(T+1)}{A}}$$

Moreover, we can make the same sustitutions using the entrepreneur participation constraint, meaning that the maximand becomes $N\times$ (B.13). This maximand is independent of δ and θ_E and (B.16) is already substituted so it becomes a maximisation over N. The first order condition is:

$$\frac{3N^2}{2A} - 2N + \frac{A}{2} + \frac{c\,(T+1)}{2} - (C + PR_{T+1})$$

which is equated to zero and solved for

$$N^* = \frac{2A}{3} - \frac{\sqrt{A}}{3}\sqrt{A + 3[2(C+PR_{T+1}) - c\,(T+1)]}$$

implying

$$\theta_B^* = \frac{2}{3} - \frac{1}{3\sqrt{A}}\sqrt{A + 3[2(C + PR_{T+1}) - c\,(T+1)]}$$

and

$$\sum_{i=1}^{11}(1+\delta^*)^i = \frac{A}{3} + \frac{\sqrt{A}}{3}\left[\sqrt{A + 3[2(C + PR_{T+1}) - c\,(T+1)]} - 9\sqrt{2C - c\,(T+1)}\right]$$

Note that we are finding a local maximum here. Given that N^* is the solution to a quadratic, there is a second root (given in this case by

$$\frac{2A}{3} + \frac{\sqrt{A}}{3}\sqrt{A + 3[2(C + PR_{T+1}) - c\,(T+1)]}$$

The second order condition, evaluated at N^*, is

$$-\frac{1}{\sqrt{A}}\sqrt{A + 3[2(C + PR_{T+1}) - c\,(T+1)]} < 0$$

confirming that N^* is in fact a local maximum. Evaluating the second order condition at the alternative root shows it to be a local minumum. Further, note the following:

$$\frac{2A}{3} + \frac{\sqrt{A}}{3}\sqrt{A + 3[2(C + PR_{T+1}) - c\,(T+1)]} \geq A$$

Since there are only two inflection points, and that the minimum lies outside the allowable range while the maximum is within it, there can be no feasible boundary maximum that displaces N^*. That is, the first order condition is increasing at 0 and decreasing at A and has a single peak at N^* over that region.

Appendix C

Equilibrium With Suspensions, Monopoly Bank

In this Appendix I present the details of the search for equilibria featuring suspensions (or liquidations) when the bank has monopoly power. I start by characterising production decisions for different regions of θ. As was the case with the competitive banking system, there are two conditions that must be satisfied at each of $\{\theta_B, \theta_L, \theta_M, \theta_H\}$.[1] First, consider the bank's perspective:

$$A\,\theta_H - 2N - I_{\hat{t}+1} - 1 - \mu - \max[0, e_{\hat{t}}^{sus} - c\,\theta_H\, I_{\hat{t}+1}] \geq \min[D_{\hat{t}},\, \alpha(\kappa + \hat{t})] \tag{C.1}$$

$$A\,\theta_M - 2[1 - (1 - \theta_M)^{\hat{t}}]N - I_{\hat{t}+1} - 1 - \mu - \max[0, e_{\hat{t}}^{sus} - c\,\theta_M\, I_{\hat{t}+1}] \geq \min[D_{\hat{t}},\, \alpha(\kappa + \hat{t})] \tag{C.2}$$

$$A\,\theta_L - 2[1 - (1 - \theta_L)^{\hat{t}}]N - I_{\hat{t}+1} - \max[0, e_{\hat{t}}^{inv} - c\,\theta_L\, I_{\hat{t}+1}] \geq \min[D_{\hat{t}+1},\, \alpha(\kappa + \hat{t} + 1)] \tag{C.3}$$

$$A\,\theta_B - I_{\hat{t}+1} - \max[0, e_{\hat{t}}^{inv} - c\,\theta_B\, I_{\hat{t}+1}] \geq \min[D_{\hat{t}+1},\, \alpha(\kappa + \hat{t} + 1)] \tag{C.4}$$

[1] And again, the conditions are presented here assuming that borrowing has already commenced at $\hat{t}$.

Each of these conditions compares the difference between marginal revenue and marginal cost (remaining investment required) with the bank's outside option (forcing the marginal entrepreneur into liquidation). For example, (C.1) tells us that if the bank is to be willing to finance *all* of the suspending entrepreneurs to production, they must expect that (at θ_H) the marginal operating revenue ($A\theta_H - 2N$) less the amount of investment still required to complete the project (which will come from the bank) will be at least as large as the debt already owed by a suspending entrepreneur. The max term on the left side of the inequality represents the 'cost' to the bank of inducing the final suspending entrepreneur to participate in the event that the remaining stream of private benefits is not expected to be sufficiently rich to do so. This cost would be paid via the setting of a post-suspension interest rate that permitted the appropriate amount of surplus to accrue to the entrepreneur.

From the entrepreneur's perspective, the following must hold:

$$c\,\theta_H\, I_{\hat{t}+1} + \max[0, e_{\hat{t}}^{sus} - c\,\theta_H\, I_{\hat{t}+1}] \;\geq\; e_{\hat{t}}^{sus} \tag{C.5}$$

$$c\,\theta_M\, I_{\hat{t}+1} + \max[0, e_{\hat{t}}^{sus} - c\,\theta_M\, I_{\hat{t}+1}] \;\geq\; e_{\hat{t}}^{sus} \tag{C.6}$$

$$c\,\theta_L\, I_{\hat{t}+1} + \max[0, e_{\hat{t}}^{inv} - c\,\theta_L\, I_{\hat{t}+1}] \;\geq\; e_{\hat{t}}^{inv} \tag{C.7}$$

$$c\,\theta_B\, I_{\hat{t}+1} + \max[0, e_{\hat{t}}^{inv} - c\,\theta_B\, I_{\hat{t}+1}] \;\geq\; e_{\hat{t}}^{inv} \tag{C.8}$$

Once θ is known, the entrepreneur weighs the value of expected private benefits plus any portion of the production revenues she can expect to receive against the proceeds from liquidation (net of bank debt). Because the entrepreneur will receive (at most) a fixed proportion of the operating surplus, and private benefits do not depend upon aggregate production, the various levels of θ that will induce re-entry by a suspender (or exit by a continuer) are not related to production. When private benefits are sufficiently rich, (C.5) - (C.8) indicate that from the perspective of the entrepreneur, $\theta_B = \theta_L$ and $\theta_M = \theta_H$. In equilibrium, each of (C.1) - (C.4) will bind, but (C.5) - (C.8) may not bind.

Suspensions / Liquidations

In the event that an entrepreneur chooses immediate liqudation at time s, she will receive net liquidation payouts of $e_t^{sus}+\delta_1 D_s$ independent of θ. If she chooses instead to suspend, then (assuming that decision is part of an equilibrium of the sort I look for) she will expect an outcome that can be given as follows:

$$\int_0^{\max[\theta_M,\,\theta_{M'}]} e_s^{sus}\, f_s^{e_0}(\theta)\, d\theta \;+\; \int_{\max[\theta_M,\,\theta_{M'}]}^{\max[\theta_H,\,\theta_{M'}]} [\,(1-\xi)\, e_s^{sus} \;+\; \xi\, c\,\theta I_{s+1}]\, f_s^{e_0}(\theta)\, d\theta \;+\; \int_{\max[\theta_H,\,\theta_{M'}]}^{1} c\,\theta I_{s+1}\, f_s^{e_0}(\theta)\, d\theta \tag{C.9}$$

while if she chooses to continue investing she expects

$$\int_0^{\max[\theta_B,\,\theta_{B'}]} e_s^{inv}\, f_s^{e_0}(\theta)\, d\theta \;+\; \int_{\max[\theta_B,\,\theta_{B'}]}^{\max[\theta_L,\,\theta_{L'}]} [(1-\xi')\, e_s^{inv} \;+\; \xi'\, c\,\theta I_{s+1}]\, f_s^{e_0}(\theta)\, d\theta \;+\; \int_{\max[\theta_L,\,\theta_{B'}]}^{1} c\,\theta I_{s+1}\, f_s^{e_0}(\theta)\, d\theta \tag{C.10}$$

where $\theta_{B'} = \frac{e_{\hat{t}}^{inv}}{c\, I_{\hat{t}+1}}$ is the smallest θ such that an entrepreneur that continued at $\hat{t}$ will be just indifferent between carrying on and liquidating at $\hat{t}+1$ on the basis of expected private benefits alone. $\theta_{M'} = \frac{e_{\hat{t}}^{sus}}{c\, I_{\hat{t}+1}}$ is the analogue for the case of a suspending entrepreneur, and the ξ and ξ' terms (discussed below) measure the likelihood that the entrepreneur will be among those selected to carry on in certain states.

To clarify a bit, consider (C.9). First, suppose that $\theta_{M'} \leq \theta_M$. By definition, suspending entrepreneurs will always be willing to return in those states in which the bank is willing finance them. When $\theta < \theta_M$, no suspending entrepreneurs will be financed, and all will receive the liquidation outcome. When $\theta > \theta_M$ (so that the bank will indeed want at least some of the suspending entrepreneurs to return) those that are selected to return will receive the private benefits stream – and by definition of $\theta_{M'}$, will prefer that outcome to liquidation.[2] Next, let $\theta_M < \theta_{M'} < \theta_H$. In this case there will be some states in which the bank will have to sweeten the pot a bit in order to ensure a returning entrepreneur of at least the liquidation outcome. When $\theta_M < \theta < \theta_{M'}$ this sweetener will ensure that returning entrepreneurs will receive the same outcome as those that do not return, but when $\theta > \theta_{M'}$ then again those selected to return will do better than those not selected (and no sweetener will be needed). Finally, if $\theta_{M'} > \theta_H$ then all suspending entrepreneurs will experience

[2]Entrepreneurs expecting only private benefits cannot credibly promise to bribe the bank to finance them and hence this possibility is not anlaysed further.

the same outcome – the liquidation equivalent – when $\theta < \theta_{M'}$, and the expected private benefit stream when $\theta > \theta_{M'}$. (C.9) covers each of the cases just described, while (C.10) does the same for the analogous discussion of the case of continuing entrepreneurs, and the relationship between θ_B, θ_L, and $\theta_{B'}$.

The final issue relates the to the selection process – what is the likelihood that a given suspending entrepreneur will be selected to continue in the event that $\theta_M < \theta < \theta_H$, or that a given continuing entrepreneur will be financed when $\theta_B < \theta < \theta_L$? Here one can use (C.1) - (C.4) to define $Q^*(\theta)$, the mass of entrepreneurs that will be financed once θ is known, and with this construct $\xi = \frac{Q^*(\theta)-(1-(1-\theta)^{\hat{t}})N}{(1-\theta)^{\hat{t}}N}$ which measures the proportion of suspending entrepreneurs that return as a function of θ and $\xi' = \frac{Q^*(\theta)}{(1-(1-\theta)^{\hat{t}})N}$ which is the ratio of the measure of eventual continuers to the measure of those that continued at $\hat{t}$.[3]

Under the competitive framework, I characterised entry by setting the expected value of doing so equal to zero; the mass N which solved that expression was the magnitude of entry. Here, things are a bit more complicated. Clearly, entrepreneurs must still find it in their interests to enter, but the bank's (monopoly) control over credit allows the bank to choose N and δ in order to maximise its own expected profits.[4]

I begin with the entrepreneur. The general form of the entry condition is given by

$$\text{Prob}(\sigma_{\hat{t}} = 0) \times U_0(\theta|\phi^*(\sigma_{\hat{t}})) \;\; + \;\; \text{Prob}(\sigma_{\hat{t}} > 0) \times U_0(\theta|\phi^*(\sigma_{\hat{t}})) \;\geq\; 0$$

which indicates that the *ex ante* probability of receiving only bad signals until $\hat{t}$ multiplied by the expected outcome given that one plays according to ϕ^* throughout the game (and thus suspends / liquidates at $\hat{t}$) plus the probability of all other $\hat{t}$-signal histories multiplied by the expected outcome given optimal play under that circumstance, must be greater than zero. Following is the full expression for the expected value of entry, given N and δ. Again, the max[•, •] terms in the limits of integration are sufficient to cover the various cases that might arise with respect to entrepreneurial payoffs and the need for the bank to improve the deal.

$$\left[\int_0^1 (1-\theta)^{\hat{t}} f^0(\theta)\, d\theta\right] \;\times\; \left\{\int_0^{\max[\theta_M, \theta_{M'}]} [e_{\hat{t}}^{sus} + c\theta\hat{t} - \min[C, \kappa + \hat{t}]]\, f^0(\theta)\, d\theta \;+\right.$$

[3]The constraints imply that $Q^*(\theta)$ is such that $Q^*(\theta_B) = 0$, $Q^*(\theta_L) = (1-(1-\theta_L)^{\hat{t}})N$, $Q^*(\theta_M) = (1-(1-\theta_M)^{\hat{t}})N$, and $Q^*(\theta_H) = N$. Therefore ξ and ξ' vary with θ from 0 to 1 between θ_M and θ_H, and θ_B and θ_L, respectively.

[4]In the text I also discuss extending the analysis to allow the bank to reduce the entrepreneurial contribution, and to allow it to make action-contingent payments (*i.e.*, to promise to pay entrepreneurs to quit). The discussion here requires straightforward amendments to deal with these cases.

$$
\begin{aligned}
& \int_{\max[\theta_M,\theta_{M'}]}^{\max[\theta_H,\theta_{M'}]} [\,\xi\,(e_{\hat{t}}^{sus} + c\,\theta\,\hat{t} - \min[C,\,\kappa+\hat{t}]) \\
& \qquad\qquad + (1-\xi)\,(c\,\theta\,T - C\,)\,]\,f^0(\theta)\,d\theta \;+ \\
& \int_{\max[\theta_H,\theta_{M'}]}^{1} [\,c\,\theta\,T - C\,]\,f^0(\theta)\,d\theta \Bigg\} \;+ \\
\left[1 - \int_0^1 (1-\theta)^{\hat{t}}\,f^0(\theta)\,d\theta\right] \;\times\; & \Bigg\{ \int_0^{\max[\theta_B,\theta_{B'}]} [\,e_{\hat{t}}^{inv} + c\,\theta(\hat{t}+1) - \min[C,\,\kappa+\hat{t}+1]\,]\,f^0(\theta)\,d\theta \;+ \\
& \int_{\max[\theta_B,\theta_{B'}]}^{\max[\theta_L,\theta_{B'}]} [\,\xi'(e_{\hat{t}}^{inv} + c\,\theta(\hat{t}+1) - \min[C,\,\kappa+\hat{t}+1]) \\
& \qquad\qquad + (1-\xi')(\,c\,\theta(T+1) - C\,)\,]\,f^0(\theta)\,d\theta \;+ \\
& \int_{\max[\theta_L,\theta_{B'}]}^{1} [c\,\theta(T+1) - C\,]\,f^0(\theta)\,d\theta \Bigg\} \\
\geq\; & 0
\end{aligned}
\tag{C.11}
$$

It now remains to solve the bank's problem. Letting $U^b(\theta|\phi)$ denote the expected profit per entrepreneur earned by the bank given that strategy profile ϕ is used, I look for the magnitude N and the initial interest rate δ_1[5] that maximise

$$N[\text{Prob}(\sigma_{\hat{t}} = 0) \times U_0^b(\theta|\phi^*(\sigma_{\hat{t}})) \;+\; \text{Prob}(\sigma_{\hat{t}} > 0) \times U_0^b(\theta|\phi^*(\sigma_{\hat{t}}))]$$

for a given t, subject to entrepreneurial participation and the incentive conditions that entrepreneurs with no good signals will suspend, and that those with one or more good signals will not suspend, where the probability weighted-term in the general form above is given by:

$$
\begin{aligned}
\left[\int_0^1 (1-\theta)^{\hat{t}}\,f^0(\theta)\,d\theta\right] \;\times\; & \Bigg\{ \int_0^{\theta_M} [\,\min[\alpha(\kappa+\hat{t}), D_{\hat{t}}(1+\delta_1)] - PR_{\hat{t}}\,]\,f^0(\theta)\,d\theta \;+ \\
& \int_{\max[\theta_M,\theta_{M'}]}^{\max[\theta_H,\theta_{M'}]} [\theta A - Q^{*'}(\theta) - (\kappa + T + 1 + \mu - C)]f^0(\theta)\,d\theta \;+ \\
& \int_{\min[\theta_M,\theta_{M'}]}^{\min[\theta_H,\theta_{M'}]} [\theta A - Q^{*'}(\theta) - (\kappa + T + 1 + \mu - C) \;- \\
& \qquad\qquad \frac{1}{2}(e_{\hat{t}}^{sus} - c\,\theta(T-t))]f^0(\theta)\,d\theta \;+ \\
& \int_{\theta_H}^{1} [\theta A - N - (\kappa + T + 1 + \mu - C)]\,f^0(\theta)\,d\theta \;-
\end{aligned}
$$

[5]Recall that $\delta_2(\theta)$ is not determined until θ is known, and that it is chosen to ensure that all surplus not required to satisfy entrepreneurial participation constraints winds up with the bank.

$$
\begin{aligned}
& \left[\int_{\min[\theta_M,\,\theta_{M'}]}^{\min[\theta_H,\,\theta_{M'}]} [\xi\,(e_{\hat{t}}^{sus} - c\,\theta(T-t))]\, f^0(\theta)\, d\theta \;+\right. \\
& \left.\int_{\min[\theta_H,\,\theta_{M'}]}^{\theta_{M'}} [(e_{\hat{t}}^{sus} - c\,\theta(T-t))]\, f^0(\theta)\, d\theta\right] \quad \Bigg\} + \\
\left[1 - \int_0^1 (1-\theta)^{\hat{t}}\, f^0(\theta)\, d\theta\right] \quad \times \quad & \Bigg\{ \int_0^{\theta_B} [\min[\alpha(\kappa+\hat{t}+1), D_{\hat{t}}(1+\delta_1)+(1+\delta_1)] - (PR_{\hat{t}}+1)]\, f^0(\theta)\, d\theta \;+ \\
& \int_{\max[\theta_B,\,\theta_{B'}]}^{\max[\theta_L,\,\theta_{B'}]} [\theta A - Q^{*''}(\theta) - (\kappa+T+1-C)] f^0(\theta)\, d\theta \;+ \\
& \int_{\min[\theta_B,\,\theta_{B'}]}^{\min[\theta_L,\,\theta_{B'}]} [\theta A - Q^{*''}(\theta) - (\kappa+T+1-C) \;- \\
& \qquad\qquad \frac{1}{2}(e_{\hat{t}}^{inv} - c\,\theta(T-t))] f^0(\theta)\, d\theta \;+ \\
& \int_{\theta_L}^{\theta_M} [\theta A - N - (\kappa+T+1+\mu-C)]\, f^0(\theta)\, d\theta \;- \\
& \int_{\max[\theta_M,\,\theta_{M'}]}^{\max[\theta_H,\,\theta_{M'}]} [\theta A - Q^{*'}(\theta) - (\kappa+T+1-C)] f^0(\theta)\, d\theta \;+ \\
& \int_{\min[\theta_M,\,\theta_{M'}]}^{\min[\theta_H,\,\theta_{M'}]} [\theta A - Q^{*'}(\theta) - (\kappa+T+1-C) \;- \\
& \qquad\qquad \frac{1}{2}(e_{\hat{t}}^{sus} - c\,\theta(T-t))] f^0(\theta)\, d\theta \;+ \\
& \int_{\theta_H}^{1} [\theta A - N - (\kappa+T+1-C)]\, f^0(\theta)\, d\theta \;- \\
& \left[\int_{\min[\theta_B,\,\theta_{B'}]}^{\min[\theta_L,\,\theta_{B'}]} [\xi'\,(e_{\hat{t}}^{inv} - c\,\theta(T-t))]\, f^0(\theta)\, d\theta \;+\right. \\
& \left.\int_{\min[\theta_L,\,\theta_{B'}]}^{\theta_{B'}} [(e_{\hat{t}}^{inv} - c\,\theta(T-t))]\, f^0(\theta)\, d\theta\right] \quad \Bigg\}
\end{aligned}
\tag{C.12}
$$

and where

$$Q^{*'}(\theta) = \frac{1}{2}\,(\theta A - (T - \hat{t} + 1 + \mu - \min[C,\ \kappa + \hat{t} + 1] - \min[\alpha(\kappa+\hat{t}), D_{\hat{t}}(1+\delta_1)] - \max[0, (e_{\hat{t}}^{inv} - c\,\theta(T-t))])$$

and

$$Q^{*''}(\theta) = \frac{1}{2}\,(\theta A - (T - \hat{t} - \min[C,\ \kappa + \hat{t}] - \min[\alpha(\kappa+\hat{t}+1), D_{\hat{t}}(1+\delta_1) + (1+\delta_1)] - \max[0, (e_{\hat{t}}^{sus} - c\,\theta(T-t))])$$

This expression can be conflated somewhat by burying some of the conditionality in an implicit $Q(\theta)$. These expressions esentially represent a weighted average of the operational outcome less bank-sourced (investment) inputs less any inducements required to motivate entrepreneurial participation

for those that suspend and those that continue at $\hat{t}$ respectively. The 'min-max pairs' of integrals are used to to explicitly capture the variation in $Q^{*'}$ that will result if entrepreneurs do indeed require these inducements, while the terms in square brackets represent the amount of surplus that must be shared in order to meet participation constraints. Whenever entrepreneurial participation constraints are not an issue (*i.e.*, when $\theta_{B'} < \theta_B$ and $\theta_{M'} < \theta_M$) all integrals with a min[$\bullet, \bullet$] term serving as an integration limit will disappear.

I construct a Lagrangian and simultaneously solve first order conditions derived therefrom. All numerical solutions in the thesis are found using the FindRoot procedure in Mathematica and hence are approximate. In practice I use a naive grid search procedure both to identify appropriate starting points for the numerical solutions, and to verify that the solutions found are indeed maximising profits. The largest T for which reliable numerical solutions can be found depends upon the other parameters of the problem (especially the prior distribution). I focus on the ability of the bank to generate early (socially beneficial) suspensions that are more profitable than the case of no suspensions. The potential for a regulator or central bank to play a role in ensuring that a particular equilibrium is played, perhaps via the introduction of a deposit insurance premium, is left for future research.

Appendix D

Notation

This appendix contains some discussion of the notation relating to debt as well as a table of all notation used in the thesis.

D.1 Debt Contracts

A debt contract specifies a maturity date, a maximum face value, and a loan rate for each period. Here we consider the expression of the total debt incurred at the beginning of period t by a firm with an active project, that has not suspended, and given that the entrepreneur contributes $C \geq 0$ to the project. It is a very general expression, reflecting the fact that the loan rate may differ from one period to the next, and that C is not fixed in relation to κ. I do however assume that both κ and C are integers to ease notation a bit. Debt can be expressed as

$$D_t(\Delta) = \sum_{i=a}^{t-1} \left(\prod_{s=i}^{t-1} (1 + \delta_s) \right) + I(C < \kappa)(\kappa - C) \prod_{s=0}^{t-1} (1 + \delta_s) \tag{D.1}$$

where $I(C < \kappa)$ is an indicator variable that takes the value 1 when C is less than κ and $a = \max[0, C - \kappa]$ denotes the first period in which the unit investment requirement is borrowed. In the special case that $C = 0$ (so all investment funds are borrowed) and debt is riskless (so $\delta_s = 0 \, \forall \, s$) the expression reduces to

$$D_t(\Delta) = \kappa + t.$$

Note that $D_t(\Delta)$ does not account for any debt service charges (or new borrowing) that will be incurred in period t, nor does it account for the possibility of earlier suspensions. A firm that

suspended in period r would have, at the beginning of t, outstanding debt of

$$D_t(\Delta) + \mu \prod_{s=r}^{t-1}(1+\delta_s).$$

For most of the analysis we consider only those contracts that specify a constant default rate δ for the duration of the contract. Assuming the contract was initiated at $t = 0$ and the maturity is larger than t, (D.1) simplifies to

$$D_t(\Delta) = \sum_{i=a}^{t-1}(1+\delta)^{t-i} + I(C < \kappa)(\kappa - C)(1+\delta)^t \tag{D.2}$$

Since D_t is the debt one enters a period owing, a firm that simply rolls debt over for one period with no new borrowing will owe $D_t(1+\delta)$ while a firm that has also borrowed another unit of investment at t will owe $D_{t+1} = D_t(1+\delta) + (1+\delta)$. This latter expression can be rearranged as $D_{t+1} - D_t = \delta(D_t + 1) + 1$, which is just debt service plus new debt. Finally, one can express the total amount borrowed, net of any debt service charges, at the beginning of period t, by an entrepreneur that has not suspended, as

$$D_t|_{\delta=0} = t - a + I(C < \kappa)(\kappa - C)$$

D.2 Notation Table

Table D.1: Notation Used in the Thesis

Variable	Description	Comments / Additional Restrictions
$\theta \in [0,1]$	binomial parameter drawn by Nature	terminal demand shift parameter
$\alpha \in [0,1)$	liquidation parameter	exogenous, indexes irreversibility
$\mu \geq 1$	project reinitiation cost	exogenous, sunk once paid
$\kappa \geq 0$	one-time project initiation fee	exogenous, paid at time 0
$c \geq 0$	private benefit	exogenous
$T > 0$	project maturity	exogenous finite integer
$A > 0$	demand function parameter	exogenous
$C > 0$	entrepreneur's contribution to project	exogenous
Γ	$\{\alpha, \mu, \kappa, c, T, A, C\}$	exogenous parameter vector
$N(\hat{t}, \Delta \mid \Gamma)$	mass of entry	endogenously determined
$\Delta(\hat{t}, N \mid \Gamma)$	debt contract	endogenously determined
$\hat{t}(N, \Delta \mid \Gamma)$	time of first suspensions or liqudations	endogenously determined
$\bar{t}(\Delta \mid \Gamma)$	latest first suspensions or liqudations	relevant to competitive credit market
$Q(\theta) \geq 0$	aggregate industry production	$Q(\theta) = N$ if all entrants produce
$P(\theta, Q(\theta))$	demand function	$P(Q(\theta), \theta) = \theta A - Q(\theta)$
I_t	investment required from t to T	assumes no suspensions after t
D_t	debt accumulated to t	assumes no suspensions before t
PR_t	principal accumulated to t	assumes no suspensions before t
δ	lending rate	constant within contract
Σ_s	time s information set	$\sigma_s \in \Sigma_s$ is a signal history of length s
$\beta e(a, b)$	prior beliefs about θ	$a = b$ imposed throughout
$f_s^{e_0}(\theta)$	worst time s posterior beliefs about θ	$\beta e(a, b + s)$
$\phi(\Sigma)$	strategy profile	maps signal histories into actions
$U_s(\theta \mid \phi)$	expected outcomes if ϕ played	risk-neutral
θ_B	$\theta < \theta_B \Rightarrow$ all entrepreneurs liquidate at $\hat{t} + 1$	conditional on playing ϕ^*
θ_L	$\theta_B < \theta < \theta_L \Rightarrow$ further suspensions at $\hat{t} + 1$	conditional on playing ϕ^*
θ_M	$\theta_M < \theta < \theta_H \Rightarrow$ some reinitiation at $\hat{t} + 1$	conditional on playing ϕ^*
θ_H	$\theta > \theta_H \Rightarrow$ complete reinitation at $\hat{t} + 1$	conditional on playing ϕ^*
θ^E	$\theta \geq \theta_E \Rightarrow$ price $\geq$ debt	applies in no suspensions equilibria