Explaining the Corporate Demand for Risk Management: Financial and Economic Views

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Explaining the Corporate Demand for Risk Management: Financial and Economic Views

Abstract

The purpose of this thesis is to review a number of academic perspectives on the practice of risk management in primarily widely-held (i.e. quoted) firms. In particular the currently dominant modern finance approach is criticised on the grounds that it offers an overly narrow view of corporate risk management behaviour. The core of the modern finance approach is that risk management is said to exist as a means to alleviate the adverse impact of various financial and capital market based agency and transactions costs that prevent the firm's stakeholders from achieving a Pareto efficient distribution of risk amongst themselves. However, in what follows it is argued that the presence of such agency or transactions costs do not provide a complete rationale for corporate risk management. Indeed fruitful research is already being done in the areas of organisational behaviour, sociology and psychology. Yet, what remains to be fully explored is the short run economic impact of risk management on a firm. In view of this a new economic framework for risk management is proposed based on the twin economic concepts of risk related "pure penalties" (which represent an unambiguous cost to a firm) and "technological non-linearities" (which can affect the structure of a firm's revenue, cost and production functions). Both of these phenomena can have a significant effect on the expected profits of a firm. Moreover, it is demonstrated that there are numerous scenarios in which risk management may be used by an expected profit maximising firm.

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Chapter 1:
Introduction

1. The Role and Development of Risk Management

Risk is a consequence of life itself. In fact both individuals and firms have been informally coping with risk for thousands of years[1]. Yet, despite the prevalence of risk in society academic interest in the area of corporate risk management has only begun quite recently. In fact the "birth" of the discipline can largely be traced back to only the late 1950's and early 1960's, since it was not until this time that a formal definition of corporate risk management was developed or indeed widely accepted (Snider 1991, Williams et al 1995). The crux of this early definition was risk management's role as an insurance buying function. As such the main province of risk management was seen to be "pure risk" avoidance, the idea being that it should help to identify and then eliminate (or at least substantially reduce) a firm's exposure to the financial impact of insurable pure risks (such as the risks of fire, theft, employee injury or legal liability claims). Pure risks were defined as risks that could only depress the profitability of a firm (see Chapter 2, section 2). Moreover, pure risks were typically seen as being non-business risks (e.g. Carter & Crockford 1974, Mehr & Hedges 1974) in that they were more an unfortunate by-product of a firm's manufacture of goods and services rather than an integral part of the production process.

Contemporary (1980's-90's) research into corporate risk management has moved along away from emphasising the importance of insurance buying and pure risk avoidance. In fact there can almost be said to have been an explosion in the various different types of role that have been attached to risk management (see Chapter 2). This explosion has, however, developed out of two key insights. The first is that risk management should be a holistic function (Shapiro & Titman 1985, Kloman 1992,

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1 One of the earliest recorded examples of risk management is the marine insurance arrangements that were drawn up by Phoenician traders around 3000 years ago.

Haimes 1992, Williams et al 1995), that addresses not just insurable pure risks but also all the many other types of risk that a firm can face (such as financial risks, political risks, or business risks like fluctuations in consumer demand or cost changes etc.). The second is that risk management should, like any other business discipline, aim to meet the global objectives of the firm (e.g. Shapiro & Titman 1985, Doherty 1985, Kloman 1992, Williams et al 1995)[2]. The view being that in order to be successful risk management must become an increasingly integrated, if not central, part of the business activities of a firm.

Yet, although many contemporary writers are united in their belief in the widespread scope and need for corporate risk management the discipline is far from "mature" (Williams et al 1995, p22). For example, the significance attached to the specific duties and functions that can be carried out by risk managers (such as risk identification and measurement, risk control and risk financing) varies considerably, amongst both academics and practitioners. In addition, the many and various attempts to explain why firms actually invest in risk management have been on something of an ad hoc basis[3]. Thus it would seem that the discipline of risk management is one that is still evolving and at the moment this process would appear to be quite slow. What the subject lacks is a coherent framework from which to understand the risk management decisions of firms.

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2 For example Williams et al (1995) define risk management as: "a general management function that seeks to identify, assess, and address the causes and effects of uncertainty and risk on an organisation.". They then go onto say that "[t]he purpose of risk management is to enable an organisation to progress toward its goals and objectives in the most direct, efficient, and effective path.".

3 Hood et al (1992) call this the "Risk Archipelago" (see also Hood & Jones 1996, p3-6).

2. Rationale of Thesis

As stated in section 1 above corporate risk management is still quite an immature discipline. This immaturity can perhaps be best illustrated by the subject's preoccupation with two rather fundamental questions (Shapiro & Titman 1985):

(i) To what extent does a firm need to manage its exposure to risk?

(ii) Given that risk management is necessary, how should a firm go about managing its exposure to risk?

In recent years these questions have given rise to numerous different insights (see Chapter 2), however, most of them share a common ancestry - modern finance theory. The basic argument is that if financial/capital markets were perfect firms would not need risk management. In such an environment stakeholders would hold (without cost) fully diversified asset portfolios within which they can diversify away the effects of most risks. Risk management is therefore only assumed to be of value when circumstances conspire to make the markets in which stakeholders trade less than perfect. Of course in the real world numerous such market imperfections exist - from the dead-weight losses that can be associated with portfolio management, bankruptcy and taxation, to the problems of incomplete and asymmetric information. It is these imperfections that are then used to explain both why and how firms invest in risk management.

Within this thesis the view that risk management can exist to counter the imperfections present in financial and capital markets is accepted. However, it is argued that the current focus on modern finance theory means that some other important motivational factors (many of which also represent imperfections in both the internal and external markets faced by firms) for risk management have largely been ignored. Indeed fruitful research is already being done in the areas of organisational behaviour, sociology and psychology[4]. Yet, one important discipline remains largely undeveloped by risk management theorists - neo-classical economics.

The primary purpose of this thesis is, therefore, to begin to develop an economic theory of risk management. Admittedly a considerable amount of research has already been conducted into the economic value of insurance and more generally risk management (e.g. Mossin 1968, Ehrlich & Becker 1972, Dionne & Eeckhoudt 1985, Briys & Schlesinger 1990, Briys et al 1991, Parry & Parry 1991, Schneider 1992, Sweeney & Beard 1992, Froot et al 1993, Di Mauro 1994, Gollier et al 1997). However, the vast majority of this work has focused on the preferences of risk averse *individuals* rather than those of firms[5]. Being influenced by the attitudes of various, often conflicting stakeholder groups, a firm's behaviour will generally be much more complex than that of an individual (Arrow 1963, Razin 1976, Goldberg 1990). This means that it is not usually possible (or indeed desirable) to assign a utility function to a firm or even give it a specific "human" attitude towards risk.

Given the multi-personal nature of a firm's decisions it is often better to select more simplistic decision making criteria. The one proposed in this thesis (see Chapters 4, 5 & 6) is *short run profit maximisation*. At first glance such an assumption may seem surprising. One of the major tenets of the modern finance approach is that while risk management may increase a firm's long term market value it often represents a cost in the short run (see Doherty 1985, Smith & Williams 1991). As such risk management would appear to be of little value to a myopically profit maximising firm. However,

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4 For an excellent introduction into this area see Glendon & McKenna (1995) and Hood & Jones (1996).

5 The notable exceptions to this point are the works of Parry & Parry (1991), Schneider (1992) and Froot et al (1993). More on their work in Chapters 4 and 5.

economic models of the theory of the firm under risk demonstrate that this need not be so. In particular it will be argued that even in a world where all stakeholders are risk neutral and there exists no tax or bankruptcy costs a firm may still invest in risk management. Furthermore, in oligopolistic industries such a move may not always be designed to reduce risk, instead in some circumstances firms may actually invest in risk increasing devices, since doing so will actually raise their expected profits.

While drawing extensively on economic theory this thesis is not intended to be a piece of pure economic research. Instead it is designed specifically to extend our understanding of risk management within organisations. It is hoped that this work will encourage new lines of investigation, with a greater focus on what should be a core issue for corporate risk management - profit. Although it has been recognised that firms often follow objectives other than the earning of profit it is hard to reject that for many it remains an important issue (see, for example, Hay & Morris 1991, p292-296, Schoemaker 1993). Moreover, by focusing on such a simple economic objective the analysis of a firm's risk management decisions should become more tractable. Indeed by incorporating corporate risk management into a formal economic context it is hoped that a rather more coherent and relevant basis for future research into the discipline can be developed.

3. **Outline of Thesis**

Chapter 2 of this thesis commences with a brief review of the currently dominant modern finance approach to risk management (e.g. Cummins 1976, Doherty 1985, Shapiro & Titman 1985, Smith & Williams 1991, Skogh 1989 & 1991, Grillet 1992 & 1993)[6]. In this research risk is viewed as an implicit contractual claim between on

[6] Note, however, that in the UK research into the organisational behaviour based "cultural theory" (see chapter 6, section 3.3.2.2) approach to risk management appears to be getting increasingly popular. Already it has been discussed extensively in the books by Glendon &

the one hand well-diversified shareholders who are largely indifferent to most (except systematic) risks and on the other the firm's non-shareholder stakeholders (employees, creditors, third parties, etc.) who because of various asset market imperfections (such as indivisible and non-marketable assets, for example) would prefer to have risk removed. Unfortunately the argument then goes that the presence of various transactions costs, most notably: information asymmetries, bounded rationality and free rider problems, make it difficult for non-shareholder stakeholders to achieve efficient market solutions on their own (Easterbrook & Fischel 1985). In this context the purpose of risk management is seen as not only being to cost effectively reduce risk but also to align shareholders' interests with those of the firm's other stakeholders. In so doing risk management is said to help to ensure the optimal allocation of risk and jointly maximise the welfare of all parties having contractual relationships with the firm. This even includes well-diversified shareholders, since by lowering the compensation demands of the firm's other stakeholders the presence of risk management should (providing it is cost effective) raise a firm's mean cash flows and hence the value of equity.

The modern finance approach to risk management has undoubtedly helped to guide research into risk management by focusing attention on the important questions of "why?" and "how?" firms should invest in risk management (see section 2, above). However, whether the approach is a reliable predictor of real world behaviour is an empirical matter. Unfortunately, current empirical research into the modern finance approach to risk management has been on something of an ad hoc basis: a number of studies exist, but, their results lack any real generality. Indeed most studies have focused on specific risk management tools (in particular derivatives and insurance) or industries and often both (see for example Mayers & Smith 1990, Tufano 1996).

McKenna (1995), Hood & Jones (1996) and in journals such as: The British Journal of Management, Safety Science and Risk Decision and Policy.

Others have even gone a step further investigating the behaviour of only one firm or stakeholder group (e.g. Gegax et al 1991, Doherty & Smith 1993, Viscusi 1993 etc.). In response to this lack of breadth Chapter 3 reports the results of a questionnaire distributed to a wide cross-section of 127 large UK companies in the Summer and Autumn of 1993. As well as summarising the respondents' motives for the practice of risk management in general, the validity of the modern finance approach is formally tested. This is done by conducting a number of multinomial probit estimations to examine whether the importance assigned to these motives differs systematically across the sample according to a firm's financial and organisational characteristics and the preferences of its management.

On balance the results of the various regression analyses do not provide convincing proof of the validity of the modern finance approach. Admittedly the attitudinal nature of the questionnaire used to gather the data does temper the strength of this conclusion (although currently there is no other source of general risk management information that could be used - see Chapter 3). However, the evidence in support of many of the specific hypotheses of the modern finance approach is extremely limited. In fact in only the "Productivity (Injury)" model does a firm's financial or organisational characteristics have any real effect on manager's responses. Furthermore in this and many other models the signs of the significant coefficients are not always as expected.

The purpose of Chapter 4 is to introduce the main idea of this thesis - that corporate risk management research can be usefully extended by incorporating it into neo-classical economic theory. In particular it will argue that the agency and transactions costs put forward by the modern finance approach are merely a subset of a much larger group of *economic* issues.

Unfortunately the most popular mechanism through which past research has tried to explain the economic consequences of risk is expected utility theory. Admittedly this approach does have some merit. For example, it has often been said that expected utility theory provides a good representation of so called "rational" utility maximising behaviour under uncertainty (see Shiller 1997), moreover, it provides a consistent basis from which to understand a decision maker's behaviour under different models of risk. However, despite its widespread use Chapter 4 begins by arguing that the applicability and tractability of models incorporating expected utility theory are often highly suspect. This is particularly the case in the corporate context. Being influenced by many, often conflicting, stakeholder groups it is hard to imagine that a firm will possess the same subjective likes or dislikes for risk that an individual decision maker might. Instead the suggestion is that it is often better to assume that a firm's decisions are motivated by rather more objective concerns, such as profit[7].

The next (and main) part of Chapter 4 then begins to examine why a supposedly risk neutral, expected profit maximising firm might wish to invest in risk management. Although such firms might reasonably be thought of as being indifferent to risk, recent economics based research has illustrated that this need not always be the case. Indeed many different causes of this lack of indifference have been identified, however, these can generally be classified according to two main groups. The first group are known as "pure penalties" (Martin 1981), and denote risk related factors that can either unambiguously raise a firm's operating costs or lower its revenues. The second group of factors are commonly termed "technological non-linearities" (see Aiginger 1987, Ch. 4 or Driver & Moreton 1992, Ch. 4). These non-linearities can arise when two elements are present. First the firm must make its price and or output decisions ex-ante (i.e. before the state of the world and hence its final profits is known) - this forces it to maximise expected rather than actual profits. Second the firm's total and or marginal profit function must be strictly concave (or potentially

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7 This is not to say that firms might sometimes appear to exhibit subjective preferences for risk. However, even in such circumstances a firm's "attitude" can often be traced to rather more objective concerns (e.g. see Goldberg 1990).

even convex) in the random variable(s) faced. The situation is then analogous to that of a expected utility maximising individual (von Neumann & Morgenstern 1944, Pratt 1964, Arrow 1965), the only difference being that a firm's behaviour is firmly rooted in its desire to maximise expected profits rather than utility.

Although the presence of "pure penalties" or "technological non-linearities" might generate a concern for risk in even an expected profit maximising firm it does not necessarily follow that it will invest in risk management. Risk management can be a costly exercise, moreover, the efficiency with which certain tools might be able to reduce a firm's exposure to risk is often highly questionable (Briys et al 1991). The purpose of Chapter 5 is, therefore, to explore this issue more fully and examine whether or not an expected profit maximising firm will actually want to invest in reducing its exposure to risk.

Unfortunately the risk management decisions of a firm can be highly sensitive to the economic environment it finds itself in (such as the cost, production or market conditions faced - Aiginger 1987), however, a basic model is constructed in order to demonstrate the economic importance of risk management. From this model three different solutions are provided, each one based on a distinct market form. Interestingly perfect competition largely yields the standard result of the modern finance approach that a risk neutral firm will not generally purchase risk management unless it alleviates either agency or transactions costs. Yet, in both monopoly and duopoly markets it is demonstrated that the market power of a firm can create a "technological non-linearity" which causes both its total and marginal profit function to become concave in final output. When exposed to output fluctuations this can then cause the expected output and profits of such firms to fall, prompting investment in risk management.

Although Chapter 5 demonstrates that firms operating in imperfectly competitive markets are often more likely to invest in risk management, an important limitation of this analysis is that it largely ignores the strategic consequences of a firm's actions. Chapter 6, therefore, discusses the possibility that decisions on corporate risk management purchases may well have a strategic dimension. Oligopolistic markets are characterised by strategic interdependence, whereby, the decisions of one firm are influenced by those of all other firms in the market - and vice-versa. This situation can create both opportunities and threats for oligopolistic firms, many of which are intensified in a world of risk. As such it is argued that the role of risk management may be much broader than the simple alleviation of "technological non-linearities" or "pure penalties": instead firms may use it to maximise any risk related strategic opportunities or minimise any threats.

The analysis begins in a simplified and effectively static environment in which identical but self interested duopolists are required to simultaneously decide on their exposure to risk. Each firm's exposure to risk is then allowed to condition the nature of competition played out in the final output market and hence its expected profits. Using such a framework many different outcomes are possible, however, particular attention is given to several interesting scenarios. These include both "*Risk Wars*" and "*Certainty Wars*" in which self interested firms respectively expose themselves to excessive degrees of risk and certainty and also potentially costly co-ordination equilibria where a firm must second guess the behaviour of its rivals.

The analysis is then extended to incorporate rather more dynamic interactions between duopolists. In particular the possibility that self interested duopolists may become aware of and attempt to control their tendency to select jointly Pareto inefficient outcomes is explored. The theoretical basis for this analysis is that of a multi-stage game with "closed-loop" equilibria (e.g. see Fudenberg & Tirole 1986, Shapiro 1989a, Slade 1995). The essential characteristics of such games is that at each stage firms are able to fully remember and make *strategic* decisions conditioned on what has gone before. A firm may, therefore, make commitments to either punish its rival for engaging in non-cooperative behaviour or rather more interestingly to punish itself if it was to do the same. Using this insight it is then argued that some of the tools that a firm can use to control its exposure to risk (such as external insurance, captive insurance, physical risk control devices etc.) may be employed as commitment devices in "risk games". As such risk management may be more than a simple internal control device (in a similar manner to non-executive directors) but could also be used to improve a firm's external relations with its competitors as well.

In addition to discussing a number of possible limitations and extensions of the current analysis Chapter 7 rounds the thesis off with a brief summary of the main contributions that economic theory can offer to the development of a theory of risk management.

Conceivably the most important contribution of economic theory is its ability to demonstrate that a firm's risk management decisions can make a direct contribution to its short run profits. The returns from risk management have typically been seen as being both hard to measure[8] and taking a long time to materialise (see Chapter 2). In an economic context, however, the benefits of risk management are often not only immediate but highly tangible as well. This insight can then be used to extend the circumstances under which risk management may be of use to a firm.

A second related contribution of economic theory is that it places much more emphasis on the mean returns (i.e. profits) of a risky decision than its variance.

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8 It would be difficult for a firm to estimate how many third party liability suits might be avoided through investment in environmental risk management, for example.

Perhaps as a consequence of expected utility theory[9] much of the research into the modern finance approach to risk management still focuses on how seemingly risk averse stakeholders will react to increases in the variance of their returns (see Chapter 2)[10]. The trouble with this, however, is that a decision maker's attitude towards the variance of his or her returns is an inherently personal one, as such it is very difficult to achieve a reliable prediction on how different decision makers will respond to the same level or type of risk. The advantage of focusing on the mean returns of a risky decision is that this problem can be largely eliminated. In general it is reasonable to assume that all decision makers will prefer more returns to less - thus where risk can be shown to have a direct impact on the mean returns of a decision maker it becomes much easier to make general predictions.

Finally economic theory can be used to provide a definite link between a firm's core business and risk management decisions. Certain authors in the modern finance approach to risk management (e.g. Froot et al 1993, Stulz 1996) have already recognised that a firm's risk management function can be used to support both its long term investment and short term operational decisions, however, what this research has failed to do is provide explicit proof of this link. By using economic theory it is hoped that this thesis will provide some supportive theoretical evidence.

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9 It is hard to deny that expected utility theory has not had a major influence on many of the subsequent theories of firm and or individual behaviour in a world of risk.

10 However, it should be noted that the modern finance based research into convex tax functions and bankruptcy costs does not share this problem - see Chapters 2 and 4.

Chapter 2:
The Modern Finance Approach to Corporate Risk Management

1. Introduction

Before the 1960's the discipline of risk management had not really been formally recognised (Snider 1991). Until this time the accepted wisdom was that most non-business risks should (where possible) be simply transferred to an insurer, the idea being that a firm should focus on its core activity of making money rather than devoting any real attention to keeping the assets that it already had.

However, during the latter half of this century and especially in the 1980's and 1990's there has been an explosion in both practical interest and academic research into the field of risk management[1]. Much of this research has been developed from modern finance theory (in particular the Capital Asset Pricing Model) and associated agency and transactions cost research. The basic idea behind this modern finance approach is that most firms do not invest in risk management because they are risk averse, instead it is argued that a firm (or rather its managers) will only undertake such investment if it increases the long term wealth of its largely risk neutral owners. This insight has since lead to the development of numerous associated theories to explain the corporate demand for risk management, it is these theories that are reviewed in this Chapter.

The next section outlines the development of the modern finance approach, explaining how it evolved out of the rather unrealistic assumption that firms are risk averse[2]. Section 3 then goes onto to critically evaluate the ways in which risk

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1 See Kloman (1992) and Williams et al (1995) for two good reviews of the development of risk management.

2 For a detailed critique of the problems associated with using risk aversion in models of

management is believed to be of value to a firm and its stakeholders, while section 4 applies these theories to a number of important stakeholder groups. Section 5 finishes with a brief summary and conclusion.

2. Developing the Modern Finance Approach to Risk Management

Many early writers in the field of risk management tried to demarcate it from other management disciplines on the grounds that its purpose was to deal with pure rather than speculative risks (Mowbray 1930). The taking of speculative risks - which offer the prospect of either a gain or a loss - was seen to be the primary purpose for business. In fact it was widely recognised that in order to make a profit firms must take speculative risks, by launching a new product or entering into a new market, for example. Pure risks on the other hand were seen as both an unfortunate and unavoidable by-product of this activity. Pure risks only offer the prospect of loss and as such it was assumed that they would simply depress the profits of a firm[3].

This rather depressing rationale for risk management lead many early theorists to conclude that firms would generally act in a risk averse way towards pure risks. A good example of this reasoning is provided in Carter & Crockford (1974). They

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corporate risk management see Chapter 4, section 2.

3 Note, however, that more recently it has been argued that the distinction between pure and speculative risks is rather semantic (Williams et al 1995). Typically, all risks have both pure and speculative elements. For example, a homeowner often faces the risk of both positive and negative fluctuations in the value of his or her house. These fluctuations can be the result of many different occurrences, from say a fire or subsidence or a change in the demand for houses. Yet for some reason occurrences such as fires are seen as pure risks, while a reduction in the demand for houses is seen as being a speculative one (since the demand for houses can also increase).

argued that since risk management deals with risks that can only depress the profitability of a firm, its purpose should be to protect a firm's assets from harm by cost effectively reducing both the frequency and severity of loss. Other notable authors such as Mehr & Hedges (1974) also supported this view, however, they took it a step further by developing a number of more specific motives for corporate risk management.

- Protect the firm from bankruptcy.

- Ensure that the firm maintains a high level of efficiency and growth both pre- and post-loss. This embodies a number of sub-objectives including: keeping risk management costs down as much as practicably possible, maintaining market share and ensuring continuity of performance by providing ample funds for reinvestment.

- Peace of Mind: The aim being that risk management should leave managers free to pursue profitable speculative ventures without having to worry about pure risks. Thus ensuring that they do not pass up positive net present value projects simply because of their large downside potential.

- Good citizenship/social responsibility: Where it was argued that a firm should seek to reduce the risks faced by their employees, suppliers, customers and third parties, even at the expense of its profitability.

More recent research has rejected the idea that risk management arises out of corporate risk aversion. This view was initially raised by Olson & Simkiss (1982) who criticised the idea that risk management was simply there to reduce a firm's exposure to pure risk. Viewing risk management as a specialist aspect of financial management, they argued that its function should be the same as any other financial discipline: to help maximise the difference between the risks a firm's owners face and their returns.

"The objective of the risk manager is the same as the objective of the portfolio manager or chief financial officer. It is to increase the wealth of shareholders or owners by selecting strategies that entail the optimal combination of expected returns and risk." (Olson & Simkiss 1982).

However, as Doherty (1985) points out Olson & Simkiss made no attempt to develop their proposition by explaining how risk management could achieve such an "optimal combination" of risk and return.

Perhaps the reason why Olson & Simkiss did not develop a financial framework for risk management decision making was because Cummins (1976) had partially done so already. Although not criticising the then fashionable focus on corporate risk aversion Cummins did at least stress the need for risk management expenditure that directly contributes towards the long term global objectives of a firm (or rather its owners). Perceptively, Cummins recognised that risk management could be integrated into a number of existing theoretical approaches (for example neo-classical microeconomics), however, the decision making framework that he chose to focus on was the Capital Asset Pricing Model (CAPM).

In order to increase the value of its owners' stakes[4] a firm needs to select risky

[4] Given the number of diverse claims within an organisation (employees, managers, consumers, etc.) it is rather hard to assign overall objectives to a firm. However, most finance theorists assume that the purpose of a firm is to maximise its long term value to existing owners, whether they be bond or equity holders.

investments which maximise the difference between its expected cash flows and the returns demanded by all its investors (employees, suppliers, consumers etc., as well as those demanded by owners). Developed simultaneously by Sharpe (1964) and Lintner (1965) the CAPM attempts to predict what a firm's investors' returns will be.

Rightly or wrongly (see Chapter 4) one of the key assumptions of the CAPM is that a firm's investors are risk averse, preferring an investment that yields a certain income to a risky prospect of equal expected return. Consequently the riskier the investment the greater will be the level of compensation demanded. In helping to predict these compensation claims (otherwise known as an investor's risk premium) the CAPM then allows firms to calculate the net present value of a project[5] and select those that generate the greatest income.

Using the CAPM Cummins argued that risk management will only be of value to a firm's owners if, all things being equal, it can help to decrease the non-diversifiable risks they face or increase their returns. Although suggesting that his framework could be applied to all the firm's risk management decisions Cummins illustrated this proposition by exploring the optimum level of insurance deductible[6]. In this example Cummins then argued that the proportion of any given loss a firm retains should increase up to the point where the associated premium savings (equivalent to the marginal benefit of risk retention) are entirely offset by the cost the firm must bear in terms of increased owner risk premiums (the marginal cost of retention).

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5 This is calculated by subtracting the predicted compensation claims of investors from the expected return of the investment.

6 Where insured losses incorporate deductibles the policy holder is required to retain part of the potential loss, such as the first £100 per occurrence.

Given that the CAPM is a widely accepted investment tool it might appear to represent a rather good starting point from which to evaluate the effectiveness of a firm's risk management decisions, however, there is a fundamental flaw. The key proposition of the CAPM is that *all* investors can create a portfolio, known as the market portfolio, which consists of every risky investment within an economy (for example: stocks, bonds, real estate and even human capital), in the exact proportions necessary for them to diversify away the effects of all firm specific or unsystematic risk. Consequently the only risk that will influence an investor's decisions and hence the value of the firm, will be systematic[7], which cannot be diversified away. Indeed Main (1983a) has criticised Cummins's work on this basis, arguing that, since most pure risks are firm specific, the CAPM would appear to be an inappropriate basis from which to evaluate the cost effectiveness of risk management decisions. Others have gone even further and suggested that if the predictions of the CAPM are true then it is more than just an inappropriate basis for evaluating risk management, it renders the whole process redundant (see Cho 1988 for a review).

However, the hypothesis that a firm's owners will not value risk management (at least with respect to diversifiable unsystematic risks) does seem to contradict the available evidence. For example, Cassidy, Constand & Corbett (1990) demonstrated that the equity value of a firm rises after planned increases in risk management expenditure are announced to shareholders. Moreover, Sprecher & Pertl (1983) even found that large, firm specific, fortuitous losses decrease the value of a firm by around 4%. In short there would appear to be something of a paradox, in theory a firm's owners should be indifferent even hostile to risk management (assuming it is costly or destroys any natural hedge between the returns of an owner's investments - Mayers &

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7 Systematic risk measures the degree to which the variance of an investment's return co-varies with the returns of all other risky investments within the market portfolio.

Smith 1983, Doherty & Schlesinger 1985), however, in practice they would seem to find it quite desirable. The question that many have since tried to answer is why?

An obvious explanation for the apparent paradox between the predictions of the CAPM and a firm's owners' apparent concern for risk management is that the assumptions which underlie the CAPM are invalid. In fact modern finance based researchers have long shared this view, arguing especially that the CAPM's requirement of a perfect market[8] does not properly reflect real world trading environments (see Brealey & Myers 1991 for a good review). A classic critique is Levy's (1978) Generalised Capital Asset Pricing Model in which he relaxes the CAPM's perfect market assumption in order to explain why a firm's owners might value its attempts to reduce certain theoretically diversifiable risks. What Levy observed was that certain owners may possess assets which are indivisible or face market transaction costs (such as brokerage fees or information gathering and processing costs) that would constrain their ability to construct mean-variance efficient portfolios[9]. As such he argued that it is quite possible that a firm's owners will be averse to unsystematic risk and inflate their compensation claims accordingly.

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8 The assumption of a perfect market embodies the following:

- That asset markets are frictionless with zero transactions costs (Coase 1937, Arrow 1969, Williamson 1975),

- That investors can invest any fraction of their "capital" in assets and all assets are marketable.

- That asset markets are perfectly competitive - hence investors act as price takers and cannot influence the market price of their assets.

9 The owners of small firms are a prime example of this since they are likely to have most of their wealth tied up in one organisation (Fama & Jensen 1983).

However, Levy's criticism of the applicability of the CAPM to the owners of widely held firms (i.e. shareholders) is rather limited. When considering the effects of market imperfections on a large quoted company he was unable to show that the investment behaviour of many of its shareholders would be significantly different from the predictions of the CAPM. The shareholders of quoted firms are not only able to divide up their wealth across many industries but can also trade on established stock markets, thus improving the marketability of their assets. Moreover many of these shareholders are large financial institutions (e.g. banks, unit trust and pension funds) that are able to take advantage of significant economies of scale in order to minimise the impact of any further market imperfections. As such it would seem that the shareholders of widely held firms are likely to remain indifferent to risk even in a less than perfect market.

Although Levy's Generalised Capital Asset Pricing Model may not explain how the shareholders (especially institutional ones) of quoted firms could gain directly from investment in risk management it can still be used to should how they may benefit indirectly. This insight was recognised by authors such as Doherty (1985) and Shapiro & Titman (1985) who argued that while shareholders might be able to create mean variance efficient portfolios the firm's other investors will find this much more difficult[10]. Adopting a contractual approach to the firm Doherty and Shapiro & Titman viewed it as a nexus of contracts between many different stakeholder groups (for example: employees, consumers, bondholders, suppliers, shareholders and even third parties). What they then concluded was that the concerns and preferences of all these groups would have a *financial* impact on the firm - whether they explicitly

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10 Earlier authors like Mayers & Smith (1982) and Main (1982) had already investigated the corporate demand for insurance in this way, however, they failed to explain the demand for other risk management devices.

invested money into it or not[11].

Of course if the markets a firm's stakeholders traded in were able to operate as "perfectly" as the stock market then they should all be indifferent to the adverse effects of unsystematic risk. Moreover, even if stakeholders cannot achieve mean variance efficient portfolios it is possible that firms will be able to draw up contracts that shift risk from more risk averse stakeholders to groups such as shareholders that are less risk averse (see, for example, Cheung 1969, Stiglitz 1974, Mayers & Smith 1982, Milgrom & Roberts 1992). However, what Doherty and Shapiro & Titman observed was that the markets in which stakeholders trade are frequently far from perfect[12]. Their argument then went that these market imperfections would not only constrain the ability of non-shareholder stakeholders to create a mean-variance efficient portfolio, but also restrict the ability of firms to shift risk from these groups to shareholders (either because of shareholders' limited liability or the fact that the impact of certain physical risks - such as the risk of employee injury - cannot be easily shifted). Thus just as in Levy's model the suggestion was that the compensation claims of poorly diversified stakeholders would become inflated by the presence of unsystematic risk. This, in turn, would have a knock on effect on the firm's shareholders causing them to benefit indirectly from investment in risk management. The reason for this was that any firm which reduced its exposure to unsystematic risk would lower the compensation claims of its non-shareholder stakeholders. Then assuming that any investment in risk management is cost effective[13] it should serve to

11 In the words of Doherty (1985): "[t]he firm finds itself at the centre of a web of economic relationships contracted in a set of distinct but interrelated markets".

12 For example, the health and financial risks faced by employees, consumers and third parties are rarely either divisible or marketable.

13 Risk management is not a free good, so as with any investment its benefits must exceed its costs.

raise the firm's mean cash flows and hence the value of its shareholder's equity.

3. Financial Motives for Risk Management - The Hypotheses of the Modern Finance Approach

The recognition in the mid 1980's that in order to be of value risk management would need to increase the size of a firm's cash flows meant that researchers could no longer rely on their old stand-by: corporate risk aversion. Indeed many new and richer theories have since been proposed to explain the corporate demand for risk management. Much of this work, however, has rested upon the modern finance based foundations laid by authors such as Doherty (1985) and Shapiro & Titman (1985) focusing on the effects of three interrelated forms of largely financial market failures:

1. Non-divisible or marketable capital,
2. Transactions costs,
3. Agency conflicts.

These market failures form the crux of the modern finance approach to risk management. On the one hand they are used to explain the invalidity of the predictions of the CAPM and thus justify investment risk management - the idea being that stakeholders which experience these failures will encourage a firm (or rather its owners and managers) to invest in risk management. However, on the other hand it has been suggested that these failures may also attenuate a stakeholder's ability to achieve a beneficial reduction in risk. As such another role for risk management, or rather certain risk management tools (such as insurance - see section

3.3) has been proposed: to facilitate the efficient functioning of "risk markets", in situations where stakeholders are unable to protect themselves against being exposed to Pareto inefficient[14] level of risk.

The purpose of this section is to review the broad hypotheses that underpin the modern finance approach to risk management. In the next part various thoughts regarding the personal ability of stakeholders to achieve a beneficial reduction in risk are explored. Sub-section 3.2 then reviews the suggested roles for governments in ensuring the efficient functioning of risk markets. Finally, sub-section 3.3 concludes with a brief discussion of the suggestion that both market forces and government intervention may not always be strictly necessary.

3.1 *Can Poorly Diversified Stakeholders Encourage Risk Management Expenditure on their Own?*

One of the fundamental ideas behind the modern finance approach to risk management is that where stakeholders cannot eliminate their own exposure to risk (whether it be due to the existence of non-marketable and indivisible assets or the existence of transactions costs such as retraining fees or information gathering and processing expenses) they are likely to value a firm's attempts to do it for them. Unfortunately it has also been recognised that while stakeholder groups such as employees, third parties or creditors[15] may obtain considerable benefit from risk

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14 Pareto efficiency is a common measure of economic welfare. It is maximised where no one can be made better off without someone else being made worse off.

15 Just like shareholders the firm's creditors are often seen as being able to achieve mean-variance efficient portfolios. However, they will often act in a more risk averse way than shareholders (Easterbrook & Fischel 1985). One reason for this is that creditors have to bear a disproportionate amount of any bankruptcy costs that might be faced by a firm (Jensen & Meckling 1976). Moreover since debt based assets are rarely as liquid as equity creditors may find it much more costly to remove the effects of unsystematic risk and as such may prefer the

management the effective owners and controllers of the firm: shareholders and managers (who act as shareholders' representatives) may not. Thus the argument then goes that since shareholders and managers may be personally indifferent to the effects of most unsystematic risks[16] they might actually prefer to invest nothing at all in risk management.

One problem is that risk management is costly: insurance premiums can contain significant loadings for factors like profits, administration costs and moral hazard monitoring expenses for example[17], while safety devices are often both expensive (Schmit & Roth 1990, Schneider 1992) and difficult to appraise (see Briys et al 1991). Moreover, it has even been suggested (see Mayers & Smith 1983, Doherty & Schlesinger 1985) that risk management tools such as insurance may serve to reduce any beneficial natural hedges[18] in a shareholder's equity portfolio (that could be created by negatively correlated fluctuations in the dividend/capital returns provided by one firm and those of another, for example). Consequently, the argument then goes that shareholders and their managers may seek to avoid investing in risk management devices that do not directly benefit them. Instead they are likely to prefer to invest in more productive assets[19] and so doing expose the firm's other stakeholders to

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firm to do it for them (for example it is generally harder to find a buyer for debt than it is for equity).

16 It should be noted that this is need not always be the case. See sub-section 3.3 for more information.

17 As Main (1982) points out shareholders are often indifferent about the choice between whether to purchase actuarially fair insurance or create their own "home made" (Doherty 1985 Ch. 6) investment portfolios since both mechanisms achieve the costless elimination of risk.

18 See Appendix 4 for a definition of a natural hedge.

excessive amounts of risk (see Easterbrook & Fischel 1985, Grillet 1992).

This conflict between managers/shareholders and the firm's other, less well diversified stakeholders can perhaps be best explained by referring to Jensen & Mecklings' (1976) research into "agency costs". In Jensen & Mecklings' model firms exist as a nexus of agency relationships between principals (the purchasers of goods and services) and agents who are hired to undertake actions and make decisions on the principal's behalf. Problems arise because the goals of these two parties conflict. Although the principal hires agents to achieve his or her aims they will, if possible, prefer to act opportunistically and further their own ends instead. For example, an employer will require maximum (consummate) productive effort from his or her employees, while they will generally prefer on the job leisure.

Figure 1 about here

Jensen & Meckling illustrate this proposition by exploring managers' incentives to consume perquisites (fancy offices, corporate jets, expensive lunches etc.) at the expense of the firm's profitability and subsequently the value of equity. Figure one shows an indifference curve map of managers' preferences between profits and perquisites (containing two possible indifference curves U_1 and U_2). As illustrated managers receive significant utility from consuming perquisites, however, since their continued consumption of these benefits depends on the survival of the firm and that they are often residual claimants they will need to at least partially constrain their consumption. Thus an owner-manager who owns 100% of the firms assets, for example, will spend a relatively small amount on perquisites since for every pound they spend they will lose a full pound of income - as represented by the budget constraint curve YY'. Such an owner-manager will, therefore, maximise his or her

19 For example: research and development, new machinery etc.

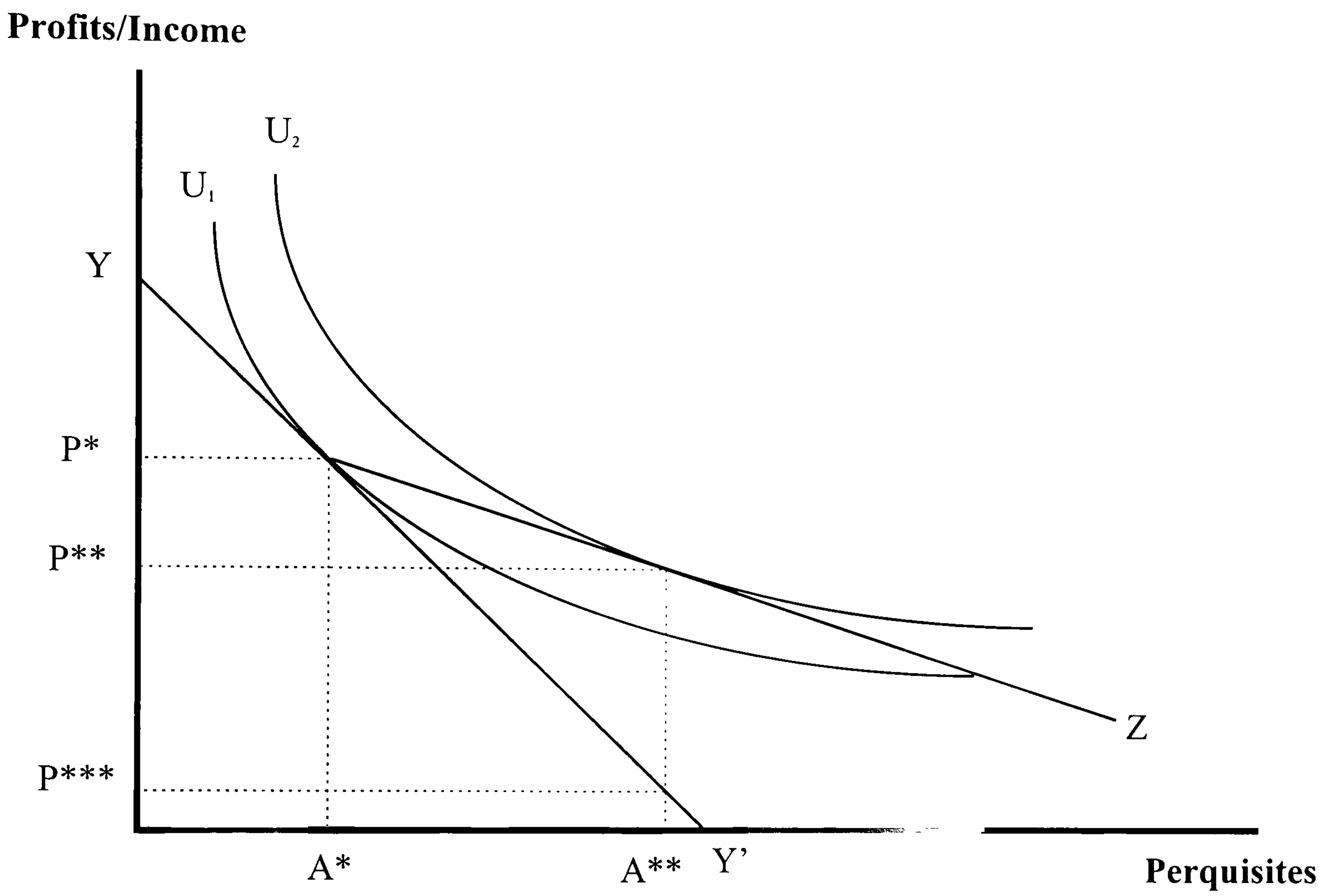

Figure 1: Incentives for Agent Opportunism

profits at P^* - where their indifference curve is tangential to the budget constraint curve. Note that while this is not the true profit maximising point, the perquisites that the owner-manager consumes are necessary to ensure that they remain in the job and, therefore, represent a valid cost.

Next suppose that the manager sells some proportion of the firm's assets to one or more external investors but retains all of the decision making powers. In so doing the manager's budget constraint will expand (in this case to YZ) since the cost of perquisite consumption is now shared with these new owners. A self seeking owner-manager will now be able to increase his or her expenditure on perquisites to point A^{**} while suffering only a relatively small drop in income (from P^* to P^{**}). The new shareholders will, however, be forced to bear the remainder of the associated reduction in income (from point P^{**} to P^{***}) without benefiting from the increased consumption of perquisites.

Using Jensen & Mecklings' agency framework, risk reduction can then be viewed as an implicit contractual claim (Cornell & Shapiro 1987) between managers/shareholders and all other stakeholder groups. In essence, stakeholders act as the principal and hire managers to reduce the risks that they face. Unfortunately, managers acting in shareholders' interests may not undertake the desired amount of risk reduction, since shareholders will bear the majority of the associated costs without receiving any of the benefits. Interpreting it another way, shareholders benefit from not investing in risk reduction, while the firm's other stakeholders, face most of the costs.

However, even though the firm's shareholders and managers may not share the same risk management objectives as the firm's other stakeholders, it has been suggested that they could still value invest in risk management. Agency theory generally assumes that a principal will be aware of an agent's incentive to attenuate his or her welfare, consequently stakeholders are likely to demand some extra form of remuneration to compensate for any unwarranted exposure to unsystematic risk. Moreover, at the extreme they may even refuse to enter into certain contractual relationships altogether. Shareholders should now, in theory, be forced to bear some, if not all of the costs associated with their opportunistic behaviour, providing them with an incentive to reduce it. In the words of Thompson (1988):

"It follows that all parties have a potential interest in finding a contractual solution which minimises agency costs".

Perhaps the simplest response to risk related agency conflicts is for stakeholders to demand a monetary premium from the firm's managers and shareholders whenever they are exposed to risk. Indeed ever since Adam Smith's observation that workers in unsafe or otherwise unpleasant jobs demand a compensating wage differential numerous authors have explored the risk-return trade offs exhibited by stakeholders[20]. However, it is Viscusi (see 1978, 1979a and 1993) who has perhaps made the largest contribution to this area[21].

The basis for Viscusi's risk-return model is expected utility theory[22]. Indeed in line the traditional predictions of this model Viscusi assumed that stakeholders' compensation demands (or put another way the amount that they will sacrifice in

20 See especially Oi (1973, 1974), Thaler and Rosen (1976) and Rosen (1986).

21 It should be noted that while Viscusi has largely constrained himself to exploring Smith's observed risk-*wage* trade off, his model is equally applicable to predicting the behaviour of non-employees.

22 For more on expected utility theory see Chapter 4.

order to improve their safety) would increase with both the frequency and severity of loss (since the marginal utility of wealth is assumed to be positive) and the degree of risk aversion they exhibit. However, what is much more critical to Viscusi's model is that stakeholders are also assumed to possess state dependent utility functions[23] and consequently would prefer it if they did not experience a loss (see Cook & Graham 1977, Viscusi 1978). It is this assumption that is then used to illustrate why workers will demand high, in fact increasingly high, compensating differentials for risks that they would rather avoid.

Figure 2 about here

Figure 2 illustrates Viscusi's risk-return model for two firm-specific groups of expected utility maximising stakeholders labelled 1 and 2 and the stakeholder market as a whole - as denoted by the curve XX[24]. Given the state dependent nature of losses, the indifference curves[25] for each individual stakeholder group (as denoted by EU_1 and EU_2 respectively) as well as the global risk-compensation curve are a positive and *strictly convex* function of stakeholders' exposure to risk. Thus not only will exposure to higher levels of risk yield greater compensation demands from stakeholders but these demands will also rise at an increasing rate. As such managers and shareholders

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23 State dependent losses permanently lower an individual's welfare. Such losses are usually assumed to be physical in nature (loss of limbs, brain damage etc.), however, even financial risks may appear to be state dependent if such losses permanently lower an investor's mean returns.

24 The curve XX represents the points of tangency between each individual firm's offer curve and its stakeholders' constant expected utility loci (i.e. their indifference curve).

25 In this case these indifference curves denote combinations of risk and compensation that yield the same level of utility.

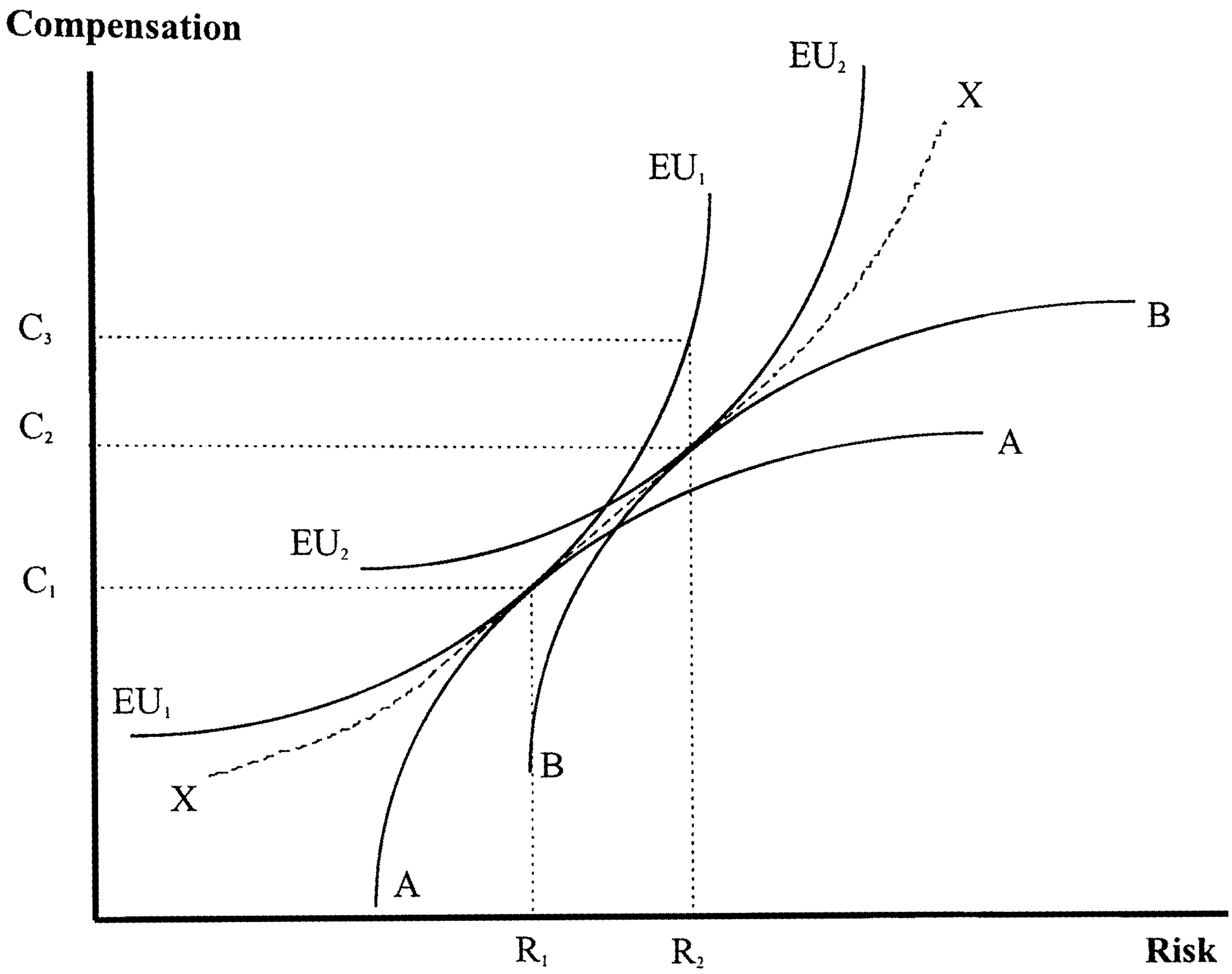

Figure 2: Viscusi's Risk Return Model

that expose their employees to risk should quickly pay the price. For example, in the current example a firm with the offer curve AA (which denotes the optimal combinations of risk and compensation offered by the firm to stakeholders) would attract stakeholders with the indifference function EU_1 (since this is tangential to AA). These stakeholders will then be prepared to bear a level of risk R_1 in return for the compensating differential C_1. However, if the firm wanted to increase its stakeholders' exposure to risk to R_2 it would have to pay at least in C_2 compensation in order to attract a new group of less risk averse stakeholders with the indifference function denoted by EU_2 (which is tangential to the new offer curve BB). Note also that if the firm was to expose its existing stakeholders (group 1) to this level of risk they would require a much higher and in fact Pareto inefficient level of compensation (C_3) relative to group 2.

Interestingly many labour and consumer market studies appear to support Viscusi's hypothesised positive relationship between risk, risk aversion and stakeholders' compensation claims (see Viscusi 1993 for a comprehensive review). Moreover they have also revealed that stakeholders are often extremely risk averse, attaching significant values to both their lives and their continued financial well-being. In fact estimations of an individual's value-of-life have ranged from $3 million to as high as $8 million (1990 US$) for a fatal injury and $25,000-$50,000 for a non fatal one. These results have also been supported by a number of questionnaire based studies that have attempted to assess stakeholder's own opinions about the costs associated with the risks that they face. Again stakeholders (although consumers and employees in particular) have often been found to be willing to sacrifice substantial amounts of income to reduce even comparatively small risks (see Jones-Lee et al 1985, Gegax et al 1991, Rundmo 1992, Rodgers 1993 and Evans & Viscusi 1993)[26].

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26 However this research must be interpreted with care. The labour market studies are often

Faced with the possibility of sizeable ex-ante (i.e. pre-loss) compensation claims from stakeholders a firm's shareholders might well be expected to try to reduce these demands and thus increase their profits. Risk management expenditure should then occur up to the point where the marginal cost of risk management equals its marginal benefit in terms of a reduction in stakeholder compensation claims. However, although certain stakeholders in certain situations may be able to motivate expenditure on risk management in this way the effectiveness of such a free-market based solution to the Pareto efficient allocation of risk is by no means certain. Indeed just as particular market imperfections such as indivisible assets may prevent stakeholders from personally eliminating their exposure to risk other imperfections may also constrain their ability to get the firm's self-seeking owners or managers to do it for them. In the literature these imperfections are commonly known as: "transactions costs".

In a pure CAPM world stakeholders are assumed to operate under a free market mechanism (just as in classical economics) that will allow them to buy and sell all the goods, services and investments (including risk transfer/reduction devices) that they are willing and able to pay for or supply. However it has long been recognised (Coase 1937) that in the real world the free market model will not lead to a Pareto efficient allocation of resources because of certain constraints, or what Arrow (1969) and later, Williamson (1975) termed: transactions costs[27]. Numerous transactions costs have

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based on inconsistent and unreliable accident reporting procedures (i.e. the definition of a "serious" accident often varies) meaning that they are likely to have either over or under-estimated any true risk return trade-off. Furthermore while the questionnaire work does admittedly circumvent this problem by considering the opinions of employees directly, it is likely to have encouraged perceptual bias in respondents as a result of framing and mental availability effects (e.g. Tversky & Kahneman 1973, 1981). For a more detailed discussion of these criticisms see Chapter 3, section 2.

been identified, but perhaps the most significant for risk management are those associated with information gathering (see Easterbrook & Fischel 1985, Skogh 1989, 1991, Grillet 1992). Ex-ante (i.e. pre-loss), acquiring and processing sufficient information to allow stakeholders to accurately monitor their exposure to risk is likely to prove highly expensive if not impossible[28] (factories will need to be surveyed, products subjected to numerous tests, financial statements scrutinised, for example). This then restricts stakeholders' ability to assess the risks they face and provides the firm's shareholders with the opportunity to expose them to risks that they have not been adequately compensated for.

Fortunately, many risks can at least be assessed ex-post (i.e. after a loss has occurred). Where possible this may be enough to prevent opportunism in the first place. Stakeholders who realise that they have been unwittingly exposed to risks that they have not been adequately compensated for are likely to either cancel or attempt to re-negotiate their contracts. This represents a cost to shareholders who should go onto realise that failure to invest in risk management can lead to higher compensation claims in the future or even the loss of valuable contracts altogether (see Viscusi 1979b & 1980).

However, it should be noted that the threat of ex-post contractual re-adjustment is not always going to be an effective deterrent for managerial and or shareholder opportunism. One major issue is the time it can take to gather sufficient information. For example the effects of latent hazards, like radiation or asbestos can take years to materialise - well beyond the natural termination of any contract. This fact can then prevent stakeholders from learning about their true exposure and thus allow

27 See Williamson (1989) for a good review of this literature.

28 See Simon (1957), Williamson (1975) and Hart & Holmstrom (1987) for seminal discussions of information gathering and monitoring problems

shareholders and managers to reduce expenditure on the mitigation of important risks (see Ringleb & Wiggins 1990, 1992; Barney et al 1992). Another obstacle is that information gathering and any resultant contractual negotiations/re-negotiations are public goods. Rational stakeholders will, therefore, attempt to free ride on the efforts of others and will avoid getting involved in costly bargains, preferring to let others pay for these goods and then reaping their non-excludable benefits. Obviously if all stakeholders attempt to free ride (which is likely), they will not be able to either monitor or enforce risk management expenditure and shareholder/manager opportunism will remain unchecked.

Furthermore, even if non-shareholder stakeholders can begin to negotiate with shareholders/managers it is by no means certain that they will be able to achieve a Pareto efficient outcome. One condition for Pareto optimality is that a decision maker will act in an economically rational way, seeking to maximise the value of his or her own personal utility function. Unfortunately, many individual stakeholders may not behave rationally (i.e. in this case not in accordance with expected utility theory). Instead individuals who have to make difficult decisions in environments where little information is available, and where the outcomes may be highly undesirable, are known to resort to 'rules of thumb' (heuristics) which depend more on their perceptions of the risks involved than any objective criteria[29]. The presence of heuristics in the decision making processes of even a few stakeholders can then have serious implications for Pareto efficiency. As Ringleb & Wiggins (1992) point out, irrational individuals who have no direct experience of the risks they face are more likely to under rather than over estimate their impact (this is known as the availability heuristic - Tversky & Kahneman 1973). These irrational stakeholders may, therefore, be prepared to accept very low, Pareto inefficient risk premiums for the risks they

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29 See Pidgeon et al (1992) and Shiller (1997) for good reviews of the heuristics literature.

face, providing rational stakeholders with a rather stark choice: either they refuse to enter into contracts (and receive nothing) or engage in high risk ones which generate sub-optimal (but positive) levels of return.

Finally, where stakeholders cannot properly assess risks, they may be equally ill-equipped to evaluate the effectiveness of risk management mechanisms designed to reduce them. Shareholders could abuse this, providing cheap minor improvements which appear to indicate their commitment to stakeholders but in the end prove ineffective. Again rational stakeholders should be aware of this, however this may still not lead to a Pareto efficient allocation of risk. Fearing that all safety improvements may be worthless stakeholders might even refuse to lower their compensation claims for real improvements in safety, thereby further reducing a firm's incentives to invest in risk management.

3.2 *The Role of Governments in Motivating Risk Management*

When market forces are perceived to be ineffective a common solution is government intervention. As such is hardly surprising that where poorly diversified stakeholders are unable to prevent themselves from being exposed to "excessive" levels of risk some researchers have suggested that they may receive assistance from the government[30]. Yet the attitudes of the modern finance approach towards government intervention is somewhat ambiguous - with just as many authors arguing that it will do harm than those who suggest it may do good.

Government intervention in risk markets typically takes the form of statutes in either civil or criminal law. Perhaps the most prevalent form of civil protection from risk is

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30 See Viscusi et al (1992) for a detailed discussion on the role of government intervention in risk management.

the concept of legal liability. In its most basic form the principle of legal liability allows a person (or group) to sue (i.e. seek monetary compensation from) any party that has negligently exposed them to physical or financial loss. The suggested advantage of this system is that it allows stakeholders to receive compensation for losses ex-post, even when they initially underestimated or were forced to accept such risks (Spence 1977a). This it is argued should then provide shareholders and managers with a powerful ex-ante incentive to invest in risk management since no matter how long a risk takes to materialise they will end up having to pay for their opportunism (e.g. Shavell 1984a). However, if liability suits were truly effective they would rarely occur. Unfortunately they are rather common (especially in the USA), a fact which does rather question their total effectiveness.

One question over the total effectiveness of legal liability suits is that the actual level of compensation paid is sometimes insufficient to cover the financial consequences of a stakeholder's losses. The trouble with this is that where stakeholders are not fully compensated shareholders and managers will not bear the full cost of their opportunism and as such will be less inclined to prevent it. A possible cause of this problem highlighted in the modern finance literature is that a firm's owners may turn out to be "judgement proof" - possessing insufficient funds to fully compensate stakeholders for the consequences of their actions (Shavell 1986)[31]. Moreover, it has even been suggested that firms might be able to avoid paying certain liability claims altogether by spinning-off hazardous activities into smaller, legally separate, process specific companies (Ringleb & Wiggins 1990 & 1992, Barney et al 1992). However, for many the advantages of such a strategy are often outweighed by the associated costs. External suppliers can act opportunistically and lower the quality or raise the

31 As Shavell (1986) notes this is especially likely to occur in firms which possess limited liability.

price of inputs. Also, given the risks associated with the assets for sale, buyers may be unwilling to purchase them (except for a very low price) and firms eager to maintain a good reputation may prefer to control these assets so as to avoid any future bad publicity. Finally with the possible introduction of new retroactive and joint and several liability laws (see section 4.3 below), divestment may no longer protect previous owners from civil actions.

It is also worth noting that where stakeholders' utility is "state dependent" the ability of liability suits to promote risk management expenditure can be further attenuated (see Cook & Graham 1977, Viscusi 1980). For example, sufficiently serious injuries (loss of limbs, permanent breathing problems, death etc.) that permanently affect an individual's mental and physical health can rarely be adequately compensated for ex-post. Courts have admittedly attempted to attach financial values to state dependent losses, however, this has often lead to excessive compensation awards[32]. Excessive awards challenge the effectiveness of liability suits. The prospect of very high compensation awards can encourage moral hazard on the part of the plaintiff who may attempt to misrepresent the size of their loss or even participate in deliberate contributory negligence. In addition, larger awards increase the chance that a firm may turn out to be judgement proof and could even raise its incentive to seek socially undesirable ways to avoid them (either by divestment or by hiring top lawyers to exploit legal uncertainties) - circumstances which are likely to lead to a reduction rather than an increase in risk management expenditure (Ringleb & Wiggins 1990).

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32 Indeed as Viscusi et al (1992) point out, since the 1970's compensation awards have contained ever growing allowances for non-economic factors (such as mental anguish or pain and suffering). A result which would appear to indicate that liability claims are not being based upon objective economic criteria, but rather the whims of judges and jurists.

Finally perhaps the "biggest" (Freeman & Kunreuther, 1996) suggested problem with liability suits is that it is often very difficult to establish a causal link between exposure to a particular hazard (especially latent ones) and the alleged losses of a plaintiff. This can then lead to opportunism on the part of both the plaintiff and defendant with each party exploiting legal uncertainties for their own advantage. For example, the defending firm might try to avoid punishment even though it (privately) knows that it responsible, while plaintiffs may unfairly seek compensation for losses they (or some other party) were responsible for[33]. Admittedly the purpose of a law court it to detect and prevent such opportunism, however, the efficiency with which they can do this is questionable. Court cases can lead to both plaintiffs and defendants incurring considerable legal expenses as they argue over who actually caused a given loss. In fact, in some cases these costs can be so great that they far exceed the plaintiff's original compensation claim (see Engelmann & Cornell 1988, Freeman & Kunreuther 1996).

The second main suggested option open to governments is to resort to criminal law. Criminal law based devices usually take the form of regulations designed to directly *prevent*, ex-ante, certain prescribed losses from occurring (see Shavell 1984a&b, 1987, Kolstad et al 1990). Usually these devices are aimed at encouraging a reduction in physical risk. Indeed most developed nations have some form of ex-ante safety regulation designed to protect vulnerable groups like consumers, employees and third parties (for a more detailed discussion of the reasons why see section 4 below) from being exposed to an excessively high risk of injury[34]. Failure to adhere to these laws may then involve the imposition of fines on the firm or even its enforced closure (both temporary and permanent). Moreover, with increasing frequency further

33 Additionally a guilty firm may even be able to avoid detection in the first place (Shavell 1984a&b).

34 See Carter & Crockford (1974, section 6.3) for a review of current UK safety legislation.

penalties are being directed at a firm's senior management - such as fines, imprisonment or removal from office - in an attempt to provide them with a personal incentive to manage risk (for example, see Shavell 1987, Ch. 12).

One of the major supposed advantages with using ex-ante regulation is that the government (or rather its appointed regulators) often possesses superior monitoring abilities over stakeholders in terms of both information gathering and processing powers (see, for example, Shavell 1987, Ch. 12, Viscusi et al 1992, Ch. 10). In addition, since government regulators are formally employed to monitor firms they should have less of an incentive to free ride. However, despite the superior skills and incentives possessed by government regulators even they are unlikely to be able to ensure a Pareto optimal allocation of risk. One problem is that government regulation can sometimes not go far enough with certain major risks being under regulated (see Shavell 1984a, Hood et al 1992)[35]. Moreover others have argued that the effectiveness of existing regulations can be seriously attenuated when they are ambiguously worded (Gun 1993), too complex or improperly enforced (Genn 1993)[36].

Surprisingly authors such as Schneider (1992) and Di Mauro (1994) have even suggested that over regulation can lead to a reduction in risk management expenditure. Admittedly their argument is based on the unproved assumption that risk management expenditure is largely a fixed cost, however, it is hard to reject the fact that some (if not all) elements of risk management expenditure are fixed. Then

35 Although the deleterious effects of under regulation can sometimes be reduced where civil liability laws are used in conjunction with ex-ante regulation (see Shavell 1984b, 1987, Kolstad et al 1990).

36 For example, in a study of UK health and safety regulations Genn (1993) revealed that inspectors paradoxically made more frequent visits to large firms even though it was the smaller ones that tended to have a poorer safety record.

providing that increased compliance costs cause a reduction in output (which unless demand is perfectly inelastic is likely) they argue that the average unit cost of a firm's risk management programme will also rise. This will in turn rationally prompt a reduction in risk management expenditure - since its fixed cost is now spread out over a smaller level of output - and possibly even an increase in risk.

3.3 *Will Shareholders and Managers Always Want to Expose the Firm's Other Stakeholders to Excessive Levels of Risk?*

Where stakeholders are unable to prevent excessive exposure to risk and government regulation proves ineffective there would not seem to be much if any role for risk management. However, even in such circumstances researchers in the modern finance approach have suggested that the value of risk management to shareholders and managers is rarely zero. The following section explores the reasons why.

One interesting possibility is that managers may be much more risk averse than the people they represent - shareholders. If this is true then managers should be able to enforce increased investment in risk management, despite shareholders' wishes to the contrary. For example, Parry & Parry (1991) argue that if managers are exposed to the risk of personal liability suits or criminal prosecution they may require investment in risk management as part of their remuneration package. Furthermore, authors such as Donaldson (1963), Amihud & Lev (1981), Smith & Stultz (1985) and May (1995) have even suggested that there may be an agency conflict between shareholders and their managers who could opportunistically invest in reducing the risks of financial distress and bankruptcy[37]. This, it is argued, is due to the considerable firm specific capital that managers may have invested in a firm (both pecuniary and non-

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37 Note that where outside shareholders possess large block holdings managerial opportunism is likely to be attenuated (e.g. see Amihud & Lev 1981).

pecuniary), coupled with the labour market stigma associated with being involved in a failing/failed firm.

Yet, the hypothesis that managers are more risk averse than shareholders is by no means certain. Indeed Mayers & Smith (1982) have even argued that since managers can possess shorter time horizons than shareholders they may actually expose shareholders to too much risk. However, more recent studies have shown that the exact behaviour of managers will often depend on their reward structure[38]. It has, for example, been demonstrated that managers who receive the bulk of their remuneration as a normal salary (or profit/"performance" related pay) are likely to behave in a risk averse way. On the other hand, those that possess large common stock holdings[39] or share options are much more likely to exhibit risk preferring/neutral preferences (see Agrawal & Mandelker 1987, Lypney 1993, Tufano 1996). Moreover, a number of empirical surveys into managerial attitudes towards risk illustrate that managers do take risks and that senior managers in particular are not very risk averse (MacCrimmon & Wehrung 1986 & 1990, March & Shapira 1987).

Another rather enlightened approach to justifying investment in corporate risk management has been to suggest that even shareholders may be directly concerned about risk. The basis for this argument is the observation that although shareholders may be indifferent to any unsystematic variability in their firm's long term cash flows they will still care about the direct effect that risk can have on the mean level of these

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38 See Oviatt 1988 for a review of managerial incentive mechanisms.

39 Although May (1995) does provide some evidence to indicate that where a CEO's stock holdings represent a sizeable portion of their wealth they are likely to expend more of "their" firm's resources on risk reduction.

flows and hence the value of their firm (see especially Shapiro & Titman 1985)[40]. Indeed as will be shown in Chapter 4 there are numerous circumstances in which the presence of risk may serve to directly reduce a firm's expected market value (or even its short run profits), however, current risk management research has largely focused on just two cases - the transactions costs of bankruptcy and taxation.

In the real world liquidating a firm's assets is generally costly. Upon bankruptcy firms face numerous legal and administrative costs (see Warner 1977) as well as losing the value of any outstanding tax credits (De Angelo & Masulis 1980) or investment opportunities (Myers 1977). Thus in the presence of a positive risk of bankruptcy (i.e. where the firm has purchased debt[41]and faces unpredictable fluctuations in its cash flows) it has been argued that these costs should serve to lower the expected cash flows of a firm and thus decrease its return on equity (e.g. Mayers & Smith 1982, Shapiro & Titman 1985, MacMinn 1987, Rawls & Smithson 1990). If risk management can, therefore, help to prevent these bankruptcy costs by reducing the probability of bankruptcy the argument then goes that its presence should be able increase the firm's mean cash flows and thus the value of levered equity.

With respect to taxation it has been suggested that investment in risk management can help to reduce a firm's tax liabilities in one of two main ways (see Mayers & Smith 1982 & 1990, Main 1983b, Rawls & Smithson 1990, Eeckhoudt et al 1997). The first tax related benefit derived from risk management is very similar to the case of

40 Of course, just like every other stakeholder group shareholders will be concerned about systematic risk. However, while risk management devices may be able to alleviate the impact of some systematic risks (for example, earthquakes and floods - see Doherty 1985, Kunreuther et al 1993) they are usually more effective at dealing with unsystematic ones (see Dufey & Srinivasulu 1983).

41 Without debt a firm cannot in theory go bankrupt.

bankruptcy costs outlined above. All losses are tax deductible after they occur (ex-post), however risk management expenditure (such as insurance), is deductible pre-loss (ex-ante). Hence by investing in risk management the firm is able to write off its loss related expenses earlier than if it simply allowed losses to happen and then financed them ex-post. Tax payments are thus delayed enabling the firm to reduce its future tax costs and increase expected cash flows. The second benefit, however, is rather different, relying on the existence of a convex tax schedule.

Figure 3 about here

As shown in figure 3, a progressive tax code or one with carry forward or back provisions creates a strictly convex tax schedule in which the effective tax rate rises (at an increasing rate) with a firm's pre-tax income. Now imagine that without risk management the firm faces an equal (50%) chance of experiencing two possible states of nature: one in which the firm earns a low pre-tax income PTI_1 and another in which it receives the higher income PTI_2. At the lower level of income the firm pays a level of tax T_1, while at the higher income this rises to T_2 giving it an expected tax liability of E(T)[42]. However, with insurance or risk management the value of E(T) is likely to fall. Risk management which reduces the variability of a firm's pre-tax profits will move PTI_1 and PTI_2 closer together thereby reducing the firm's expected tax liabilities - up to a maximum of $T(PTI_{MEAN})$ where all risk is eliminated[43].

In the light of the above discussion it would seem that even when both governments and poorly diversified stakeholders are unable to force investment in risk management circumstances may arise when managers and shareholders will

42 Where $E(T) = [0.5*T(1)] + [0.5*T(2)]$

43 Note that this is an application of Jensen's Inequality. For more information on this see Chapter 4, section 3.3.

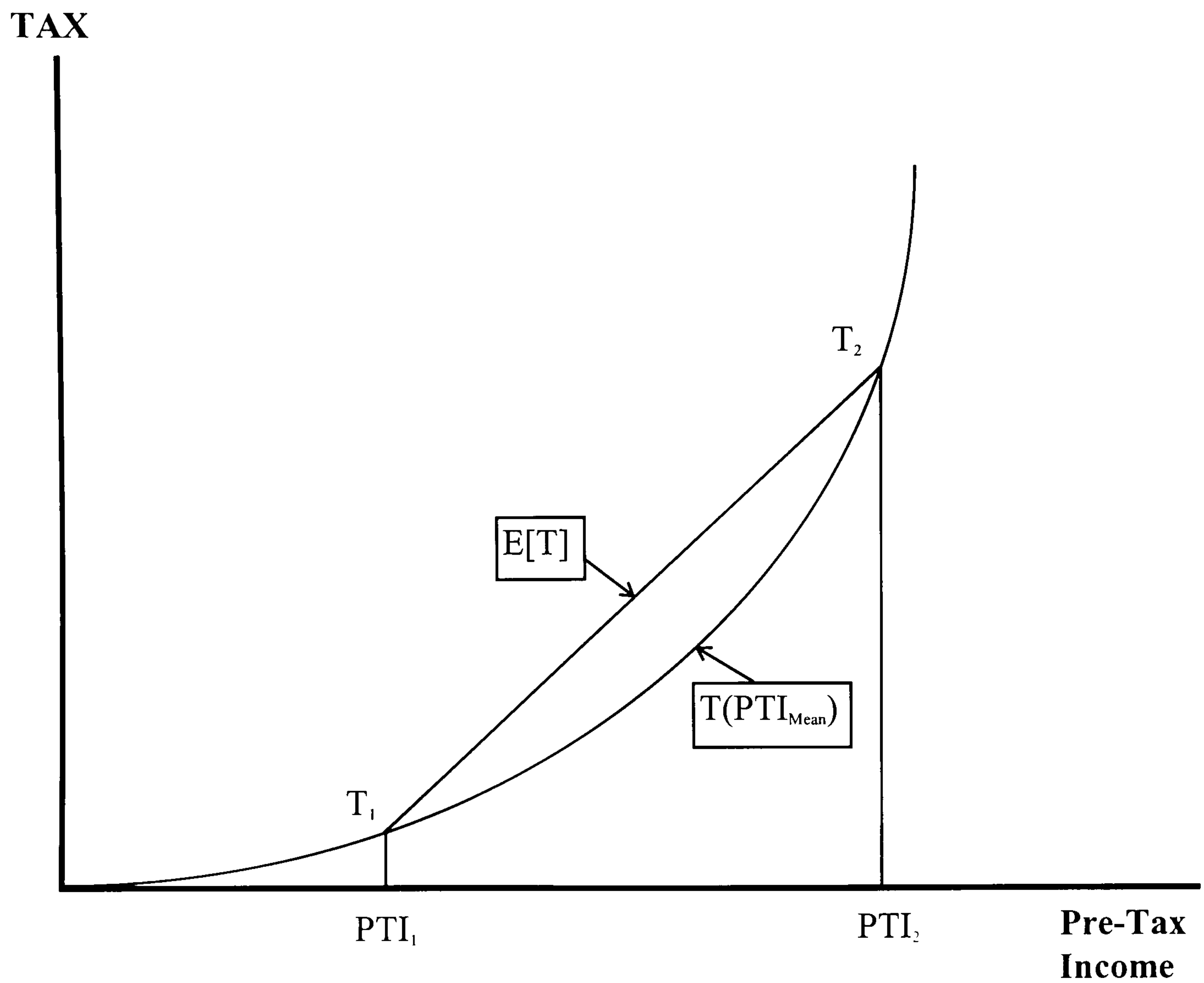

Figure 3: Incentives for Risk Management with a Convex Tax Function

unilaterally reduce a firm's exposure to risk. However, the scale of any bankruptcy or tax related incentives for risk management should not be over-estimated. For example it has been argued that the costs of bankruptcy are largely non-existent (Miller 1977) or at worst very small (Haugen & Senbet 1988)[44]. Moreover the tax benefits of risk management can be slight where a firm faces does not face a strongly convex tax function (e.g. as in the UK where there is a single rate of corporation tax of 30%). In short, even if shareholders' and managers' do benefit from reductions in risk their preferred levels of investment in risk management are still likely to be far below those desired by other stakeholders[45].

Where risk averse stakeholders or governments are unable to encourage investment in risk management and the firm's shareholders and managers are largely (if not completely) indifferent to risk the situation would seem to be quite bleak. Yet, even in such an environment it has been suggested that risk management - or rather certain specific risk management tools - may still be of value to a firm. However, rather than providing a simple reduction in risk the role of risk management in this context is perceived to be rather different. Instead it is claimed that risk management may also be used to help improve the efficient functioning of "risk markets" (e.g. see Easterbrook & Fischel 1985, Katzman 1985, Holderness 1990, Skogh 1989, 1991, Grillet 1992, Freeman & Kunreuther 1996).

The argument goes that if non-shareholder stakeholders or governments are unable to

44 Although Summers & Cutler (1988) provide evidence that this need not always be the case. They reported that upon filing for bankruptcy in 1987 the value of Texaco's equity fell by $817 million.

45 Indeed as Genn (1993) points out real world managers are often quite unconcerned about small losses (such as the injury of one employee) which do not threaten the solvency of their enterprise.

cost effectively ensure adequate investment in risk management, risk markets may break down with certain stakeholders refusing to participate in the operations of the firm altogether (or at best charging very high rates of compensation). Cessation of trade is not, however, a very desirable situation for shareholders or managers. Instead it is logical to assume that they might well try to find some way to credibly commit themselves to investment in risk management and thus signal their willingness to meet the wishes of their fellow stakeholders (see Smith & Williams 1991).

The primary commitment device that has been proposed in the literature is conventional external insurance. Relative to stakeholders and governments insurance companies often possess a comparative advantage in terms of monitoring and constraining the opportunistic behaviour of shareholders, at least in relation to firm specific, pure, risks[46]. Firstly insurers are specialist information gatherers and are able to collect and accurately process information at a lower cost than anyone else. Secondly by agreeing to indemnify stakeholders in the event of certain specified losses insurers possess a vested interest in ensuring that they do not occur.

There are, however, alternatives to insurance. Indeed in some cases insurance may prove to be quite ineffective. The problem is that even insurance companies can sometimes lack the information necessary to monitor and constrain the actions of shareholders and their managers[47]. Consequently where the cost effectiveness of insurance is low, firms may prefer instead to exploit retention funds, captive

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46 In fact as both Katzman (1985) and Freeman & Kunreuther (1996) have pointed out it is often better for government regulators to leave the enforcement of environmental legislation to insurers because of their superior monitoring abilities.

47 This is especially likely for firms operating in areas of rapid technological change and or those which face a risk of low frequency but high severity losses (see Doherty & Smith 1993).

insurance companies or other risk financing devices (such as derivatives). In fact self-insurance arrangements are likely to be just as effective at constraining shareholder opportunism (if not more so) as conventional insurance since shareholders will be forced to bear the full cost of their actions.

In short, risk management has been seen as not just a device to reduce risk but also as a means to prevent opportunism and align shareholders interests with those of the firms more risk averse stakeholders. Whether in conjunction with insurance, self-insurance, government or direct stakeholder sanction, risk management may be able to function as a bonding device. In so doing it monitors and constrains shareholder and manager opportunism and signals their commitment to serving the interests of *all* stakeholders.

4. The Value of Risk Management to Individual Stakeholder Groups

One of the primary advantages of the modern finance approach to risk management is that it can be applied to all the stakeholder groups that comprise a firm. However, despite the widespread applicability of the basis tenets of the approach, the exact risks faced by different stakeholders and the extent to which agency and transactions costs may impact upon them is often claimed to vary. The purpose of this section is, therefore, to examine rather more closely the implications of the issues raised in section 3 in relation to several specific stakeholder groups.

4.1 *Employees*

Employees are exposed to the risks of both physical injury and redundancy - risks which they generally cannot remove for themselves. When faced with a high risk of physical injury or redundancy a firm's employees are likely to require some form of extra compensation in the form of higher wages. They may also lower their productivity, leave the company[48] or sue their employers for negligence in the event of physical injury. In addition there are a number of health and safety regulations (for example, the Health and Safety at Work Act 1974) designed to protect employees, and failure to comply with these laws can lead to the imposition of fines and possibly even the imprisonment of senior managers.

With respect to their exposure to physical risks employees are often thought to be powerful bargainers, even in the absence of liability laws or government regulation. Many possess valuable firm specific skills and or are represented by unions and professional associations that reduce information gathering costs and help prevent free riding (e.g. see Viscusi 1980, 1983). Indeed authors such as Gegax et al (1991) have reported that, when compared to non-union employees, unionised workers often demand greater levels of compensation for the risks they face. Moreover, even in the case of latent hazards employees are often quite well informed. As Barney et al (1992) point out, employees are often aware of the fact that their jobs are hazardous but are prepared to risk injury because of the relatively high wages they receive[49].

Despite the apparent market power of employees Viscusi (1993) has suggested that in economic downturns - where the supply of labour exceeds its demand - even unionised employees may be unable to negotiate efficient contracts that reduce or adequately compensate them for the risks that they face. However, while shareholders and managers may be better able to exploit their employees during recessions, such a move will not attract a high quality work force. Poor quality staff may cause a firm's

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48 Viscusi (1993) claims that if an employee's exposure to physical risk could be eliminated, manufacturing quit rates in the USA would be reduced by up to one third.

49 Although as Barney et al admit these risk-wage premiums tend to be rather small when compared to the risks faced.

productivity to fall (see Doherty 1985 Ch. 2), thereby providing managers with an incentive to engage in loss prevention expenditure even when employees' bargaining power is weak. Similarly Doherty (1985) has also suggested that investment in risk management may also raise the productivity of a firm's work force by helping to prevent post loss disruptions in production. If machines or inputs are lost (as a result of fires, breakdowns etc.) the marginal productivity of labour may fall - since there will either be too many workers relative to the number of remaining machines or they will simply run out of inputs to assemble.

In addition to protecting employees against physical injury shareholders and managers may also wish to protect them from the risk of redundancy. By helping to prevent large losses which may cause bankruptcy and financial distress, it has been suggested that risk management could help to decrease wages, lower labour turnover and increase productivity (see Shapiro & Titman 1985, Smith & Stultz 1985). Firms which face a high risk of bankruptcy will either have to significantly increase worker salaries or lose their most productive personnel as they move to more secure jobs, furthermore Brockner et al (1992) have reported that even those employees that stay are likely to reduce their productivity. At very high levels of redundancy risk Brockner et al revealed that employees become apathetic, deciding to reduce their productivity and relax, since they believe that they are unlikely to remain with the firm for long. However, they also warn that if employees feel too safe in their jobs productivity will fall again. When the risk of bankruptcy is low employees prefer to pursue their own objectives (for example on the job leisure) since there is little fear of redundancy.

Thus given the relative bargaining power of most employees and their ability to collect and process information effective risk management expenditure that reduces the risks they face is likely to be imperative even without government intervention.

However, there are invariably groups which can be exploited: the non-unionised, the very poor or uneducated, illegal immigrants etc.. As a result some form of government regulation or compulsory insurance arrangement (Employers Liability and National Insurance in the UK and Workers Compensation in the USA) is always likely to be necessary.

4.2 *Consumers*

Consumers are exposed to the risk of physical injury if a product malfunctions and the possibility of financial loss if the firm is unable to honour product guarantees or provide continuity of supply (Shapiro & Titman 1985). Because of marketability and divisibility problems consumers can often find it very difficult to diversify away the effects of such risks, however, a considerable amount of evidence exists to indicate that the incentives they generate to get firms to do it for them can be considerable. One useful incentive device possessed by consumers is the ability to exert a degree of market power. The implication being that consumers who fear that a firm may be exposing them to an undesirable level of risk will often be able to punish such behaviour by switching to a safer supplier instead.

Much of the evidence in support of the hypothesis that consumers will not knowingly deal with firms that expose them to excessive degrees of risk is anecdotal. For example, Shapiro & Titman (1985) report that when Chrysler, an American car manufacturer, was near to bankruptcy it found it very hard to encourage consumers to buy its cars (largely because they feared the implications that this might have for the availability of spare parts and the validity of any guarantees). Similarly, scares about the safety of asbestos in the 1970's and 80's have all but destroyed the industry and similar scares appear to be ruining the reputation of its substitute, fibreglass (Sells 1994). Finally, another interesting example of the market power of consumers was Source Perrier's rather exuberant response to the presence of above regulation levels of Benzene in what was probably only a few batches of Perrier in 1990. Source Perrier actually recalled the entire world supply of Perrier for over a month at cost of FFr430m (FT 11th May 1990). However, had Source Perrier not withdrawn Perrier its reputation for purity could have been lost causing sales to fall considerably.

In addition to the available anecdotal evidence a number of formal studies also appear to indicate that consumers are able to punish firms that expose them to excessive degree of especially physical risk. There is, for example, the work of Jarrel & Peltzman (1985) who provide evidence that product recall announcements in the drug and auto industries lead to an average six percent decline in the value of a firm's equity. Similarly Jones-Lee et al (1985), Rodgers (1993) and Evans & Viscusi (1993) have all reported that consumers are often prepared to pay significantly higher prices in order to improve the safety of the products they buy[50].

However, it should be noted that opinions regarding a consumer's ability to encourage risk management are not all positive. Of particular relevance is the work of Bromily & Marcus (1989) who directly challenge Jarrel & Peltzmans' result[51]. Using a longer event study they revealed that the equity value of a firm usually rebounds to its original level within a week and in some cases rises even higher. This Bromily & Marcus claim would seem to suggest that consumers (and to some extent shareholders) are unaware of the true impact that poor product safety might have upon their welfare. Yet, Borenstein & Zimmerman (1988) argue that such rebounds are simply the result of shareholder expectations that consumers will often forgive the occasional accident, providing that the firm has a good overall reputation for safety[52].

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50 Further studies do exist, see Viscusi (1993) for a review.

51 See also Davidson et al (1987).

Furthermore, using the result of a questionnaire survey Jones-Lee et al (1985) revealed that consumers are often prepared to pay far more for observable safety improvements than they will demand in compensation for equally obvious deteriorations in safety. This implies that while equity values may be unaffected by the occasional accident, firms should still want to improve the safety of their products because of the significant premiums they can load onto the prices of their products.

Despite the apparent market power of consumers in relation to some risks it is still possible that they may not always be able to encourage Pareto efficient levels of investment in risk management on their own. One major problem is the latency of certain physical hazards (such as the risk of expose to harmful chemicals like DDT). With a latent hazard there may be a considerable delay between consumption and injury, a factor that can prevent consumers from quickly (if ever) learning about their exposure to risk and seeking adequate compensation from firms[53]. Moreover, a consumer's involvement in potentially thousands of different companies means that for less obvious risks they can sometimes experience very high information gathering costs and free-rider incentives. Admittedly a number of non-governmental pressure groups do exist to help consumers achieve reductions in risk (for example, the Consumer's Association, that publishes WHICH magazine), however, such groups often lack the resources to deal with every issue. As a result it is possible (e.g. Viscusi et al 1992, Ch. 23) that consumers may also need to be protected by ex-ante government regulations (such as minimum product safety standards) and in relation to physical risks strict liability laws[54].

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52 For more on this literature see Chapter 3, section 2.

53 For more on this see section 3 above.

54 See Carter & Crockford (1974, section 6.3) for a list of UK consumer related statutory safety requirements.

Strict liability is a rather different and perhaps even more contentious concept to the conventional type of negligence based liability described above. In the current context strict liability implies that when a consumer alleges that he or she has been injured through the use of a defective product they do not need to prove negligence on the part of the retailer or manufacturer only that there exists a causal link between the injury and the product's defect (Consumer Protection Act 1987). The claimed main advantage of strict liability is that it should encourage firms (or more specifically managers and shareholders) to better police their own activities and consequently increase expenditure on risk management (see Freeman & Kunreuther 1996). However, Grillet (1993) criticises the use of strict liability rulings. He argues that if managers and shareholders are unable to defend against large liability claims they may develop a fatalistic attitude towards risk control. The danger then is that they may reduce their firm's expenditure on safety - because they believe that they will face large and potentially solvency threatening liability suits even if they have an effective risk management programme. Moreover, rather than preventing opportunism and increasing Pareto efficiency Grillet also argues that the additional costs imposed by strict liability rulings may simply increase managers' and shareholders' incentives to find ways round liability claims (see section 3.2 above) or where this is not possible lead to certain products from being withdrawn altogether.

4.3 *Third Parties*

Externalities occur where the welfare of third parties is influenced by activities in which they have no direct involvement[55]. In classical economic theory activities that

[55] In fact third parties are sometimes known as "involuntary stakeholders" (Easterbrook & Fischel 1985).

enhance an individual's or firm's utility/profits are assumed to increase social welfare by the same amount. However, in practice activities that enhance private interests may either damage social welfare or increase it by a sub-optimal amount (this is known as a positive externality)[56]. Economic activities create numerous externalities, however, one of the most common is the negative externality of environmental pollution. Pollution represents a significant cost to society, both financially (in terms of cleanup costs, reductions in property values) and physically (e.g. injuries, latent illnesses etc.), although it is a cost that can be reduced through the use of risk management.

Even though third parties have no direct economic relationship with a firm they can still influence its decisions. Indeed in a perfect market Coase (1960) has even argued that market forces represent the best solution to most externality problems, the only governmental role being the assignment and enforcement of property rights. Then who pays for the externality should simply depend upon whether the firm (or rather its managers and shareholders) has a legal right to pollute or affected third parties have a right to prevent it. Either way the adverse effects of pollution (or indeed any other externality) are prevented without any loss of Pareto efficiency, although one side will obviously be more satisfied than the other.

Perhaps in recognition of the state dependent nature of their utility functions (see section 3.1) third parties are generally assigned the right to prevent pollution (at least this is the case in most developed nations). However, whether third parties can really do this effectively is open to debate. For example, gathering information on environmental hazards is likely to prove highly expensive and time consuming, especially since many are latent hazards the effects of which may take years to fully

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56 For a good discussion of this topic see Gravelle & Rees (1992, Ch. 18).

materialise. Moreover, free riding is likely to be a significant problem. Unlike the risks that employees and consumers are exposed to pollution is often a global matter (e.g. the depletion of the ozone layer will affect the entire planet), consequently an individual's incentive to help prevent pollution is likely to be very small since they will appropriate only a minute proportion of their action's benefits (see Viscusi et al 1992, especially Ch. 21).

Partly in response to the significant problems of imperfect information acquisition and enforcement environmental safety regulations and liability laws are often both numerous and severe[57]. For example, in developed nations ex-ante regulations typically dictate quite stringent minimum safety standards or maximum pollution levels and non-compliance can lead to significant fines and even the imprisonment of those responsible (see Viscusi 1992, Ch. 21). Environmental liability laws also tend to be quite harsh, especially in America. In fact Muoghalu et al (1990) estimate that the market value of an American firm will fall by, on average 1.2% (which translates into an average cost of $33.3 million) at the filing of an environmental law suit. A result which would appear to indicate that the risk of third party liability suits are a reasonably effective deterrent against shareholder opportunism[58].

The severity of the impact of US law suits on firm value probably stems from the nation's Superfund Act (1980). Under the act firms face joint, several and strict liability for actions that damage the environment. Joint and several liability means

57 Other supposedly less rational reasons for the stringency of many environmental regulations and liability laws include the influence of political concerns, the media and pressure groups who exploit heuristics such as dread and information availability (e.g. see Nelkin 1988, Viscusi 1992, Ch. 19, Hood et al 1992, Yardley et al 1997)

58 Although the strength of this deterrent will also depend on a firm's perceptions regarding whether or how quickly they believe they will be caught and the returns to pollution.

that any firm (supplier, distributor, co-producer etc.) that was involved in a particular pollution episode can be held either partially or fully liable even if is was not directly responsible. The aim of joint and several liability is to encourage firms to monitor each other and ensure that pollution does not take place. However, Grillet (1993) argues that such policies are misguided and can lead to levels of risk taking and pollution that far exceed pre-regulation levels. For example, firms that face large liability suits, even when they were not directly responsible, may decrease their expenditure on pollution prevention since they believe that they will be held liable anyway. To make matters worse Grillet even suggested that an increase in the number and size of liability suits might restrict the capacity of insurance firms to insure such risks. This could then prevent shareholders and managers from exploiting their valuable monitoring function and, thereby, paradoxically increase the chance of opportunism[59].

UK environmental liability laws are much less harsh and for the moment it seems that the creation of more severe liability laws is unlikely (although the recent Environment Act in 1990 does threaten the possibility of joint and several liability for latent hazards in the future - see Dowding 1995). Indeed fortunately for many British firms and insurers a recent attempt to lay the precedent for strict environmental liability failed. In 1993 Cambridge Water tried to sue Eastern Counties Leather for pollution it caused decades ago. However, the House of Lords ruled that firms will not (as yet) be made responsible for pollution damage that could not be "reasonably foreseen" (FT 10th December 1993).

Interesting recent research has also suggested that the need for blunt instruments such

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59 See also Shapiro (1993) for a similar argument in relation to the unlimited liability regime proposed for oil transporters in the 1990 Oil Pollution Act.

as legal liability and direct government regulation is diminishing. Of particular relevance is the work of Klassen & McLaughlin (1996) who in the light of empirical research argue that market forces can have an important role to play in motivating environmental risk management. One explanation for this phenomenon is the increased public awareness of and concern for the dangers of environmental pollution (see, for example, Rosewicz 1990). In addition many people are now willing to pay substantial premiums for products produced by environmentally friendly processes. Indeed firms are now slowly beginning to wake up to this fact. Some like the Body Shop and Ben & Jerrys' (American premium ice cream manufacturers) have already profited from this phenomenon (for example, see FT August 11th, 1994). Moreover, it would appear that firms cannot get away with mere announcements about their environmental commitment but must also back them up with substance. A prime example of this is the controversy that surrounded the Body Shop in 1992/3 when it was claimed in a Channel 4 TV report that it was not as environmentally or animal friendly as it seemed. In the year subsequent to the report both the Body Shop's profits and share price fell substantially an occurrence that is claimed to be at least partially linked to the report (e.g. see FT May 28th 1992, September 17th 1992 and June 26th 1993).

4.4 *Creditors and the Agency Costs of Debt*

Despite the inability of employees, consumers and third parties to diversify away the effects of unsystematic risk, it is likely that the assets of stakeholders such as creditors are sufficiently divisible and marketable to allow them to achieve mean variance efficient portfolios on their own (although often not without some cost). However, what some modern finance based risk management theorists have argued is that the presence of agency and transactions costs can create situations in which even creditors may value reductions in unsystematic risk (see Greenwald & Stiglitz 1990 & 1993).

The basic argument goes that the shareholders of firms in possession of outstanding risky debt will possess an incentive to rearrange its financial structure in order to transfer wealth from creditors to themselves[60]. Unfortunately, while such transfers may increase the value of shareholders' equity they arise out of investment decisions that more than proportionately reduce creditors' returns and hence the overall value of the firm (Chen & Kim 1979).

Jensen & Meckling (1976) were the first to investigate the agency costs of debt. Once debt had been purchased they argued that managers, acting in shareholders interests, would pass up valuable low risk investments in favour of variance increasing projects of lower or even negative expected returns. Shareholders' motivation for such opportunism was the fact that they often possess limited liability and are residual claimants. This situation then enables debt to be likened to a European call option the value of which typically increases with the level of risk faced (Black & Scholes 1973).

The value of a European call option increases with the level of risk because of the rather asymmetric nature of its payoffs - where the monetary payoffs associated with increasingly good states of nature far exceed any losses in adverse ones. In the context of debt purchase, for example, shareholders have essentially sold the firm to their creditors in return for the option to buy it back - in instalments, paid on set dates.

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60 With risky debt creditors face the prospect that they will lose some of their initial capital if a firm defaults. Admittedly they can be protected by me-first rules, however, these are rarely perfect. Even when debt is secured creditors could be left with nothing if a firm's assets are destroyed or prior claims are sufficiently large (e.g. trade creditors, tax demands, fines etc.). Furthermore shareholders might be able to exploit contractual loopholes to invalidate creditor's me-first claims (see Chen & Kim 1979).

Therefore, shareholders will only exercise their option to buy the firm back if it earns a level of return that exceeds their creditors' debt interest payments, otherwise they will simply default and let the creditors keep the firm. Default is relatively costless for limited liability shareholders since they can never lose more than the initial value of their investment stake. However, as residual claimants there is no upper limit on their returns. Consequently, shareholders will prefer to invest in high risk projects which offer the prospect of very large gains and losses since these projects will increase their likely returns without affecting the maximum level of loss. In contrast creditors prefer low risk investments since any increase in risk will only decrease their returns. Unlike shareholders, they receive a fixed return and will not be compensated for any increase in default risk, facing simply an increase in the risk that they will be left with nothing. Easterbrook & Fischel (1985) sum this up quite well: "[b]ecause limited liability increases the probability that there will be insufficient assets to pay creditors' claims, shareholders of a firm reap all of the benefits of risky activities but do not bear all of the costs" .

Myers (1977) discussed another agency cost associated with the purchase of debt: the so called "under-investment problem". He argued that firms in financial distress will (providing that managers are acting in shareholders interests) pass up certain discretionary investments that would only be of value to creditors. For example, assume that a firm experiences a large fortuitous loss which destroys its assets (as a result of a fire or chemical spill etc.). The firm could reinvest and replace its lost assets, however, because of business interruption problems (loss of sales during rebuilding, customer switching costs etc.) it may be unable to make future debt repayments, at least in the short run. Consequently shareholders will not sanction reinvestment since they will be forced to hand the firm over to its creditors whether or not it occurs. Instead they will prefer to keep any available investment funds and issue themselves with a large final dividend of some form[61].

However, despite shareholders' and managers' incentives to act against the wishes of their creditors, many authors feel that the extent to which these two groups may be able to act opportunistically is limited. Creditors often possess both the incentive and the skills to monitor the opportunistic behaviour of shareholders and managers (Easterbrook & Fischel 1985). In addition, they also have the power to seriously punish firms they believe to be behaving opportunistically - by being able to demand significant additional interest charges or even refusing future credit requests altogether (see Mello & Parsons 1992). Risk management is, however, one possible solution to the debt agency cost problem. By reducing the risk that a large fortuitous loss may cause insolvency risk management prevents the transfer of wealth from creditors to shareholders, thereby lowering the cost of debt (Mayers & Smith 1987, MacMinn 1987)[62].

4.5. *Suppliers*

Like creditors, suppliers stand to make a loss if a firm goes bankrupt. As such it has been suggested that suppliers should also value and try to encourage risk management expenditure that helps to prevent this (Shapiro & Titman 1985).

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61 Although many debt contracts contain dividend restrictions shareholders may be able to find ways round them. For example, owner-managers could simply consume extra perquisites.

62 Admittedly other solutions to debt agency conflicts do exist, for example: dividend restrictions, ensuring that debts mature before additional investment takes place, providing creditors with re-negotiation rights and the issuing convertible bonds (see Haugen & Senbet, 1981). However these solutions are often ineffective, impractical or costly so in many circumstances risk management is likely to be the cheapest option (see Kim et al 1977). Indeed MacMinn (1987), Davidson et al (1992) and Khang (1992) all argue that debt agency cost reduction is one of the prime motives for insurance and (more generally) risk management.

In any market transaction a supplier will often incur numerous sunk costs - for example, they will need to negotiate a price, build up client goodwill (by providing business lunches, advertisements etc.) and develop any special modifications to their product. In the event of their client's bankruptcy, however, all these costs will have been wasted. Consequently, firms which are believed to face a high risk of bankruptcy are likely to find that new suppliers in particular will raise the price of their product or even refuse to trade altogether (Shapiro & Titman 1985). Thus by reducing a firm's risk of bankruptcy, managers and shareholders should be able to both increase suppliers' willingness to do business with them and significantly lower input prices.

High risk firms may also find it difficult to get trade credit. Firms who are likely to stay in business will value a good credit reputation since it provides them with an easy and cheap way to borrow money (albeit for a short while). However, if a firm is unlikely to survive it may, in an attempt to forestall bankruptcy, mistreat its trade creditors by delaying repayment for as much time as possible. In addition, if credit is outstanding when the firm goes bankrupt trade creditors may find that they end up with nothing. Of course trade creditors are likely to be aware of this and firms that face a high risk of bankruptcy may well be denied credit or at best be charged high rates of interest (see Shapiro & Titman 1985 for a good discussion of this topic).

5. Conclusions

The purpose of this Chapter was to review the currently dominant modern finance approach to corporate risk management expenditure. In this approach risk is viewed as an implicit contractual claim between on the one hand well diversified shareholders (and their representatives managers), who are largely indifferent to most fortuitous risks and on the other non-shareholder stakeholders (in particular employees, creditors, third parties, consumers and suppliers), who because of various market imperfections (for example, indivisible and non-marketable assets) would prefer to have it removed. Moreover, the argument then goes that the presence of various transactions costs, most notably: information asymmetries, bounded rationality and free rider problem makes it difficult for stakeholders or governments to achieve efficient market solutions on their own (see especially Easterbrook & Fischel 1985). The fundamental role for risk management in this context is then seen as a solution to the twin problems of imperfectly diversified stakeholder portfolios and shareholder or manager opportunism. By helping to alleviate these problems it is argued that risk management should ensure a Pareto efficient allocation of risk for all stakeholder groups. This even includes well diversified shareholders since by lowering the compensation demands of the firm's other stakeholders the presence of risk management should (providing it is cost effective) raise a firm's mean cash flows and hence the value of its equity.

The modern finance approach to risk management has undoubtedly done much to further our understanding of the behaviour of firms in a world of risk. In particular it has rejected the rather negative and unrealistic view that firms' exhibit the same kind of simple risk averse behaviour expected of individuals. Furthermore the theoretical underpinnings of the modern finance approach to risk management are well developed and a-priori at least they would seem quite plausible. However, despite these observations the usefulness of the approach is far from certain. One issue, already discussed in the introduction of this thesis, is that the modern finance approach to risk management stems from a rather narrow theoretical base. Thus while some of the ideas outlined in this Chapter may apply to certain firms in certain situations it is not at all certain that they will be generally applicable. In what follows, however, (see Chapters 4, 5 & 6) it will be shown that economic theory can be used to provide a rather more comprehensive framework to explain the role of risk management in firms.

Furthermore a major problem with the modern finance approach is that the ideas it has spawned have been developed on something of an ad hoc basis. In part this may reflect the real world diversity of firm behaviour under risk, however, such variety restricts the approach's ability to develop a coherent predictive theory of risk management. Indeed all the modern finance approach really attempts to do is explain the past risk management decisions of firms rather than try to suggest what might actually happen in the future. The trouble is that the ideas developed within the approach are based on what can happen when the real world departs from the perfect market assumptions of the CAPM. As such it is founded more on the failure of modern finance theory to explain observed behaviour than its ability to reflect the actual behaviour of firms. A model of risk management that is based on economic theory - which attempts to predict the real world behaviour of firms (see for example Gravelle & Rees 1992, Ch. 1) - should not share this problem. This may then allow us to not only reliably predict whether a particular firm operating in a particular environment will want to invest in risk management but also the impact that its risk management decisions will have on its core business ones (such as what or how much to produce or what price to charge, etc.).

However, before proceeding with an in-depth review of the proposed new economic framework for risk management (see Chapters 4, 5 and 6) it is important to consider the empirical validity of the modern finance approach. The rationale behind this is that even if the modern finance approach does stem from a narrow or potentially unsound theoretical base there is little point looking for an alternative framework if it represents a realistic view of corporate risk management decisions. The next Chapter, therefore, reports the findings of past empirical research into the modern finance approach and the results of some new empirical research conducted especially for this thesis.

Chapter 3:
Empirical Evidence Regarding the Modern Finance Approach to Risk Management

1. **Introduction.**

As was shown in Chapter 2 the modern finance approach to risk management is an amalgam of many different and sometimes conflicting theories, however, while interesting and in certain cases highly plausible (at least a priori) they have not yet received adequate empirical attention. The purpose of this Chapter is, therefore, to provide a more extensive investigation into the practical relevance of the modern finance approach than has yet been attempted.

A considerable amount of empirical research into the practice of risk management already exists, however, the general applicability of the results of these studies is highly questionable. Indeed most studies have focused on specific risk management tools (in particular derivatives and insurance) or industries and often both (see for example Mayers & Smith 1990, Tufano 1996). Others have even gone a step further investigating the behaviour of only one firm or stakeholder group (e.g. Gegax et al 1991, Doherty & Smith 1993, Viscusi 1993 etc.). In response to this lack of breadth the main part of this study reports the results of a questionnaire distributed to a wide cross-section of 127 large UK companies in the Summer and Autumn of 1993. As well as summarising the respondents' motives for the practice of risk management in general, the Chapter attempts to test the validity of the modern finance approach by including an analysis of whether the importance assigned to these motives differs systematically across the sample according to a firm's financial and organisational characteristics and the preferences of its management.

The Chapter proceeds with a critical review of previous empirical work in the area. In section 3 the methodology used for collecting the data in the current survey is addressed and summary statistics presented. Section 4 outlines the main hypotheses and descriptive variables as well as explaining the analytical approach that is undertaken. The results of the analysis are then detailed in section 5 in which it is shown that there appears to be little strong evidence of any systematic relationship between the motives suggested for the practice of risk management and firm organisation or performance. The final section offers a brief summary and some concluding remarks.

2. Previous Empirical Research on the Validity of the Modern Finance Approach.

Almost all empirical research into the applicability of the modern finance approach[1] has suffered from the same problem: the lack of meaningful data regarding firms' risk management activities (Tufano 1996). This dearth of information has lead to quite a variety of ad hoc approaches to testing the theories proposed, however, most of this research can be classified into five main types:

i. Event studies - that examine how the stock market reacts to information concerning a firm's exposure to risk (e.g. Sprecher & Pertl 1983, Cassidy et al 1990, Knight & Pretty 1997).

ii. Stakeholder specific studies - some of which have just used ready published data (e.g. Viscusi 1993), while others have undertaken questionnaire surveys and experimental studies to examine the personal attitudes of respondents towards risk (e.g. Gegax et al 1991, Lypney 1993).

1 See Chapter 2 for a detailed review of the modern finance approach to risk management.

iii. Case studies - in which the motives behind the risk management decisions of either an individual firm or a small group of firms are examined (see Doherty & Smith 1993, Genn 1993).

iv. Studies that have focused on industries and/or risk management tools for which there is published data. (e.g. Mayers & Smith 1990, Tufano 1996).

v. Combination studies - where the results of questionnaire surveys are used in conjunction with published data about a firm's financial and organisational characteristics (e.g. Khang 1992, Nance et al 1993).

The event study was one of the first methods used to test the predictions of the modern finance approach to risk management. In fact as early as 1983 Sprecher & Pertl used this approach to examine the effect that large fortuitous losses (which were roughly taken to mean any loss that was in excess of 10% of a firm's net worth) would have on the value of a firm's equity. Although using only a very small sample (27 firms which experienced large losses between 1969-1978) Sprecher & Pertl did reveal that large losses could have quite a significant impact - reducing the equity value of a firm by around 4%. Many subsequent event studies have also supported the view that shareholders are likely to react unfavourably to the news of non-business related crises such as product recalls or environmental pollution (e.g. Jarrel & Peltzman 1985, Cross et al 1989, Muoghalu et al 1990, Klassen & McLaughlin 1996). Moreover it has even been demonstrated that investment in risk management will generally illicit a positive response from shareholders (e.g. Cassidy et al 1990, Klassen & McLaughlin 1996). However, there is also evidence to the contrary. For example, in their study of the airline industry Davidson et al (1987) did not find any evidence that large losses impact upon a firm's value, while Borenstein & Zimmerman (1988), Bromily & Marcus (1989) and Knight & Pretty (1997) have found that following the announcement of a large loss the equity value of a firm will often quickly rebound back to its original level or even increase.

One interesting explanation developed especially by Knight & Pretty (1997)[2] for the fact that the equity value of a firm may quickly recover after the announcement of a major disaster is that such announcements can generate two conflicting effects. The first effect is negative and takes account of the stock market's expectation of both the current and future costs of a disaster (clean up and business interruption costs or anticipated liability claims, for example). The second effect, however, is positive and reflects the fact that a company which shows an ability to competently manage the effects of a large disaster could benefit from increased stakeholder confidence. Consequently, a firm (or rather its managers) that demonstrates an ability to cope in a widely publicised crisis may well find that value of its equity increases, thus helping to mitigate the negative consequences of a disaster[3].

However, despite the intuitive plausibility of Knight & Prettys' theory it is by no means certain that this is the real explanation for the rather divergent results that have been yielded by risk management event studies[4]. For example, one major problem with event studies is that fluctuations in a firm's equity value can rarely be assigned to a particular event. This "noise" makes it very hard to determine whether a change in a firm's equity value is really due to non-business related losses or other concerns such as changes in the macro-economic environment or dividend announcements. The

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2 See also Borenstein & Zimmerman (1988) for the beginnings of this idea.

3 For more on the relationship between stakeholder confidence and the value of a firm's equity see Chapter 2.

4 Indeed Bromily & Marcus (1989) argue that the conflicting nature of stock market reactions to disasters is largely due to the irrational behaviour of shareholders.

upshot of this is that the results of these studies will tend to be quite unreliable[5] a problem that is also often compounded by the relatively small sample sizes used. Moreover, as with any other detailed hypothesis, the idea that good crisis management may help to increase firm value cannot really be adequately tested in an event study. Although an event study can be used to demonstrate an apparent relationship between exposure to risk and shareholders' valuation of a firm's equity the underlying causes of this relationship cannot be so easily proven. In effect all an event study can do is investigate the degree to which shareholders will react to updated information regarding a firm's exposure to risk. Thus in no way can any definite conclusions be reached regarding why such a reaction is taking place. Indeed it is entirely possible that the supposed relationships between risk and equity value identified in event studies are due to factors other than those predicted up until now.

Unfortunately more rigorous tests of the modern finance approach appear to suffer from ever greater information gathering and reliability problems. For example, the easy availability of employee accident statistics[6] has lead to a considerable amount of empirical research into the validity of Viscusi's hypothesised risk-return relationship. In the main these studies have been quite positive (see Viscusi 1993 for a review), revealing that employees will generally demand higher wages as the level of risk (measured in terms of the number and seriousness of accidents they experience) increases. However, there are a number of serious flaws with this type of study. One problem is that they largely focus on fatal and or serious injuries, thereby ignoring the

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5 Even those studies that attempt to control this problem, say by excluding firms which made profit/dividend announcements at the same time as they experienced an abnormal loss, are rarely free from noise - see, for example, the discussion in Klassen & McLaughlin (1996 p1204-1205).

6 Employee accident statistics as with much other labour force information are often collected and published by governments.

impact of less serious events and also importantly "near misses" since these are not commonly reported. Another is that the accident statistics used in these studies tend to be unreliable and often vary, with the figures depending on the definition of what constitutes a serious accident, whether only work related accidents are included and on the criteria used to demarcate specific industry sectors. In addition, published statistics rarely analyse the causes of accidents in sufficient detail (e.g. whether they were due to employer or employee negligence etc.).

One way in which some studies have attempted to counter the poor quality and reliability of reported accident data is to conduct surveys of stakeholders' own assessments of the risks that they face (e.g. Viscusi & O' Connor 1984, Gegax et al 1991, Lypney 1993[7]). Such studies also have the added advantage of taking into account stakeholders' perceptions regarding their exposure to risk and indeed many of the surveys have shown that stakeholders tend not only to be averse to risk but that they frequently over-estimate their exposure (Rundmo 1992, Viscusi 1993). Yet, despite such cogent results the methodological validity of this work is still suspect. Many of these surveys ask questions based on rather artificial and simplified scenarios meaning that stakeholders' responses may not reflect their actual, real world, behaviour (where factors such as convenience, free riding or information gathering costs may become more important). Moreover the presentation of questionnaires used by many of these researchers (e.g. their focus on pure risks) is likely to have encouraged perceptual bias, either as a result of framing (see Schoemaker & Kunreuther 1979, Hershey & Schoemaker 1980, Tversky & Kahneman 1981) or mental availability effects (Tversky & Kahneman 1973).

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7 The study by Lypney (1993) is somewhat different from the rest in that he conducted an experimental study of managers' hedging decisions. Interestingly Lypney found that when managers were given more concave remuneration functions they tended to hedge more risk than was desirable for shareholders. In addition, as with other studies in the area, a manager's perceptions regarding risk were found to be quite important.

Another response to the lack of good quality publicly available information has been to conduct case studies of particular firms (Doherty & Smith 1993) or of specific issues (the impact of regulation in particular) in relation to a group of firms from either one (Suokas 1993) or a number of different industries (Genn 1993, Gun 1993). This approach has yielded a number of interesting results, most notably that government regulation appears to be quite an effective motivating force for risk management[8] and that firms often place great importance on portraying a safe image to their stakeholders (Genn 1993). In addition, Doherty and Smiths' (1993) analysis of British Petroleum's (BP) insurance strategy lead them to conclude that tax benefits and real service efficiencies (i.e. the specialist underwriting and claims management services etc., offered by insurers) provide a reasonable incentive for insurance purchases. However, they also suggest that the costs of bankruptcy and financial distress are not very significant motivational factors.

Unfortunately, although case studies can provide a lot of relevant information about the behaviour of one or perhaps a small group of firms their conclusions cannot always be readily applied to other firms or situations. Doherty and Smiths' (1993) study of BP is a case in point. BP is a very large company (in fact one of the largest in the UK) operating in a high risk industry, consequently the issues that may be of more (or less) concern to it are not necessarily those that may influence the risk management decisions of other firms. For example, smaller, less solvent firms are likely to be much more concerned about the costs of bankruptcy or financial distress than BP.

8 For example Gun (1993) concludes that the rate of serious workplace accidents in Australia would be double what it is now without regulation.

A similar although much less labour intensive approach to the case study has been to focus on industries or risk management tools for which there is publicly available information. In particular several authors (Mayers & Smith 1990, Cummins & Sommer 1996, Kleffner & Doherty 1996) have exploited the more stringent reporting requirements in the insurance industry to examine the motives behind these firms' attempts to manage their exposure to risk. Similarly others have investigated the reasons why (primarily) non-financial firms purchase directors' and officers' liability insurance (Core 1997) and engage in derivatives hedging (e.g. Tufano 1996 - who looked at the gold mining industry and Geczy et al 1997 - who focused on the use of currency derivatives) since in certain countries and or industries information regarding these activities is made publicly available. Interestingly many of the broad conclusions in each of these studies are quite similar. For example in most cases (the most notable exception being the gold mine research by Tufano) increases in the risk or costs associated with financial distress and or bankruptcy provided some of the strongest incentives for investment in risk management. Moreover the extent of owner and manager (and in the case of Cummins & Sommer, consumer) risk aversion also seemed to have a consistently positive impact. However, the impact of taxation and agency cost considerations are largely discounted.

The use of observed, ready published data in this fashion does have much to commend it. One major advantage is that this work can make use of very large sample sizes. Tufano, for example, was able to study the hedging activities of around 50 gold mining firms over a number of years, while Mayers & Smith had access to data regarding the reinsurance purchases of 1,276 property and liability insurance companies. This allows the use of wide confidence intervals while also permitting a comprehensive test of all of the modern finance approach's main predictions - thus removing the risk of mis-specification due to the absence of relevant correlated independent variables. Moreover, observed, published data tends to be highly reliable[9]. Being based on the actual decisions and circumstances of firms it provides a much more accurate reflection of the real behaviour of firms than any other medium. However, since published data is only available for certain industries and certain risk management tools, any conclusions that are reached may again not be generally applicable. Indeed as Tufano points out the lack of significance of the bankruptcy and agency cost hypotheses in his study may well be due to the fact that the costs of financial distress and bankruptcy are rather small in gold mining. Gold mining firms can inexpensively "moth-ball" productive assets making it easy for them to temporarily cease production (when the price of gold is low for example). Moreover they produce an unbranded commodity product with no requirements for after-sales service so that consumers are unlikely to lose out if any one firm goes bankrupt.

Attempts at more general studies have been made, however, rather unfortunately, these do require the direct collection of survey data in order to gain an indication of a firm's risk management activities. One of the earliest surveys of the motives behind a firm's risk management decisions is the work of Main (1982). Main sent a questionnaire to the Fortune top 500 firms in the US in which he asked their Chief Executive Officer to rate on a scale of 1 (low) to 5 (high) the importance of eight possible factors that might motivate their demand for insurance. The results of a factor analysis then indicated that corporate insurance was mainly purchased for its ability to reduce the risk of financial distress (since this could give rise to agency and

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9 In statistical terms the reliability of data refers to its consistency. In this sense it reflects two aspects (see Bryman & Cramer 1990, p 71):

External reliability - the ability of a given type of data to provide the same prediction in a re-test (where a different sample is used or the same sample is re-examined).

Internal reliability - the ability of a given type of data to accurately reflect the actual issues that are being measured (e.g. a firm's willingness to purchase risk management).

bankruptcy costs). However, Main also concluded that another important role for insurance was its ability to signal a firm's financial soundness to both capital markets and (much less importantly) other stakeholders such as employees.

Other researchers have more fully investigated the practical relevance of the modern finance approach by regressing the survey information that they have obtained about a firm's risk management activities against published data regarding its financial and organisational characteristics (see especially: Khang 1992, Nance et al 1993, Dolde 1993 & 1995). Being perhaps the most comprehensive pieces of research to date these studies have provided some important results. There is, for example, limited support of risk management's role in reducing tax liabilities and in preventing agency conflicts between managers/shareholders and creditors (contrary to the insurance and derivative specific research of authors such as Mayers & Smith 1990 and Tufano 1996). In addition the personal circumstances of shareholders and to a lesser extent those of managers have also been found to significantly affect a firm's decision to invest in risk management[10]. Yet despite the improved generality of the results of such studies they have still only focused on the demand for certain specific risk financing tools (such as insurance and derivatives). Thus it is not clear whether the results of this research are applicable to the use of other risk management tools such as physical risk control or risk retention devices[11]. In addition, several important hypotheses have been ignored. For example since insurance cannot deal with all the costs that may be associated with a particular risk the impact of government intervention (both civil and criminal) and public opinion on the demand for risk management have not yet been properly tested.

10 However, it should be noted that the small sample sizes used by many of these studies does question the significance of their results.

11 For definitions of these terms see Appendix 4.

This study, therefore, attempts to respond to this criticism by examining the motives behind the corporate demand for risk management in general.

3. Questionnaire and Sample Construction.

3.1 *The Questionnaire*

Because of the lack of published information it was decided that as with many previous studies (e.g. Main 1982, Khang 1992 etc.) the best way to gather data about a firm's corporate risk management activities would be to distribute a questionnaire. The main purpose of the questionnaire was to discover why UK firms spend money on risk management. A number of questions were posed, which investigated the role of risk management in controlling the impact of risk on each of the main stakeholder groups: employees (in relation to physical risk and the risk of redundancy), consumers, third parties, creditors (which included trade creditors), and shareholders. In accordance with the theoretical research reviewed in Chapter 2 several different motivational factors were considered, including how risk management might affect stakeholder compensation claims (in terms of wages, prices, interest rates, etc.), their willingness to do business with a firm, the incidence of liability claims, the risk of criminal prosecution and finally a firm's public image[12].

Given the competitive sensitivity of cost related information and the time that it might take to gather, respondents were not asked to detail the exact amount that their firm spent on managing the risks faced by each of its stakeholders[13]. Indeed preliminary

12 A full copy of the questionnaire is detailed in Appendix 1.

13 Admittedly in his analysis of the motives behind corporate insurance purchases Khang (1992) did ask respondents to detail exactly how much they spent on insurance. However, despite only requesting insurance premium information (and not expenditure on physical risk control, retention etc.) the complexity of this request meant that he had to send out a rather simplified

discussions with risk managers revealed that respondents would be much less likely to reply to a questionnaire which requested hard financial data about their risk management programmes. Therefore a discrete attitudinal scale was used for each of the questions. Admittedly this does reduce the reliability of the results described in sections 3.3 and 4 below. Although respondents were asked to answer all questions on the basis of what was important to their *company*, rather than themselves, it is impossible to be sure that their personal opinions did not influence their responses. Thus it may be that the questionnaire data collected reflects what respondents feel should be the motivations for their company's risk management programme rather than what their company's motivations actually are. However, despite this limitation it was felt that the use of a discrete attitudinal scale represented the best solution to a rather tricky problem.

To ensure consistency all questions were composed in a similar fashion. Thus in each case respondents were simply asked to express, on a scale of 1 (unimportant) to 5 (important), how important they thought their company's risk management programme was in helping to alleviate the adverse impact of each stakeholder group's hypothesised responses to risk (see tables 3 and 4 and Appendix 1 for more information). In addition, a separate "don't know" box was included in each question to prevent blank replies.

In recognition of the fact that a respondent's own experiences and opinions might affect their replies the questionnaire also sought to collect data on a variety of control variables relating to their personal characteristics. Respondents were asked standard questions about their job description, qualifications, pay structure, and level of experience. Moreover they were also asked to give an indication of their risk attitudes,

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questionnaire (for example all reference to liability insurance was excluded). Furthermore, Khang only received a usable response rate of 27.3%.

including a description of the most suitable level of insurance cover for their own possessions and their company's assets (scored from 1 = Wholly Insured to 5 = Wholly Uninsured) and whether they saw themselves as being more or less of a risk taker than their senior management (scored from 1 = Less to 5 = More). Finally respondents were asked whether, in comparison with senior management, they were more or less likely to consider the long term impact of their company's investment decisions (scored from 1 = Less to 5 = More).

3.2 *The Sample*

Following detailed discussions with risk managers a finalised questionnaire was sent to a sample of 310 firms in June 1993. The criteria for selection were as follows:

- Since the modern finance approach to risk management is most applicable to large firms (as their owners/shareholders are best able to diversify away the effects of unsystematic risk) sample firms had to be in the top 350 of the UK Times One Thousand 1992-1993 company listings.

- In order to get the required company information for the analysis firms had to be listed on the FAME company database

- Because much of the modern finance approach is targeted at non-financial services firms banks, insurance underwriting, insurance broking and other financial companies were excluded.

In recognition of the fact that many firms still do not possess a formal risk management team two identical questionnaires were sent to each firm one addressed to the "risk manager" the other the "finance manager". In so doing it was hoped that someone with at least a knowledge of their firm's exposure and attitude towards risk would answer the questions[14]. Where double replies were received (in only five companies) they have been excluded from the analysis in order to help avoid any institutional bias.

After the initial mailing and a follow-up reminder letter with a further copy of the questionnaire (in September 1993) 114 usable responses were finally received, representing a response rate of around 36.8% of firms (this excludes the double replies)[15]. A description of the characteristics of sample firms is provided in Table 1.

Table 1: Details of Sample Firms

n = 114, Year = 1992

	Mean	*Standard Deviation*	*Min*	*Max*	*Quartiles* 1	2	3
Turnover £ million	2548	4232.7	238	33250	600	1341	3050
Pre-tax Profit as % Turnover	8.575	11.1	-24.5	57.3	2.2	6.7	12
Gearing Ratio	99.6	164.6	0.40	1633.8	35.3	66.7	110

FT Actuaries Sector:

Capital Goods and Oil & Gas	46
Consumer Groups	36
Other Groups	32

Source: FAME, London Business School

14 In many respects it may have been better to send the questionnaire to a firm's Chief Executive since they are likely to have the most control over the behaviour of a firm (as in Main 1982). However, CEO's are notoriously unreliable respondents (see Harrison 1992), moreover they are likely to pass questionnaires onto the relevant subordinate anyway.

15 In total 127 replies were received. This includes the double replies and replies with missing responses.

Table 2 lists the details of the sample's respondents. As found in Khang (1992) the response rate of those describing themselves as "risk managers" (60.5% of respondents) was much higher than that for finance mangers (23.7% of respondents). Interestingly much of the remainder described themselves as Lawyers or Company Secretaries - perhaps an indication of the importance of the legal aspects of risk management.

Also of interest was the fact that although many respondents were quite "risk averse" when it came to their personal possessions (68.4% preferring full or near full insurance), far fewer were concerned about the financial impact of their firm's exposure to risk - with only 39.5% preferring full or near full insurance[16]. This supports the findings of MacCrimmon & Wehrung (1986) and Shapira (1986) that managers tend to be less averse to risks that are framed as business decisions. Furthermore on balance respondents did not see themselves as any more or less risk averse than their senior management, however, as many were keen to point out they were actually quite senior themselves (only 22.8% had a direct superior that was non-board level).

16 Full insurance is indicated by a response of 1, near full insurance a response of 2.

Table 2: Details of Respondents

n = 114

Variable Name	*Mean*	*% important*	*% unimportant*
Personal Insurance (from 1 = Wholly Insured to 5 = Wholly Uninsured)	2.190	68.4 (insured)	8.8 (uninsured)
Company Insurance (from 1 = Wholly Insured to 5 = Wholly Uninsured)	2.702	39.5 (insured)	20.2 (uninsured)
Risk Taker (from 1 = Less to 5 = More)	2.877	22 (more)	28.1 (less)
Long-Term View (from 1 = Less to 5 = More)	3.316	32.5 (more)	7.9 (less)

Direct Superior:	CEO	18
	Board Level	70
	Non-board Level	26
Job Description:	Risk/Insurance	69
	Finance	27
	Other	18
Years Experience*:	Mean	15.74
	Standard Deviation	8.42
	Minimum	0.0
	Maximum	32.0
Number of Respondents Receiving Profit-Related Pay:		37
Number of Respondents Receiving Share Options:		83

* Due to a number of missing responses only 104 observations were available to calculate the summary statistics for respondents' years of experience.

Source: Questionnaire data

3.3 *A summary of managers' responses regarding the importance of risk management.*

Before proceeding with the full regression analysis it is instructive to consider some of the issues that arise out of the raw results. Table 3, therefore, lists manager's responses to each of main subjects in the questionnaire.

Table 3: Risk Management Questionnaire Results

On a scale from 1 (unimportant) to 5 (important),
how important is risk management in:

		Mean	% important (4 or 5)	% unimportant (1 or 2)
A. In Relation to the Risk of Employee Injury				
-	more productive workforce	3.684	65.8	18.5
-	reducing labour turnover	2.833	27.2	38.6
-	reducing wage costs	2.930	35.1	39.5
-	reducing employee liability costs	4.254	81.5	7.1
-	conforming health and safety regulations	4.316	83.3	7.9
B. In Relation to the Risk of Employee Redundancy				
-	producing a more productive workforce	2.605	29.9	49.1
-	reducing labour turnover	2.325	19.3	57
-	reducing wages costs	2.500	17.2	53.3
C. In Relation to Consumer Safety				
-	consumer safety regulations	4.228	79	11.4
-	reducing consumer liability costs	4.228	80.7	7
-	reducing loss of consumer confidence	3.737	64	21

D. In Relation to the External Environment				
-	reducing regulatory and legal costs	4.070	71.9	7.9
-	ensuring a good public image	4.167	81.6	10.5
-	ensuring an ethical approach to business	3.833	70.2	17.5
E. In Relation to Creditors				
-	reducing trade creditor costs	1.974	21.1	72.8
-	reducing short term debt costs	2.246	26.4	65.8
-	reducing long term debt costs	2.053	18.4	69.3
F. In Relation to Shareholders				
-	maintaining existing dividends	3.474	55.2	24.6
-	increasing dividends	3.132	38.6	33.3
-	reducing tax liabilities	2.754	33.3	47.3
-	reducing financial distress/bankruptcy	3.509	53.5	23.7

Source: Sample of 114 UK Risk and Finance Managers, 1993

Of the reasons for undertaking risk management listed as "Important" in table 3, respondents placed a considerable amount of emphasis on ensuring statutory compliance with government regulations, governing such matters as employee health and safety (83.3%), product safety (79%) and environmental safety (71.9%). Firms also seem to practice risk management in order to limit possible legal liabilities to employees (81.5%) and consumers (80.7%). Thus the main purpose of risk management seems to be the avoidance of contractual, tortious or statutory liabilities. A result which would appear to support Genn's (1993) conclusion that current UK regulation is actually quite effective in ensuring that large firms invest in risk management.

Government regulation may not, however, always be necessary. Interestingly as suggested by authors such as Genn (1993) and Klassen & McLaughlin (1996) a firm's public image was also deemed to be quite important with many respondents supporting the view that risk management has a valuable role to play in maintaining the goodwill of third parties (81.6%) and to a lesser extent consumers (64%). However, the work of authors such as Gegax et al (1991), Brockner et al (1992) or Viscusi (1993) is not well supported with employees appearing to have little power in motivating risk management either through demanding higher wages, lowering their productivity (except perhaps with their exposure to physical risks) or leaving the firm.

There is even some evidence that risk management is practised in order to bring direct benefit to the firm's shareholders via maintaining the value of their dividends with 55.2% of respondents ranking this motive as important (4 or 5). Moreover, the majority of respondents (53.5%) also felt that risk management had a role in helping to avoid the costly effects of financial distress and/or bankruptcy, thus partially supporting the propositions of Myers (1977) and Mayers & Smith (1987). However there is little evidence to suggest that risk management is utilised to reduce a company's tax burden or to reduce the firm's cost of debt capital (contrary to Main 1983b).

4. Testing the Relationship Between Risk Management Motives and Firm Specific Characteristics.

While the results described in table 3 provide an interesting indication of the factors that may motivate corporate risk management expenditure the true validity of the modern finance approach rests upon whether these responses can be explained by variations in a firm's financial performance and organisational characteristics and or the opinions of its management. The purpose of this section is, therefore, to outline some of the main hypotheses adopted by the modern finance approach and explain how they are investigated in the current analysis.

4.1 *Hypotheses*

To ensure consistency the hypotheses to be tested are similar to those adopted by previous empirical research into the modern finance approach. They are as follows:

(1) That the motivation for occupational risk management is not randomly distributed, but depends on the firm's financial performance and organisational characteristics and the preferences of its management.

(2) That the measure of importance attached to all the various motives for risk management outlined in table 3 will vary according to certain specific measures of financial performance. Here two possibilities may arise. The most readily accepted hypothesis is that proposed by Shapiro & Titman (1985) who argue that the incentive for corporate risk management will increase as the firm's financial position deteriorates (e.g. as turnover/profits fall and gearing rises), since an injury or accident is more likely to result in costly financial distress. On the other hand, capital and liquidity constraints may discourage managers and shareholders from investing in risk reduction devices in practice.

(3) Firms involved in traditionally riskier industrial sectors will value each of the proposed motives for risk management more. This should arise because of the greater potential for government intervention, bankruptcy and taxation, as well as the likelihood of very high stakeholder compensation claims.

(4) As suggested in Mayers & Smith (1990) well diversified firms will attach less importance to managing the costs associated with, in particular, taxation,

financial distress and bankruptcy (since cash flow fluctuations should be reduced through pooling). In addition well diversified firms may also attach less importance to reducing stakeholder compensation claims in the more risky areas of its business since the relative impact of these claims is likely to be small.

(5) Larger firms are more likely to attach a greater importance to the public image and regulatory benefits of risk management but less importance to the costs associated with bankruptcy. While larger firms might be expected to face lower bankruptcy costs (as argued in Mayers & Smith 1990) they also tend to receive the most government and media attention (Genn 1993).

(6) That capital intensive firms will attach especially great importance to the management of risk because of the potentially greater bankruptcy costs they may face. Note also that this factor should be especially significant with respect to liability claims due to the fact that capital intensive firms are less judgement proof (Shavell 1986).

(7) That a respondent's concern about risk management will be stimulated by his or her risk aversion, remuneration package and level of expertise in risk management. This embodies the following sub-hypotheses:

i. That more risk averse respondents will attach a greater importance to all the ascribed motives for risk management.

ii. That those respondents which take a longer term view than their senior management will attach a greater importance to all the ascribed motives for risk management (Smith & Williams 1991).

iii. That respondents describing themselves as risk managers will attach a greater importance to all the ascribed motives for risk management. The argument being that the impact of risk should be more "available" to them (Tversky & Kahneman 1973).

iv. That managers receiving profit related pay will attach a greater importance to all the ascribed motives for risk management, while those receiving options will attach less importance (see Lypney 1993).

4.2 *Description of Dependent and Independent Variables*

4.2.1 Dependent Variables.

The dependent variables used to test the hypotheses listed in section 4.1 are comprised of managers' responses to each of the various motives for corporate risk management expenditure outlined in table 3. In order to obtain the most comprehensive test of the modern finance approach each motive is treated as a separate dependent variable. Table 4 provides a description of the various terms used to denote these variables in the ensuing analysis along with the precise wording of the questions used to gather this information.

Table 4: Description of Dependent Variables for Multinomial-Choice Model

All variables have observed scores y = 0,1,2,3 or 4**

QUESTION: Considering the impact of the risk of physical injury on employees, how important is **your company's** risk management programme in contributing to the following corporate objectives?

A more productive workforce	"Productivity (Injury)"
Reducing labour turnover	"Turnover (Injury)"

Reducing your company's wage costs	"Wages (Injury)"
Reducing the legal liability costs of your company	"Liability (Injury)"
Conforming to government safety regulations	"Government (Injury)"

QUESTION: The risk of corporate insolvency exposes employees to the possibility of redundancy. In this respect how important is **your company's** risk management programme in contributing to the following corporate objectives?

A more productive workforce	"Productivity (Redun)"
Reducing labour turnover	"Turnover (Redun)"
Reducing your company's wage costs	"Wages (Redun)"

QUESTION: Considering your consumers' safety, how important is **your company's** risk management programme in contributing to the following corporate objectives?

Providing basic product safety, by complying to the relevant statutory safety regulations	"Consumer Safety"
Reducing the legal liability costs of your company	"Consumer Sales"
Reducing the losses associated with the decline of sales and consumer confidence	"Consumer Liability"

QUESTION: Considering the effect of the production process on the external environment (e.g. pollution), how important is **your company's** risk management programme in contributing to the following corporate objectives?

Ensuring that regulatory and legal costs are reduced	"Third Party Liability"
Ensuring a good public image	"Third Party Image"

Ensuring an ethical approach to your business "Third Party Ethics"

QUESTION: How important is **your company's** risk management programme in reducing the rate of interest charged by the following types of creditors, thus reducing your cost of capital?

Trade creditors "Creditor Trade"

Short term creditors "Creditor Short Term"

Bondholders "Creditor Long Term"

QUESTION: Considering your shareholders, how important is **your company's** risk management programme in contributing towards the following corporate objectives?

Maintaining existing dividends,
thus protecting the value of your company's shares "Owner Maintain"

Increasing dividends,
thus raising the value of your company's shares "Owner Increase"

Reducing your company's tax liabilities "Owner Tax"

Avoiding the costly effects of financial distress
and/or bankruptcy "Owner Bankrupt"

** Scores on the original questionnaire were scaled from 1 to 5, where 1 = "Unimportant" and 5 = "Important", however, in the ensuing multinomial probit analysis it is helpful to recode the responses for the dependent variables from 0 to 4 (see section 4.3).

4.2.2 Independent Variables.

The explanatory variables in the regression models use a mixture of questionnaire data on the personal characteristics of the respondents (as summarised in table 2) and company data for the 1992 accounting year from the CD-ROM database FAME. Full details of the explanatory variables are provided in table 5.

Table 5: Descriptions of Independent Variables

Constant	Constant intercept term.
Turnover (£000m)	Sales in sterling in hundreds of millions
Turnover * Capital Dummy	Sales in £000m times the capital goods dummy.
Profit Ratio (%)	Reported pre-tax profits divided by turnover.
Diversification	Sum of the total number of SIC product markets operated within.
Capital Intensity	Ratio of net tangible assets to the number of employees.
Gearing	Ratio of long-term liabilities and bank overdrafts to share capital and reserves.
Risk	Standard deviation of percentage returns on a firm's shares (note, non-quoted companies were allocated the industry equally weighted average score).
Capital Goods Dummy	Where D = 1 denotes firms operating in the capital goods or oil and gas sectors.
Profit-Related Pay Dummy	Where D = 1 denotes respondents who receive profit related pay as part of their remuneration package.
Options Dummy	Where D = 1 denotes respondents who receive share options as part of their remuneration package.
Risk Manager Dummy	Where D = 1 denotes respondents who described themselves as risk or insurance managers.

Personal Insurance	Measures respondents' attitudes towards insurance for their personal possessions. A score of 1 denotes an expressed preference for fully comprehensive insurance to 5 which denotes no cover.
Company Insurance	Measures respondents' attitudes towards property insurance for their company's assets. A score of 1 denotes an expressed preference for fully comprehensive insurance to 5 which denotes no cover.
Long Term Risk Taker	Indication of whether respondents felt that they were more (5) to less (1) likely to consider the longer term impact of their company's investment decisions than senior management.

Of the firm specific variables "Turnover" was primarily included as a measure of company size and the "Profit Ratio" as a measure of profitability. The variables "Gearing Ratio" and "Diversification" were included to measure the possibility of financial distress and bankruptcy since firms with greater debt exposures and lower levels of product and or market diversification are usually more susceptible to these events. "Capital Intensity" was designed to give an indication of whether a firm relied primarily on labour or machines to manufacture its products. Unfortunately at the moment there is no easy way to measure a firms exposure to "Risk" since data on this is not commonly reported[17], however, it was decided to use the standard deviation of percentage returns on a firm's shares as a proxy using data kindly supplied by the London Business School Risk Measurement Service. Obviously this measure may contain a degree of noise (since it will include speculative changes in the value of a firm's equity, for example), yet it should provide at least an indication of the level of

17 This may of course change if the recommendations of the Cadbury Committee on corporate governance (Cadbury 1992) finally become law.

total risk (i.e. the extent of cash flow fluctuations - see Shapiro & Titman 1985) faced by a firm. Furthermore, in recognition of the fact that the type and level of risk inherent in a specific industry could influence how much firms spend on risk management a dummy variable was included to pick up firms included in the FT Actuaries sector under Capital Goods plus Oil & Gas ("Capital Goods Dummy")[18]. The Capital Goods plus Oil & Gas sector has generally been considered a high risk one, thus it was expected that firms operating within this sector would attach greater importance to risk management. Finally an interaction variable "Turnover * Capital Dummy" was included to look for differences in the marginal effects of turnover dependency between firms that operated in the capital goods sector ($D = 1$) and those that did not ($D = 0$). This was done because it was expected that the risk management decisions of firms operating in the Capital Goods plus Oil and Gas sector with its traditionally high exposure to risk and substantial economies of scale might be more affected by lower levels of turnover (in terms of greater expected bankruptcy costs).

The respondent specific variables were included to test the hypothesis that a managers' personal attitudes and circumstances may influence a firm's risk management decisions. The "Profit-Related-Pay Dummy" and "Options Dummy" were included as an indication of the structure of each manager's remuneration structure. Obviously it would have been better to use precise information regarding the exact amount of profit related pay or share options received by managers as in Tufano (1996)[19]. However, given that such information is not generally reported in the UK (especially for non

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18 Unfortunately the final estimated sample (of 114 firms) was not large enough to permit a more detailed investigation of the impact that a firm's specific industry might have on its risk management behaviour. However in order to get some indication of this effect it was decided to examine whether the responses of those firms operating in the traditionally risky capital goods and oil and gas sectors were different from those that did not.

19 Even Tufano (1996) lacked completely accurate data (see p110-111).

board level executives) this was not possible. The "Risk Manager Dummy" was included to investigate whether a respondent's occupational background influenced his or her responses. Because of their experience and education risk managers may be more aware of the consequences of some risks than finance managers. The "Personal Insurance" and "Company Insurance" variables were included as a measure of a respondent's attitudes towards risk. Risk management research has long been concerned with trying to assess an individual's attitude towards risk and many quite complex methods have been utilised (e.g. Viscusi & O' Connor 1984, Gegax et al 1991, Rundmo 1992, Lypney 1993), however, it was felt that a rather more simple approach would be best in this case (in order to keep the size of the questionnaire down and increase the response rate). Individuals that purchase insurance are typically assumed to be risk averse (Mossin 1968). Consequently in the ensuing analysis the more insurance an individual deems necessary for their personal possessions and their corporation's assets the more risk averse they are assumed to be. Finally the variable "Long Term Risk Taker" was included to examine whether managers who believed themselves to take a long term view of their companies investment decisions placed more importance on risk management. Respondents were asked to compare themselves against senior management as a benchmark.

4.3 *Methodology for Regression Analysis*

The ordered but discrete nature of the questionnaire responses means that traditional linear regression analysis (such as Ordinary Least Squares) is not generally appropriate in this case. Instead it is better to use a technique which treats the dependent variables as ranked rather than continuous[20]. Therefore an ordered multinomial probit model $y^* = \mathbf{\beta}'\mathbf{x} + \varepsilon$ is investigated, where y^* is the latent

20 A simpler but less accurate method is to add respondents scores for each of the main categories in table 3 and then conduct a standard Ordinary Least Squares analysis (see Bryman & Cramer 1990, p 62-63). This was attempted (see Ashby & Diacon 1996), however, as expected the statistical significance of this analysis was very low.

(unobserved) dependent variable (e.g. the importance attached to managing environmental liability risks), **ß'** is a row vector of parameters (each denoting the impact of a change in a particular **x** on y*), **x** is a column vector of explanatory variables (e.g. firm size, diversification, etc.), and ε is a random disturbance with Standard Normal distribution[21] (for further details see Greene 1997, Ch. 19).

Because the opinions of respondents are only expressed using a five-point scale the exact value of y* is, as in much qualitative research, unobservable. However, the responses to the questionnaire can be used to provide censored information of the following form:

$$\begin{aligned} y &= 0 \text{ if } y^* \leq \mu_1 \\ &= 1 \text{ if } 0 < y^* < \mu_2 \\ &= 2 \text{ if } \mu_1 \leq y^* < \mu_3 \\ &= 3 \text{ if } \mu_2 \leq y^* < \mu_4 \\ &= 4 \text{ if } \mu_3 \leq y^* \end{aligned} \quad [1]$$

Where the μ's represent the boundary values between which respondents with a given y* select one of the five possible responses. Note that the first threshold parameter, μ_1, is typically normalised to zero (as in table 4) giving one less parameter to estimate (Liao 1994). This can occur because ordinal scales - such as the ones used in the current questionnaire - are arbitrary and may start and finish at any value.

An important characteristic of ordered probit analysis is that estimates are (usually) obtained by maximum likelihood. Consequently rather than seeking the "best fit" for a

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21 Note that ε could also be assumed to have a logistic distribution - requiring the use of a logit model instead. The differences between logit and probit models are, however, fairly slight (see Greene 1997).

relationship as in conventional ordinary least squares it is the probability with which a particular value of y will arise from a given value of an explanatory variable that is investigated. Assuming that the random disturbance ε has Standard Normal distribution with pdf ϕ and cdf Φ, this then implies that:

$$\text{Prob}[y=0] = \Phi(-\mathbf{\beta}'\mathbf{x}) \qquad [2]$$

$$\text{Prob}[y=1] = \Phi(\mu_1-\mathbf{\beta}'\mathbf{x}) - \Phi(-\mathbf{\beta}'\mathbf{x})$$

$$\text{Prob}[y=2] = \Phi(\mu_2-\mathbf{\beta}'\mathbf{x}) - \Phi(\mu_1-\mathbf{\beta}'\mathbf{x})$$

$$\text{Prob}[y=3] = \Phi(\mu_3-\mathbf{\beta}'\mathbf{x}) - \Phi(\mu_2-\mathbf{\beta}'\mathbf{x})$$

and

$$\text{Prob}[y=4] = 1- \Phi(\mu_3-\mathbf{\beta}'\mathbf{x})$$

The marginal effects of a change in a regressor on the probability that a given y will arise (Prob[y=j]) can then be obtained by partial differentiation of [2] to get:

$$\partial\text{Prob}[y=0]/\partial\mathbf{x} = -\phi(-\mathbf{\beta}'\mathbf{x})\mathbf{\beta} \qquad [3]$$

$$\partial\text{Prob}[y=1]/\partial\mathbf{x} = [\phi(-\mathbf{\beta}'\mathbf{x}) - \phi(\mu_1-\mathbf{\beta}'\mathbf{x})]\mathbf{\beta}$$

$$\partial\text{Prob}[y=2]/\partial\mathbf{x} = [\phi(\mu_1-\mathbf{\beta}'\mathbf{x}) - \phi(\mu_2-\mathbf{\beta}'\mathbf{x})]\mathbf{\beta}$$

$$\partial\text{Prob}[y=3]/\partial\mathbf{x} = [\phi(\mu_2-\mathbf{\beta}'\mathbf{x}) - \phi(\mu_3-\mathbf{\beta}'\mathbf{x})]\mathbf{\beta}$$

and

$$\partial\text{Prob}[y=4]/\partial\mathbf{x} = \phi(\mu_3-\mathbf{\beta}'\mathbf{x})\mathbf{\beta}$$

Greene (1997) notes that care should be taken in interpreting the signs of the coefficients $\mathbf{\beta}$ in ordered multinomial models because the impact $\partial\text{Prob}[y=j]/\partial\mathbf{x}$ depends on j. For example if $\mathbf{\beta} > 0$ then, from [3], $\partial\text{Prob}[y=0]/\partial\mathbf{x} < 0$ and $\partial\text{Prob}[y=4]/\partial\mathbf{x} > 0$ but the signs of the remaining marginal impacts are indeterminate. This is because any change in the overall probability distribution implies that some of its mass will be shifted both into and out of the ranges for the middle values of j. Thus when interpreting the results below all that can easily be established is whether a higher or lower value of $\mathbf{x}$ leads to an increased or decreased chance of a respondent selecting either a 0 or 4.

5. Results.

The results below provide an indication of whether the various hypotheses detailed in section 4.1 are true, at least in relation to large UK firms. Quite a large number of models are tested. Each model deals with a different one of the proposed motives for risk management that were outlined in tables 3 and 4.

The estimation of each model was undertaken using the full usable sample of 114 companies for which a complete data set was available. Note that the $\chi^2(15)$ statistic is the result of a likelihood ratio (Chi-squared) test of the null hypothesis that all non-constant parameters are zero. This provides an overall indication of the predictive power of each model in a manner similar to the F-test used for conventional ordinary least squares regression. It is commonly used as a replacement for the R^2 statistic since this is meaningless in probit models. Coefficients and *t*-statistics are presented in the normal way, however given the assumption of a normal distribution the standard normal table rather than the *t* table is used to test the significance of each coefficient.

One problem encountered with a small number of the following models is that there was an insufficient spread of responses in the dependent variable to conduct a full ordered multinomial probit analysis. This occurred in the "Government (Injury)", "Consumer Safety" "Consumer Liability", "Third Party Liability" and "Third Party Image" models where in each case almost all managers felt that risk management had an important (replying with a 4) or very important (5) role to play. In these models managers' responses have, therefore, been recoded into binary dependent variables with all responses from 1-3 coded as 0 and those of 4-5 given a value of 1. The subsequent regressions were then undertaken using conventional binomial probit analysis (see Greene 1997, Ch. 19).

5.1 *Diagnostic Tests for Heteroscedasticity and Multicollinearity.*

Two possible explanations for unexpected signs and poor significance in the coefficients of cross-section regression models is the presence of multicollinearity and or heteroscedasticity. This section reports on the checks that were undertaken in order to rule out these two undesirable effects.

Where explanatory variables are (approximately) linearly related a model can suffer from multicollinearity. Severe multicollinearity can have quite serious consequences for any econometric model, rendering both regression coefficients and t-statistics highly unreliable. The usual cause of multicollinearity is where two or more variables are included that measure the same basic effect. For example, in the current model "Sales" and the "Turnover * Capital Dummy" are constructed using the same basic data (a company's turnover in 1992) - a factor that might affect the legitimacy of the significance levels and coefficient signs reported below. However, the tests conducted to look for multicollinearity largely proved negative. In particular SPSS was used to generate Variance Inflation Factors (VIFs)[22] and correlation coefficients for each of the explanatory variables. An investigation of the pair-wise correlation coefficients[23] for each of the explanatory variables revealed that as might be expected the degree of

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22 A Variance Inflation Factor shows how the variance of an explanatory variable is inflated by the presence of multicollinearity. More technically it can be defined as:

$$\text{VIF} = \frac{1}{1-r_i^2},$$

where r_i^2 is the squared multiple correlation coefficient between a given explanatory variable and all the other explanatory variables. As the extent of collinearity, as measured by r_i^2, approaches 1 (perfect collinearity) the VIF will increase and in the limit could become infinite. Of course if there is no collinearity between the explanatory variables the VIF will simply be 1.

23 For full details of the results of this test see Appendix 2.

correlation between "Sales" and the "Turnover * Capital Dummy" interaction variable was quite high (-0.780). However, despite this high degree of correlation the relatively low VIF scores for these variables (3.579 and 3.994 respectively) would seem to indicate that multicollinearity is not a significant problem[24]. Full details of the VIF for each variable are presented in table 6, note that as a rule of thumb values greater than 10 are usually taken as evidence of severe multicollinearity (see Gujarati 1995).

Variable	Variance Inflation Factor
Capital Intensity	1.172
Risk Manager Dummy	1.204
Gearing	1.22
Long Term Risk	1.23
Profit Related Pay Dummy	1.264
Diversification	1.322
Options Dummy	1.378
Profit Ratio	1.38
Risk	1.566
Capital Dummy	1.8
Company insurance	1.869
Personal Insurance	1.921
Sales	3.579
Sales * Capital Dummy	3.994

Table 6: Variance Inflation Factors for Explanatory Variables

The main problem with heteroscedasticity is that it can render hypothesis tests on a model's coefficients invalid, as such it is very difficult to conclude with any degree of

24 As a further check for multicollinearity the regressions below were repeated without the "Turnover * Capital Dummy" interaction variable. The results of this analysis were not much different.

confidence whether reported t-statistics are accurate or not. Heteroscedasticity arises where the error variances in a regression model (i.e. ε) are not constant. Typically the error variance will increase with higher values of an independent variable although it can also decrease.

One of the most common causes of heteroscedasticity is where higher values of an explanatory variable give decision makers greater discretion in their choice over the dependent variable. In the current context this could arise for the variables: "sales", "profit ratio", "risk" and "gearing". For example the managers of more profitable firms may have much greater flexibility over the importance (and subsequent expenditure) that they attach to risk management (either because they simply have more money to spend or because shareholders are less concerned about their risk management activities). Similarly the managers of firms with higher levels of sales or lower levels of risk and gearing may also (since they are far from bankruptcy) be freer in the importance that they attach to the management of risk.

In order to check whether the error terms of the variables "sales", "profit ratio", "risk" and "gearing" were heteroscedastic a Lagrange Multiplier (LM) test was used to examine the null hypothesis that the variances of the error terms of these variables were homoscedastic (see Davidson & McKinnon 1984, Greene 1997). Following Harvey (1976) the test is quite general and assumes that the variance of ε is multiplicative:

$$var\,[\varepsilon_i] = [exp(\gamma' z_i)]^2$$

Using this formulation the null hypothesis of a homoscedastic disturbance term ($\gamma = 0$) could not be rejected at the 5% level in 14 of the 21 total regression models. However, the LM statistics of the remaining 7 models - "Turnover (Injury)", "Wage (Injury)", "Liability (Injury)", "Public Image", "Trade Creditor", "Existing Dividends"

"Bankruptcy" - were unfortunately large enough to provide possible evidence of heteroscedasticity. Table 7 reports the LM statistic calculated for each model. Note that with four degrees of freedom the critical 5% value from the Chi-squared distribution is 9.49.

Model	LM Statistic
"Production (Injury)"	6.91
"Turnover (Injury)"	14.20
"Wage (Injury)"	14.60
"Liability (Injury)"	12.95
"Government (Injury)"	1.98
"Production (Redun)"	5.13
"Turnover (Redun)"	6.58
"Wage(Redun)"	4.10
"Consumer Safety"	7.12
"Consumer Sales"	5.90
"Consumer Liability"	9.29
"Third Party Liability"	2.68
"Third Party Image"	10.42
"Third Party Ethics"	6.96
"Creditor Trade"	12.92
"Creditor Short Term"	6.32
"Creditor Long Term"	3.37
"Owner Maintain"	13.59
"Owner Increase"	4.38
"Owner Tax"	2.35
"Owner Bankrupt"	10.07

Table 7: LM Statistics

However, despite the evidence that there could be heteroscedasticity in 7 of the regression models it is not believed to represent a serious problem. As Greene (1997) points out the presence of heteroscedasticity may not always have a significant effect on the coefficient estimates in a model (and as such is unlikely to explain why some coefficients do not have the predicted sign). Moreover although quite robust, a significant LM test, as with the two other Neyman-Pearson tests (Likelihood Ratio and Wald), does not necessarily indicate that a model suffers from severe heteroscedasticity (Davidson & McKinnon 1984). The possibility that heteroscedasticity is not a serious problem is also further supported by the fact that when an attempt was made to correct the seven models for the presence of multiplicative heteroscedasticity (see Greene 1997) the significance of the explanatory variables' coefficients actually worsened.

5.2 *Results of Employee Regressions*

Table 8a: Results of Multinomial-Probit Estimations for Employee Variables

n = 114, t statistics in [], doff=99

	"Productivity (Injury)"	"Turnover (Injury)"	"Wages (Injury)"	"Liability (Injury)"
Constant	2.630	1.303	2.448	2.090
	[2.97]	[1.53]	[2.94]	[2.15]
Turnover (£000m)	0.170	0.883E-01	0.178E-01	-0.629E-01
	[1.70]	[1.77]	[0.43]	[0.76]
Turnover * Capital Dummy	-0.267	-0.893E-01	-0.140E-01	-0.163E-01
	[2.36]	[1.52]	[0.27]	[0.17]
Profit Ratio (%)	-0.797E-02	0.208E-02	-0.953E-02	0.116E-01
	[0.62]	[0.16]	[0.67]	[0.67]
Diversification	-0.187	-0.825E-01	-0.786E-01	-0.104E-01
	[2.97]	[1.75]	[1.57]	[0.17]
Capital Intensity	-0.319E-03	-0.887E-03	-0.561E-03	0.213E-02
	[0.61]	[1.27]	[0.39]	[1.16]
Gearing	0.257E-02	-0.107E-02	-0.181E-02	0.117E-02
	[1.51]	[1.19]	[1.43]	[0.65]
Risk	-0.242E-01	0.974E-02	-0.305E-02	-0.649E-02
	[1.68]	[0.62]	[0.23]	[0.46]
Capital Goods Dummy	1.280	0.480	0.205	0.229
	[3.26]	[1.61]	[0.74]	[0.62]

Profit-Related Pay Dummy	0.289E-01	-0.622E-01	0.798E-01	-0.715E-01
	[0.11]	[0.22]	[0.33]	[0.25]
Options Dummy	0.211	0.111	-0.895E-01	0.286
	[0.68]	[0.38]	[0.34]	[0.89]
Risk Manager Dummy	0.204	0.960E-01	0.447	0.343
	[0.83]	[0.40]	[1.96]	[1.24]
Personal Insurance	-0.326	-0.109	-0.182	-0.901E-01
	[2.03]	[0.75]	[1.34]	[0.51]
Company Insurance	0.495E-01	-0.285	-0.373	-0.433E-01
	[0.27]	[1.81]	[2.27]	[0.25]
Long Term Risk Taker	0.120	0.987E-01	0.875E-01	0.767E-01
	[0.72]	[0.61]	[0.54]	[0.41]
$\mu 1$	0.945	0.634	0.691	0.811
	[3.11]	[5.08]	[5.15]	[1.70]
$\mu 2$	1.530	1.631	1.436	1.488
	[4.42]	[9.39]	[8.21]	[2.87]
$\mu 3$	2.745	2.144	2.100	2.385
	[7.43]	[10.81]	[10.01]	[4.44]
$\chi^2(15)$	37.4	19.2	27.6	16.2
Significance	0.0006	0.156	0.016	0.299

Table 8b: Results of Multinomial-Probit Estimation for Employee Variables

n = 114, t statistics in [], doff=99

	"Government (Injury)"	"Productivity (Redun)"	"Turnover (Redun)"	"Wages (Redun)"
Constant	2.006	1.211	1.167	1.405
	[1.59]	[1.55	[1.48]	[1.71]
Turnover (£000m)	0.799E-01	0.181E-01	0.400E-01	0.482E-01
	[0.65]	[0.22]	[0.52]	[0.64]
Turnover * Capital Dummy	-0.132	-0.469E-01	-0.385E-01	-0.608E-01
	[0.98]	[0.50]	[0.44]	[0.67]

Profit Ratio (%)	0.413E-01	-0.215E-01	-0.912E-02	-0.203E-01
	[1.72]	[1.69]	[0.71]	[1.55]
Diversification	0.371E-01	-0.365E-01	-0.201E-02	-0.492E-01
	[0.45]	[0.70]	[0.39]	[0.88]
Capital Intensity	0.301E-02	-0.222E-03	-0.204E-03	-0.202E-03
	[0.86]	[0.14]	[0.16]	[0.12]
Gearing	-0.103E-02	0.803E-03	-0.147E-02	-0.191E-02
	[0.92]	[0.86]	[0.92]	[1.05]
Risk	-0.162E-01	-0.176E-01	-0.611E-02	-0.115E-01
	[0.86]	[1.30]	[0.44]	[0.78]
Capital Goods Dummy	0.482	0.157	0.222	0.332
	[1.05]	[0.48]	[0.67]	[0.95]
Profit-Related Pay Dummy	0.719E-01	-0.650E-01	-0.733E-01	0.137
	[0.18]	[0.27]	[0.24]	[0.51]
Options Dummy	0.837E-01	0.320	0.127	0.384E-01
	[0.21]	[1.27]	[0.42]	[0.14]
Risk Manager Dummy	-0.172	0.537	0.435	0.527
	[0.48]	[2.25]	[1.66]	[2.26]
Personal Insurance	-0.238E-01	-0.319	-0.213	-0.199
	[0.11]	[2.11]	[1.35]	[1.27]
Company Insurance	-0.310	-0.364E-01	-0.259	-0.277
	[1.39]	[0.25]	[1.69]	[1.83]
Long Term Risk	-0.418E-01	0.105	0.139	0.159
	[0.18]	[0.67]	[0.74]	[0.86]
μ_1		0.452	0.614	0.477
		[4.55]	[5.49]	[4.61]
μ_2		1.060	1.36	1.058
		[7.80]	[8.10]	[7.28]
μ_3		1.702	2.169	1.620
		[8.83]	[8.08]	[8.70]
$\chi^2(15)$	21.7	18.83	16.81	21.96
Significance	0.083	0.172	0.266	0.080

Tables 8a and 8b report the results of the employee regressions. The null hypothesis that the motivation for the management of employee injury and redundancy risk is randomly distributed is tested by the $\chi^2(15)$ statistic. This is rejected at the 5% significance level in the case of dependent variables "Productivity (Injury)" and "Wages (Injury)" and at the 10% level for "Government (Injury)" and "Wages (Redun)". There is, however, no strong evidence of any systematic application of risk management among respondents directed at reducing either of the labour turnover dependent variables, "Productivity (Redun)" or "Liability (Injury)".

The insight that a firm's financial performance can influence its motivation for employee risk management can be investigated further by examining the estimated coefficients and their significance in Tables 8a and 8b. The motive which appears to be most influenced by a firm's financial performance and organisational characteristics is the improvement of employee productivity in relation to injury ["Productivity (Injury)"]. As expected respondents were more likely to regard this motive as very important (i.e. choose the highest value of the dependent variable) in non-diversified firms in the capital goods sector with high gearing ratios (which is significant at the 14% level). However, contrary to expectation firms that exhibit low variability of return on equity (i.e. those that were low risk) also found this motive to be very important. This result may be due to the fact that such firms actually exhibit less firm specific risk because the importance that they attach to this area means that they invest more heavily in related risk management. Another unforeseen result was that "Turnover" had a positive impact on the importance ascribed to this motive (albeit only at the 10% level). However, the negative coefficient of the interaction variable "Turnover * Capital Dummy" coupled with the fact that -0.267 dominates 0.170 means that as expected the marginal effect of turnover is negative for firms operating in the capital goods sector (D=1) but positive for other firms (D=0).

With respect to the other significant models - "Wages (Injury)", "Government (Injury)", "Wages (Redun)" - the evidence of a strong relationship between the individual financial variables and the importance attached to risk management is patchy at best. There is some limited evidence that non-diversified firms attach greater importance to reducing employee wage-risk premiums in relation to the risk of injury (at the 12% level). Moreover, profitable firms appear to attach a greater importance to complying with government regulations. This was not expected, although, it may be a reflection of Shavell's (1986) "Judgement Proof Hypothesis" - whereby profitable firms are more averse to the risk of fines or enforced liquidation because they have more to lose. Genn's (1993) argument that larger and or riskier firms will attach a greater importance to the management of liability costs and regulatory compliance is not, however, well supported.

With respect to the personal influence of respondents an examination of the relevant coefficients in the various models of tables 6a and 6b shows a reasonable degree of conformity in their sign (if not always significance). For example, with only one exception ("Government (Injury)") the risk manager dummy variable has a positive sign and sometimes significant coefficient (in "Wages (Injury)", "Productivity (Redun)", "Turnover (Redun)" and "Wage (Redun)") across all the dependent variables: thus respondents who describe themselves as risk managers are more likely to regard employee risk management as important on almost all fronts. Similarly the two proxies for respondent risk aversion (level of preferred personal and company insurance) also generally exhibit negative and sometimes significant coefficients ("Personal Insurance" in "Productivity (Injury)" and "Productivity (Redun)" and "Company Insurance" in "Turnover (Injury)", "Wages (Injury)", "Turnover (Redun)" and "Wage (Redun)") supporting the contention that respondents who appear to be risk averse are more likely to favour the management of employee related risks. In contrast the signs of the profit-related pay and options dummies were not always as expected, although none of the coefficients of these two variables were significant in any of the models.

5.3 *Results of Consumer Regressions*

Table 9: Results of Multinomial-Probit Estimation for Consumer Variables

n = 114, t statistics in [], doff=99

	"Consumer Safety"	"Consumer Sales"	"Consumer Liability"
Constant	0.487	2.150	0.137
	[0.46]	[2.25]	[0.12]
Turnover (£000m)	0.104	0.188	-0.357E-01
	[0.95]	[1.58]	[0.57]
Turnover * Capital Dummy	-0.172	-0.197	-0.566E-01
	[1.46]	[1.63]	[0.67]
Profit Ratio (%)	0.181E-01	-0.939E-02	0.481E-02
	[1.07]	[0.63]	[0.30]
Diversification	-0.309E-01	-0.618-02	-0.103
	[0.45]	[0.12]	[1.55]
Capital Intensity	-0.307E-02	-0.172E-02	0.503E-02
	[0.04]	[1.02]	[1.51]
Gearing	0.114E-02	0.643E-03	-0.530E-04
	[0.66]	[0.44]	[0.05]
Risk	-0.111E-01	-0.829E-02	-0.826E-02
	[0.64]	[0.52]	[0.49]
Capital Goods Dummy	0.840	0.127	0.315
	[1.96]	[0.37]	[0.80]
Profit-Related Pay Dummy	0.432	0.174	-0.150
	[1.19]	[0.62]	[0.43]
Options Dummy	0.166	-0.349	-0.484E-01
	[0.46]	[1.17]	[0.12]
Risk Manager Dummy	0.205	0.483E-02	0.700
	[0.65]	[0.02]	[2.05]

Personal Insurance	-0.254	-0.197	-0.284
	[1.20]	[1.25]	[1.27]
Company Insurance	-0.606E-01	-0.163	0.110E-01
	[0.30]	[1.01]	[0.05]
Long Term Risk	0.178	0.151	0.438
	[0.82]	[0.91]	[1.86]
$\mu 1$		0.454	
		[3.32]	
$\mu 2$		0.955	
		[5.53]	
$\mu 3$		1.610	
		[7.92]	
$\chi^2(15)$	13.7	28.9	18.0
Significance	0.475	0.011	0.206

Table 9 reports the results of the consumer regressions. Of the three consumer models only one reports a $\chi^2(15)$ statistic that is sufficient to reject the null hypothesis that all non-constant parameters are zero, "consumer sales" at the 5% significance level.

Again as with the employee regressions there is little evidence of a significant relationship between the importance attached to consumer risk management and a firm's financial performance. In fact the significant "Consumer Sales" model reports only two almost significant coefficients for both "Turnover" (12%) and the "Turnover * Capital Goods Dummy" (11%). "Turnover" has a positive coefficient, the opposite to that expected. However, the negative coefficient of the interaction variable "Turnover * Capital Dummy" coupled with the fact that -0.197 dominates 0.188 means that the marginal effect of turnover is negative (as expected) for firms operating in the capital goods sector (D=1) but positive for other firms (D=0).

Although reporting an insignificant $\chi^2(15)$ statistic it is also interesting to note that the "Capital Intensity" variable in the "Consumer Liability" model is almost significant at the 10% level, indicating that the marginal impact is negative for $j = 0$ (i.e. unimportant) and positive for $j = 4$ (important). This would seem to provide further limited support of Shavell's argument that capital intensive firms are more likely to try to reduce their exposure to liability claims because they are less "judgement proof".

With respect to the personal influence of respondents it would appear that risk managers (significant at 5%) and those who take a longer term view (significant at 10%) are much more aware of the importance of reducing their company's exposure to the risk of liability claims. Unfortunately, however, nothing else appears to be significant, although the signs of the coefficients are quite consistent and generally as expected.

5.4 *Results of Third Party Regressions*

Table 10: Results of Multinomial-Probit Estimation for Third Party Variables

n = 114, t statistics in [], doff=99

	"Third Party Liability"	"Third Party Image"	"Third Party Ethics"
Constant	1.652	2.012	1.643
	[1.66]	[1.73]	[1.94]
Turnover (£000m)	0.380E-01	0.327	0.631E-01
	[0.52]	[1.59]	[0.96]
Turnover * Capital Dummy	-0.709E-01	-0.358	-0.848E-01
	[0.85]	[1.71]	[1.20]
Profit Ratio (%)	0.179E-01	0.992E-02	0.505E-02
	[1.17]	[0.60]	[0.46]
Diversification	0.660E-01	0.409E-01	-0.218E-01
	[0.91]	[0.49]	[0.38]
Capital Intensity	-0.461E-04	-0.634E-04	-0.477E-04
	[0.06]	[0.09]	[0.08]
Gearing	0.383E-03	-0.187E-03	0.837E-03
	[0.40]	[0.22]	[0.72]

Risk	-0.276E-01	-0.292E-01	-0.494E-02
	[1.79]	[1.63]	[0.34]
Capital Goods Dummy	0.634	0.644	0.285
	[1.63]	[1.32]	[0.94]
Profit-Related Pay Dummy	-0.283	0.106	0.908E-01
	[0.91]	[0.28]	[0.33]
Options Dummy	0.102	0.266E-01	0.188
	[0.29]	[0.07]	[0.62]
Risk Manager Dummy	0.261	0.484E-01	0.215
	[0.89]	[0.15]	[0.92]
Personal Insurance	-0.671E-01	-0.253	-0.224
	[0.36]	[1.18]	[1.42]
Company Insurance	-0.332	-0.241	-0.245
	[1.76]	[1.12]	[1.67]
Long Term Risk	0.648E-01	0.129	0.239
	[0.34]	[0.57]	[1.35]
$\mu 1$			0.602
			[3.26]
$\mu 2$			1.040
			[4.63]
$\mu 3$			1.970
			[7.65]
$\chi^2(15)$	15.6	17.7	18.7
Significance	0.335	0.222	0.178

Table 10 reports the results of the third party regressions. Unfortunately, none of the three third party models proved to be significant. Moreover, several of the few significant or almost significant coefficients failed to exhibit their expected sign (for example, the effect of "Risk" significant at 10% in "Third Party liability" and 11% in "Third Party Image" on the importance attached to risk management is negative). The most notable exceptions to this, however, are perhaps the company insurance coefficients in the "Third Party Liability" and "Third Party Ethics" models (each significant at the 10% level). This result provides continuing evidence of the importance of the respondent specific variables and, in particular, risk attitudes.

5.5 *Results of Creditor Regressions*

Table 11: Results of Multinomial-Probit Estimation for Creditor Variables

n = 114, t statistics in [], doff=99

	"Creditor Trade"	"Creditor Short Term"	"Creditor Long Term"
Constant	2.178	2.800	0.259
	[2.05]	[3.20]	[0.32]
Turnover (£000m)	-0.298	0.109E-01	0.795E-01
	[1.29]	[0.16]	[0.82]
Turnover * Capital Dummy	0.321	-0.160E-01	-0.839E-01
	[1.40]	[0.19]	[0.76]
Profit Ratio (%)	-0.158E-02	-0.205E-01	0.200E-02
	[0.10]	[1.30]	[0.14]
Diversification	-0.661E-01	-0.562E-01	-0.317E-01
	[0.99]	[0.84]	[0.50]
Capital Intensity	-0.327E-03	-0.292E-03	0.964E-03
	[0.23]	[0.24]	[1.24]
Gearing	-0.114E-02	-0.299E-03	-0.848E-03
	[0.69]	[0.28]	[0.49]
Risk	-0.181E-01	-0.160E-01	0.379E-02
	[1.13]	[1.26]	[0.30]
Capital Goods Dummy	0.242	0.149	0.469
	[0.52]	[0.44]	[1.27]
Profit-Related Pay Dummy	-0.694E-02	0.115	0.530E-01
	[0.02]	[0.38]	[0.17]
Options Dummy	0.185	-0.702E-01	0.268E-02
	[0.65]	[0.27]	[0.01]
Risk Manager Dummy	0.212	-0.346	0.559E-01
	[0.66]	[1.43]	[0.22]

Personal Insurance	-0.244	-0.272E-01	-0.131
	[1.33]	[0.15]	[0.69]
Company Insurance	-0.340	-0.344	-0.200
	[1.88]	[2.03]	[1.17]
Long Term Risk	-0.961E-02	-0.189	0.146E-01
	[0.05]	[1.06]	[0.09]
$\mu 1$	0.486	0.481	0.400
	[3.98]	[4.52]	[4.18]
$\mu 2$	0.728	0.740	0.834
	[4.96]	[5.66]	[5.77]
$\mu 3$	1.425	1.293	1.166
	[6.39]	[6.68]	[6.5]
$\chi^2(15)$	31.9	20.0	12.6
Significance	0.004	0.130	0.557

Table 11 reports the results of the creditor regressions. Only the "Creditor Trade" model reports a $\chi^2(15)$ statistic sufficient to reject the null hypothesis that all non-constant parameters are zero (at the 5% level). Moreover, even in this model few of the coefficients for the explanatory variables are significant at conventional levels. There is absolutely no evidence of any significant relationship between the importance attached to risk management and a firm's financial or organisational characteristics. In fact the only variable exhibiting the expected sign that is actually significant at conventional levels is "Company Insurance" (significant at the 5% level)[25]. This would seem to provide further evidence that it is the personal characteristics of managers and in particular their apparent attitude towards risk that is having the greatest influence on the importance attached to risk management.

25 Note also that the "Company Insurance" coefficient is significant at the 5% level in the "Creditor Short Term" model as well.

5.6 *Results of Shareholder Regressions*

Table 12: Results of Multinomial-Probit Estimation for Shareholder Variables

n = 114, t statistics in [], doff=99

	"Owner Maintain"	"Owner Increase"	"Owner Tax"	"Owner Bankrupt"
Constant	1.090	1.502	1.271	0.933
	[1.34]	[2.01]	[1.63]	[1.09]
Turnover (£000m)	0.400E-01	0.264E-01	0.371E-01	0.340E-01
	[0.50]	[0.32]	[0.55]	[0.40]
Turnover * Capital Dummy	-0.681E-01	-0.550E-01	-0.408E-01	-0.411E-01
	[0.79]	[0.61]	[0.52]	[0.47]
Profit Ratio (%)	0.995E-02	0.820E-02	0.127E-02	0.166E-01
	[0.72]	[0.77]	[0.11]	[1.18]
Diversification	-0.430E-01	-0.207E-01	-0.120E-01	-0.170E-01
	[0.77]	[0.38]	[0.28]	[0.31]
Capital Intensity	-0.235E-03	-0.258E-03	0.205E-02	-0.247E-03
	[0.29]	[0.24]	[1.71]	[0.39]
Gearing	-0.159E-02	-0.115E-02	-0.102E-02	-0.120E-02
	[1.20]	[1.02]	[0.93]	[1.18]
Risk	-0.189E-01	-0.195E-01	-0.212E-02	0.127E-01
	[1.64]	[1.85]	[0.17]	[0.80]
Capital Goods Dummy	0.656	0.518	0.341	0.343
	[2.02]	[1.57]	[1.11]	[1.11]
Profit-Related Pay Dummy	0.155	0.204	0.180	0.312
	[0.54]	[0.71]	[0.66]	[1.21]
Options Dummy	0.290	0.283	0.896E-01	0.123
	[0.99]	[0.91]	[0.33]	[0.46]
Risk Manager Dummy	0.315	0.291	0.211	0.277
	[1.25]	[1.15]	[0.91]	[1.14]
Personal Insurance	-0.104	-0.139	-0.166	-0.227
	[0.61]	[0.92]	[1.06]	[1.41]
Company Insurance	-0.165	-0.221	-0.319	-0.311
	[0.95]	[1.39]	[2.05]	[2.02]

Long Term Risk	0.313	0.208	0.569E-01	0.180
	[1.97]	[1.35]	[0.39]	[1.21]
$\mu 1$	0.534	0.671	0.550	0.331
	[3.59]	[4.53]	[4.85]	[2.90]
$\mu 2$	1.180	1.462	1.107	1.029
	[6.20]	[8.11]	[7.28]	[6.10]
$\mu 3$	1.894	1.913	1.628	1.500
	[8.83]	[9.53]	[8.92]	[7.78]
$\chi^2(15)$	24.6	21.5	22.6	23.3
Significance	0.038	0.088	0.066	0.056

Table 12 reports the results of the shareholder regressions. Interestingly all these models have $\chi^2(15)$ statistics that are sufficient to reject the null hypothesis that all non-constant parameters are zero. In the case of "Owner Maintain" the $\chi^2(15)$ statistic is significant at the 5% level while for "Owner Increase", "Owner Tax" and "Owner Bankrupt" the statistic is significant at the 10% level.

However, despite the overall significance of the models the argument that a firm's financial and organisational characteristics may influence its risk management decisions is not strongly supported. There is, for example, some evidence that firms operating in the traditionally risky Capital Goods plus Oil and Gas sector are more likely to attach importance to maintaining or increasing dividends to shareholders (significant at the 5% in "Owner Maintain" and 12% in "Owner Increase"). Yet in each of the models the sign of the coefficient for the "Risk" variable is actually negative (and significant at the 10% level in "Owner Increase") - partially contradicting the hypothesis that high risk firms will attach greater importance to shareholder risk management. This could, however, again be due to the fact that lower risk firms are low risk simply because they attach more importance to risk management.

Unfortunately the significance levels for the respondent specific variables are not much better. Again in line with many of the other models in this analysis a respondent's attitude towards risk (as reflected by their attitudes towards personal and corporate insurance) appears to be having the most influence on the importance attached to shareholder risk management ("Company Insurance" is significant at the 5% level in both "Owner Tax" and "Owner Bankrupt"). However, contrary to expectations the remuneration structure of a respondent did not have any significant impact on their responses. This would seem to contradict the claims made in the theoretical literature (see Agrawal & Mandelker 1987, Lypney 1993, Tufano 1996) that shareholders can manipulate managers' behaviour through their remuneration structure. However, since it was not possible to gather particularly accurate data regarding managerial remuneration the strength of this conclusion must be considered suspect.

6. **Conclusions.**

The purpose of this Chapter was to attempt to identify whether the various predictions of the modern finance approach explain why large UK companies spend money on risk management. Summary statistics from a survey of 127 risk, insurance and finance managers conducted in late 1993 indicated that respondents placed most emphasis on ensuring statutory compliance with government regulations and the avoidance of legal liability suits. In contrast, with the interesting exception of third parties, stakeholders (even shareholders) seem less able to encourage corporate risk management expenditure on their own. Whether this is due to information gathering problems or simply a lack of bargaining power, it would appear that market forces are not fully effective and that government intervention is still necessary in order to protect stakeholders (especially employees and consumers) against excessive levels of risk.

Subsequent estimations using a multinomial probit model revealed that the responses for around half of the hypothesised motives for occupational risk management are not randomly distributed but dependent on both a firm's financial characteristics and the circumstances of its management. However, the evidence in support of many of the specific hypotheses of the modern finance approach is rather limited. In fact in only the "Productivity (Injury)" model did a firm's financial or organisational characteristics have any real effect on manager's responses. Furthermore in this and many other models the signs of the significant coefficients were not always as expected.

On the other hand there appears to be a much stronger relationship between the dependent and respondent specific explanatory variables. Most of the coefficients for the respondent specific variables exhibited the expected sign (with the exception of the profit related pay and options dummies). Moreover a much greater number of these coefficients proved significant. One unsurprising (although reassuring) result is that risk managers seem to attach more importance to many of the ascribed motives for risk management. However, rather more interesting is the influence of a respondent's attitude towards risk. In many of the models either the personal insurance or company insurance variables had a significant negative coefficient, as such it would appear that risk averse managers are more likely to regard risk management as being very important. A result which is in line with several previous studies and in particular two of the most recent by Mayers & Smith (1990) and Tufano (1996).

Although the poor significance of the various financial and organisational variables in the current empirical study would seem to suggest that many of the predictions of the modern finance approach to risk management are not very general it is hard to be sure about this conclusion. Admittedly many of the other more in-depth empirical studies into the modern finance approach have also suffered from low significance levels, however, it is quite possible that this is due to the rather inferior quality of the data used rather than the insignificance of the approach. Indeed even in the current study the use of ordered attitudinal data to measure the various dependent variables may have lead to a degree of bias[26]. Yet, despite the uncertainty that surrounds the accuracy of current empirical research it is hard - given the existing evidence - to accept that the modern finance approach represents a panacea for understanding corporate risk management decisions. As such it would seem instructive to try to find some new approaches from which to understand both why and how firm's invest in risk management. The aim of the next three Chapters is to propose just such an approach, the roots of which are based in neo-classical economics rather than modern finance theory.

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26 For example, although respondents were asked to answer all questions on the basis of what was important to their *company*, rather than themselves, it is impossible to be sure that their personal opinions did not influence their responses. Thus it may be that the questionnaire data collected reflected what respondents felt should be the motivations for their company's risk management programme rather than what their company's motivations actually were.

Chapter 4:
Widening the Focus of Risk Management Research

1. Introduction

As stated in the introduction of this thesis risk management is in many respects quite a new discipline. Because of this newness it is, therefore, perhaps unsurprising that no distinct theoretical framework has yet been developed for risk management (e.g. see Kloman 1992, Williams et al 1995). In fact in many respects researchers in the field have behaved like magpies, borrowing the choicest ideas from other disciplines such as modern finance theory, organisational behaviour and to a much lesser extent economics.

The relative paucity of economic theory in risk management research is probably at least partly due to the tendency of those few models that do exist to rely on expected utility theory and in particular risk aversion (e.g. Mossin 1968, Ehrlich & Becker 1972, Dionne & Eeckhoudt 1985, Briys & Schlesinger 1990, Briys et al 1991, Sweeney & Beard 1992, Schlesinger 1993, Di Mauro 1994, Gollier et al 1997). Most of the non-economics based research in risk management has now largely rejected the assumption that a firm can be treated as an expected utility maximising, risk averse individual. In the mainstream modern finance based literature this is of course (see Chapter 2) based on the powerful predictions of the CAPM and the recognition that firms are often political entities (Schoemaker 1993), comprised of conflicting stakeholder groups. Similarly much of the now growing organisational behaviour based work into risk management has also emphasised the importance of stakeholders, however, these studies are based more on observed "human" violations of the axioms of expected utility theory (e.g. see Schoemaker 1982, Pidgeon et al 1992) than hard financial realities.

Yet, despite the considerable objections voiced regarding the use of expected utility theory and risk aversion in corporate risk management research it is argued over the remaining few Chapters of this thesis that alternative economic based explanations for risk management should not be ignored. Indeed by focusing on the shorter term operational decisions of a firm it will be demonstrated that a much richer framework for understanding a firm's risk management decisions can be developed. The challenge, however, is to devise an economic framework for risk management that does not rely on risk aversion.

The next section of this Chapter reviews the main arguments that can be put against the use of risk aversion and more generally expected utility theory in economic models of firm behaviour under risk. Admittedly in terms of a firm's long term investment decisions this issue has already been examined in Chapter 2, however, for many economists the CAPM based arguments of modern finance theory have not been seen as sufficient to reject their use of risk aversion. Yet, there are other firmly economic based arguments against its use, each of which will be examined here.

Having reviewed the problems associated with using risk aversion and expected utility theory section 3 offers a new economics based approach to examining the behaviour of a firm under risk. The primary foundation for this approach is the assumption that firms are short run profit maximisers and thus effectively risk neutral. Admittedly much of the recent organisational behaviour based work into risk management has largely rejected the idea that a real world firm will simply try to maximise its profits in a risky or uncertain world, however, it is argued that apparently basic economic models do still have much to contribute to our understanding of the area. On this basis two main possible economic justifications for corporate risk management are then outlined. The first is that risk can, on occasion, represent a "pure penalty" (Martin 1981) to the firm that may either raise its operating costs or lowers its revenues. The second is that firm behaviour under risk can sometimes be influenced by "technological non-linearities" which cause convexities or concavities in its profit function (see Aiginger 1987, Ch. 4 or Driver & Moreton 1992, Ch. 4). Section 4 finally rounds the chapter off with a brief conclusion.

2. "Aversion to Risk Aversion"[1]: A Critique on the use of Risk Aversion in Economic Models of Firm Behaviour Under Risk.

A major contribution of the modern finance approach has been its use of the CAPM to reject the traditional a-priori assumption in risk management research that firms can be treated as risk averse expected utility maximisers (see Chapter 2). Unfortunately, however, while this insight has been used to generate a wide range of interesting theories on the mainstream finance side of the risk management literature, many economists have actually used this work to further justify their focus on risk aversion (see Sandmo 1971, Leland 1972, Newbery & Stiglitz 1981, Varian 1990, Schlesinger 1993, Di Mauro 1994, Gollier et al 1997, and especially Greenwald & Stiglitz 1987, 1990). The problem rests on the fact that in the modern finance approach risk management is largely assumed to be the result of market imperfections that cause the firm's stakeholders to behave in a risk averse way (see Chapter 2). The reasoning adopted by these economists then goes that where certain stakeholders (especially managers and shareholders who are perhaps the most influential) are able to influence a firm's economic decisions (e.g. how much to produce of a given product and at what price etc.) the behaviour of a firm can be proxied by a risk averse utility function. In short, although it is generally accepted that a firm cannot be regarded as a true risk averse individual, the suggestion is that where powerful stakeholder groups are risk averse it can be treated "as if" (Schlesinger 1993) it is[2].

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1 Goldberg (1990).

2 Gollier et al (1997) sums this up quite well:

Admittedly the concepts of risk aversion and expected utility theory do provide a relatively simple and convenient way to explore the short run economic decisions of a firm in a world of risk (see, for example, Varian 1990). However, in what follows it is argued that this simplicity and convenience is bought at a very high cost. In particular, two main criticisms are explored. The first is that it is theoretically highly inappropriate to assume that firms may behave as if they are risk averse. The second is that incorporating risk aversion into economic models can shift the focus from a number of rather more relevant and interesting possible influences on firm behaviour under risk.

The theoretical inappropriateness of the "as if" approach to risk aversion stems from the predictions of the social choice literature and in particular in the seminal work of Arrow (1951, 1963). The purpose of Arrow's research was to examine a long running debate in the social choice literature regarding whether it is possible to aggregate individual preferences into a complete and consistent (i.e. transitive) social welfare function. Interestingly Arrow's argument was that this would not be possible, at least when the preferences of individuals' differed over three or more alternatives.

Arrow's conclusion may seem surprising, however, his basic idea was not at all new. In fact the problem of accurately reflecting individual preferences within social choices has been recognised for centuries (e.g. see Condorcet 1785) and embodied in the so called 'paradox of majority voting'[3].

"...we only see it [risk aversion] as a proxy for taking into account the imperfections of capital markets, and more specifically the fact that shareholders cannot fully diversify their portfolios.".

3 For a good discussion of this paradox see Gravelle & Rees (1992).

Paradox of Majority Voting

Consider a group of three individuals labelled $i=1,2,3$ who each possess a strict preference ordering over three alternatives (i.e. no one is indifferent between any of the alternatives): a, b and c. The preferences of each individual are then assumed to be $(a,b,c)_1$, $(b,c,a)_2$ and $(c,a,b)_3$ which must somehow be aggregated into a combined social welfare function [.]. In order achieve this the individuals are then asked to indicate their preferences by voting on each pair of alternatives.

Considering first each individual's preference ordering for the pair (a,b):

$(a,b)_1$ and $(b,a)_2$, and $(a,b)_3 \Rightarrow [a,b]$

it is obvious that 2 is outvoted by 1 and 3. Voting on the pair (b,c) then yields:

$(b,c)_1$ and $(b,c)_2$, and $(c,b)_3 \Rightarrow [b,c]$

where 2 is again outvoted by 1 and 3. However, voting on the last pair (a,c) should paradoxically give rise to the following result:

$(a,c)_1$ and $(c,a)_2$, and $(c,a)_3 \Rightarrow [c,a]$

i.e. 1 is outvoted by 2 and 3.

Example 1: Paradox of Majority Voting

Example 1 provides a classic example of this voting paradox. It illustrates that the democratic process can produce an intransitive social ordering of individual choices - where in this case a is socially preferred to b and b is socially preferred to c but paradoxically c is also socially preferred to a. This loss of transitivity is quite serious, effectively what it yields is a meaningless cyclical result that in no way represents the true preferences of any of the three individuals.

Arrow's contribution was to formalise this paradox of majority voting into a much more general theory, now termed his "Impossibility Theorem"[4]. He did this by devising four "apparently reasonable (sic)" conditions or axioms that he felt any social welfare function should possess. What Arrow then argued was that no complete and transitive social welfare function could ever simultaneously meet all these axioms[5]. They are as follows:

(i) *Unrestricted or Universal Domain.* This axiom requires that all logical combinations of individual preference orderings must be able to yield a transitive social welfare function. Thus even when a certain sub-group (such as a particular pressure group or union) of individuals shares the same preference ordering the assumption is that it will not be possible to achieve a universal social ordering unless the group's preferences can be aggregated with those of all other sub-groups.

(ii) *Non-dictatorship.* Non-dictatorship means that no one individual has the exclusive authority to determine the social welfare function in all circumstances. As such any social preference ordering must be democratically determined, taking into account the views of all individual decision makers.

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4 Arrow's research is in fact more formally known as his "General Possibility Theorem" (see Sen 1988).

5 For a good formal proof see Gravelle & Rees (1992, Ch. 17) or the original research by Arrow (1963).

(iii) *Pareto Inclusiveness*. This reflects the Paretian focus of modern economics. What it requires is that if the majority of individuals prefer one alternative to another then this should be reflected in the final social welfare function.

(iv) *Independence of the irrelevant alternatives*. In technical terms this means that any change in an individual's preference ordering that does not affect their preference between two other alternatives will not affect the social ordering of these alternatives, i.e.:

If $[a,b]$ then any change in $(.)_i$ which does not affect $(a,b)_i$ (such as a change in the individual's preference for c) will leave unchanged $[a,b]$.

What this implies is that a social welfare function must only reflect the sum of individual preferences over a number of discrete pair-wise alternatives (i.e. as in Example 4.1 individuals can only vote for one of two alternatives at any one time). Consequently an Arrowian social welfare function is ordinal and as such is not affected by an individual's strength of preference for one alternative over another (i.e. whether one alternative is considered to be the very best and another the very worst)[6].

Although Arrow's research has primarily been associated with political choices the implications of his "Impossibility Theorem" can be applied to any group decision (see

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6 In order to see this more clearly imagine that there are two decision makers (1,2) with the preference functions: $(a,b,c)_1$ and $(b,a,c)_2$. Now assume that 2's preferences alter to become $(b,c,a)_2$. What this means is that in 2's opinion a is now the worst possible alternative - thus indicating a strengthening preference for b over a. However, following the independence of irrelevant alternatives condition this change does not help the formation of a social welfare function (even though 2's dislike of a is likely to be more intense that 1's preference for it) since it is assumed to be immaterial.

Gravelle & Rees 1992, Ch. 17). Thus in relation to the behaviour of the firm Arrow's Theorem would seem to rule out the possibility of aggregating the divergent inter- and even intra-group preferences of stakeholders into a distinct corporate utility function. In short, if Arrow is correct a firm cannot exhibit subjective preferences and behave in the same way as an individual (or rather in accordance with the aggregated preferences of many individuals). Instead the only reasonable assumption regarding corporate behaviour is that a firm will simply select investment projects on the basis of first order stochastic dominance criteria (i.e. by selecting projects which yield the greatest expected value or profit for a given level of risk - see Hadar & Russell 1969) since its stakeholders will not be able to agree to it behaving in any other way.

Admittedly, the strength of the implications of Arrow's "Impossibility Theorem" for corporate decisions do rather depend on the validity of his sometimes quite restrictive axioms[7]. Indeed at the level of inter-stakeholder relations the predictions of Arrow's theorem would not appear to be particularly valid. For example, one commonly accepted way round the Theorem is too relax the independence axiom and allow participants to exhibit a strength of preference (e.g. Sen 1970, Hammond 1977, Kaneko & Nakamura 1979). Specific stakeholder groups could, therefore, indicate their intensity of feeling for different risk increasing or reducing investment alternatives (e.g. insurance, physical risk control, advertising, research and development etc.) by altering their aggregate compensation demands. Moreover it is even possible that certain cohesive groups (such as majority shareholders or senior managers) might be able to personally influence the behaviour of the firm by acting as a dictator. Indeed research into the behaviour of senior officers (May 1995, Tufano 1996) has already revealed that their preferences can have a significant impact on the risk management decisions of firms.

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7 For a comprehensive review of all the criticisms that have been levelled at Arrow's Impossibility Theorem see Sen (1970, 1986, 1988).

On the other hand, taken at the level of intra-group relations Arrow's theorem is somewhat more plausible. A good example of this is the aggregation of third party preferences. Each individual third party is likely to possess very different priorities, some preferring the firm to invest in their immediate physical safety, with others placing more importance on: social wealth generation, long term pollution effects or technological improvements (etc.). In addition, given the large number of people that are likely to comprise the total group it will not generally be possible for them to express their strength of preference for different alternatives (imagine trying to assess and then aggregate the subjective preferences of several million people) or for one individual to dominate the proceedings[8]. Of course some degree of cohesion may be provided by interest groups[9], however, it is rare for large numbers of individuals to join such groups - a fact that does rather question the Pareto inclusiveness of their actions[10].

Other stakeholder groups while perhaps more cohesive than third parties are also likely to find it difficult to achieve global preference orderings that meet all of Arrow's axioms. For example, a firm's employees may all agree that they deserve more pay or improved job security, however, differences of opinion may well arise when they try to reconcile more contentious issues such as equal opportunities, safety

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8 Indeed as Sen (1986, 1988) points out it is still not generally possible to reconcile the divergent preferences of large groups.

9 For a good discussion of the role and function of pressure groups see Dunleavy (1991, Ch. 2 & 3).

10 Although occasionally wider society may share their objectives (see again Dunleavy Ch 2 & 3).

or job demarcation[11]. Similarly the only real criteria that most shareholders are likely to be able to always agree upon is profit, with opinions regarding alternative objectives (such as corporate governance or the level of executive remuneration etc.) not always reaching a consensus (see Boros 1995, Ch. 3)[12].

Thus, even though it may be possible for specific stakeholder groups to achieve joint (and potentially mutually beneficial) social preference orderings it is much less likely that the aims of these groups will accurately represent the specific "human" concerns of the individuals that comprise them. Indeed it would seem that just as in the political context, corporate applications of Arrow's Impossibility Theorem maintain a substantial "theoretical invulnerability" (Riker 1982, p129), where even now it is hard to refute the reasonableness of its axioms in many cases. In short, while circumstances may arise in which it may be possible for stakeholders to reconcile their differences and encourage corporate behaviour that represents their subjective preferences, mutual agreements are by no means certain. As such it would generally appear to be preferable to justify observed corporate risk management behaviour on grounds other than risk aversion.

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11 See, for example, the work on democracy in trade unions. Here it has already been observed that differences of opinion can exist between full time union officers and "grass roots" members as well as between sub-groups of "grass roots" members (see, Heery & Fosh 1990, Fiorito et al 1995, Terry 1996).

12 A prime example of this was the debate concerning executive remuneration at British Gas in 1995. Many small individual shareholders felt that the company's directors had granted themselves excessive pay rises in the face of employee redundancies and tried to restrict the size of future increases. However, the motion to restrict future pay increases failed because of a refusal by institutional shareholders to back the idea (see The Economist, 4th March 1995 & 3rd June 1995).

The second major area of criticism against the use of risk averse utility functions in economics based corporate risk management research - that risk aversion can shift the focus from a number of rather more relevant and interesting economic scenarios - has been highlighted in the insightful work of Goldberg (1990)[13]. Calling risk aversion a "conversation-stopper" Goldberg observed that its use as a convenient analytical short cut in economic models has actively prevented many potentially more realistic lines of thought from being properly explored[14]. The crux issue is that giving a firm (or indeed an individual) a risk averse utility function can make any subsequent analysis of its behaviour rather complex. This will often then require the inclusion of numerous restrictions into a model (in terms of, for example, the relationship between the decision variable(s) and risk, the type of competition faced, or even the exact specification of cost, production and demand functions) that can rule out certain highly probable scenarios.

In order to see this point more clearly consider the rather simple case of a perfectly competitive firm that must decide on how many inputs to use before knowing its final

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13 See also Allen & Lueck (1995) who criticise the use of risk aversion and expected utility theory in the economics of contracts literature.

14 Interestingly this point was to some extent made earlier by Stigler & Becker (1977) who noted:

"[T]he literature on risk aversion and risk preference [is] one of the richest sources of *ad hoc* assumptions concerning tastes..... [N]o significant behaviour has been illuminated by assumptions of differences in tastes.....

.....[S]uch theories have been used as a convenient crutch to lean on when the analysis has bogged down..... They give the appearance of considered judgement, yet really have only been *ad hoc* arguments that disguise analytical failures."

However, although criticising the practical relevance of expected utility theory Stigler & Becker made no real attempt to justify or illustrate their point.

output level. The firm uses only one input (z) at a certain cost c. The market price (p) is also fixed, however, the level of final output that results from a given quantity of z varies. Output (q) is therefore random and described in multiplicative form (see Chapter 5, section 3.1.3) as:

$$\tilde{q} = f(z)\varepsilon, \text{ where } f' > 0, f'' < 0$$

Hence the variability of output is assumed to be positively related to both z and ε where $\varepsilon \geq 0$ is a random variable with a mean standardised to 1 and variance $\sigma^2 \geq 0$.

Given these assumptions a risk neutral firm will attempt to maximise expected profits according to the following optimisation condition

$$E[\pi] = E[pf(z)\varepsilon - cz] \quad [1]$$

Where E is the expected value operator.

The first and second order conditions are then simply:

$$E[pf'(z)\varepsilon - c] = 0 \quad [2]$$

or

$$pf'(z) = c = 0 \quad [2a]$$

and

$$E[pf''(z)\varepsilon] < 0 \quad [3]$$

Where [3] will be satisfied since $f'' < 0$.

Now assume that the firm is risk averse with a concave utility function that is both a continuous and differentiable function of profits so that:

$$U'(\pi) > 0, U''(\pi) < 0.$$

Consequently the firm has become an expected utility (rather than an expected profit) maximiser, its input decisions depending the following optimisation condition:

$$E[U(\pi)] = E[U(pf(z)\varepsilon - cz)]. \quad [4]$$

The first and second order conditions for a maximum are, therefore,

$$E[U'(\pi)(pf'(z)\varepsilon - c)] = 0 \quad [5]$$

$$E\left[U''(\pi)(pf'(z)\varepsilon - c)^2 - U'(\pi)pf''(z)\varepsilon\right] < 0 \quad [6]$$

Note that the second order condition for a maximum would still be satisfied for a risk averse firm when $f'' = 0$, however, such an assumption would preclude a comparison between its behaviour in the certain and risky cases (see Chapter 5 section 3.2.4, see also Sandmo 1971 or Pope & Kramer 1979). Thus in order to compare [5] with the risk neutral case rearrange it to get

$$E[U'(\pi)pf'(z)\varepsilon] = E[U'(\pi)]c$$

Then noting that the expected value of the product of two random variables (in this case the marginal utility of profit and output) is simply the covariance of the two variables plus the product of their means (i.e.: $E[x.y] = cov(x,y) + E[x]E[y]$), rewrite this expression to get

$$pf'(z)E[U'(\pi)] + \text{cov}(U'(\pi), pf'(z)\varepsilon) = E[U'(\pi)]c$$

Following Eeckhoudt & Gollier (1992, Ch. 11) move the covariance term over to the right hand side and divide both sides by $E[U'(\pi)]$ to get finally:

$$pf'(z) = c - \frac{\operatorname{cov}(U'(\pi), pf'(z)\varepsilon)}{E[U'(\pi)]} \qquad [7]$$

Comparing equation [7] with that of [2a] it should become clear that the behaviour of a risk averse firm is not only influenced by the *tangible* revenues and costs that can be generated by different levels of z but also by the additional term: $\frac{\operatorname{cov}(U'(\pi), pf'(z)\varepsilon)}{E[U'(\pi)]}$. This term describes the impact that risk has on the utility function of the firm and in effect represents the "psychological" cost of risk (Eeckhoudt & Gollier 1992 p190-191). Given that decision makers should all prefer more wealth to less the value of the denominator will always be positive, however, the value of the numerator - which effectively denotes the impact of risk on the marginal utility of profits - and hence the sign of the expression will depend on a firm's attitude towards risk. Under risk aversion the numerator will be negative, meaning that a risk averse firm will demand a lower level of z than it would in a world of certainty[15]. In short, the negative sign of the numerator essentially reflects a risk averse firm's desire to reduce its exposure to risk by lowering its demand for inputs[16]. To see this remember that in expected utility theory the slope of a risk averse decision maker's utility function of wealth is positive but concave. Hence the marginal utility of wealth received by a risk averse decision maker will decline for higher (i.e. more beneficial) realisations of the state of nature.

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15 Of course for a risk neutral firm the value of this term will be zero.

16 Remember that given multiplicative risk a reduction in z will lower a firm's exposure to output fluctuations.

Perhaps the most obvious theoretical problem to arise out of this example is that the inclusion of risk averse behaviour in economic (or indeed financial) models adds quite an elaborate non-linear term to the analysis - a concave marginal utility function of wealth. The issue is that a risk averse decision maker is not only concerned about his or her expected returns but also the extent to which actual returns may vary. This will, therefore, need to be reflected in the model along with an acceptance of the additional complexities that this can bring.

Examples of the complexities that a non-linear utility function can bring to economic models of firm behaviour abound in the literature. For example, Leland (1972) found it impossible to predict how the presence of demand risk would affect the behaviour of a risk averse, price setting monopolist except in the extremely limiting case of additive risk. Furthermore, the exact preferences of even a quantity setting monopolist could only be determined where the firm's expected returns were assumed to be increasing in the level of risk[17]. Similarly research into the economic impact of multiple sources of risk (e.g. Ratti & Ullah 1976, Eeckhoudt & Kimball 1991, Machnes 1993, Wong 1996) has also suffered from the complexities that risk aversion can bring. In fact many of the resultant models have found it necessary to specify not only the exact relationship that exists between different risks (i.e. whether they are independent or exhibit a positive or negative covariance) but also the nature of higher and quite esoteric moments of a decision maker's utility function[18].

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17 Leland calls this his "Principle of Increasing Uncertainty".

18 For example to get a clear result from their model Eeckhoudt & Kimball (1991) had to define a decision maker's utility function down to the fourth derivative. They claimed that this indicated the degree of "prudence" exhibited by a decision maker.

A further important theoretical problem regards the (limited) generality of the results of models using risk aversion. As shown in equation [7] the concept of risk aversion is based on a firm's (or individual's) *subjective* (although supposedly rational - see von Neumann & Morgenstern 1944, Schoemaker 1982) preferences for certainty over risk. However, where firms are given subjective preferences the ensuing model will need to account for the fact that they could differ in their personal distaste for risk[19]. Without such a recognition situations could arise in which an increase (or decrease) in risk may affect each individual firm in a market somewhat differently. Take the simple example of a small increase in the mean and a large increase in the variance of ε. At first glance such a change might be expected to cause all risk averse firms to reduce their demand for z. However, for firms that exhibit very low levels of risk aversion such a situation may actually be beneficial (since the expected productivity of z has increased), thereby, prompting them to actually increase their demand for z.

In order to combat the problem of differences in the strength of individual risk preferences without imposing highly limiting assumptions on the nature of a firm's risk preferences (e.g. quadratic utility), changes in risk have needed to be quite closely specified in terms of both their impact on the mean and riskiness of ε. The usual way to do this is to stick to changes which exhibit second (and sometimes even third order) stochastic dominance (see Hadar & Russell 1969 and Levy 1992) such as the introduction of a Rothschild & Stiglitz (1970) mean preserving spread[20]. However, while this can help to yield unambiguous results it does rather restrict the

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19 In fact these differences in tastes may not just depend on the extent to which $U''<0$ (and hence the strength of the negative covariance between $U'(\pi)$ and $pf'(z)\varepsilon$) but also on higher (and rather esoteric) moments of a firm's utility function such as U''' or even U''''.

20 For a change in risk to exhibit second order stochastic dominance it must be preferred by all risk averse decision makers, i.e. those exhibiting $U'\geq0$, $U''\leq0$. Third order stochastic dominance requires that: $U'\geq0$, $U''\leq0$, $U'''\geq0$.

situations that can be modelled. Indeed the above example of a small increase in the mean coupled with a large increase in the riskiness of ε would probably need to be excluded.

Thus it would seem that the use of a risk averse utility function in economic models can often create more costs than benefits. What is needed, therefore, is an alternative method to explain why a firm's short run operational decisions may be influenced by its exposure to risk. The purpose of the next section is to develop an economic framework that can accomplish this.

3. Developing Economic Rationale for Risk Management that Does Not Rely on Risk Aversion.

3.1 *Introduction*

Despite the rather strong objections that were outlined in section 2 against the use of risk averse utility functions, economic theory does have a lot to contribute to our understanding of corporate risk management decisions. However, in order to be of any real value economic based research into risk management will need to move away from the idea that firms may behave "as if" they are risk averse. In fact in what follows this notion is rejected completely, instead it is assumed that a firm is a simple short run (expected) profit maximiser. Such a focus may seem surprising to some[21], yet it will be shown that economic models built around even quite basic behavioural assumptions can be used to extend the circumstances under which risk management could be used by a firm.

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21 For example, Smith & Williams (1991) suggest that risk management will be of no value to a myopically profit maximising firm.

Admittedly the use of even non-expected utility based concepts such as profit or indeed value maximisation have recently received quite extensive criticism in certain corners of the risk management literature. The main brunt of criticism has come from the organisational behaviour based research of authors such as Clarke (1992), Pidgeon et al (1992), Anand & Forshner (1995) and Glendon & McKenna (1995). The basic tenet of this work is that given the complexity of real world organisational environments and the often irrational desires of stakeholders it is unrealistic and sometimes even dangerous (Toft 1996)[22] to think about or model risk in an objective way. Instead these authors argue that rather than following supposedly rational[23] goals such as profit or value maximisation a firm's risk management decisions are typically influenced by what are commonly termed heuristics or less formally "rules of thumb".

The idea that firms will use heuristics largely arose out of the extensive psychological based empirical research that has been conducted into the real world decision making processes of individuals under risk[24]. Of particular relevance in the seminal work of authors such as Kahneman & Tversky (1973) and their observed "Availability Heuristic" - where in an experimental study they found that events which could be recalled or imagined easily were given higher probabilities. In another experimental study Slovic et al (1980) proposed two further widely recognised heuristics - those of "dread risk" (the extent to which a risk is feared) and "unknown risk" (the extent to

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22 Toft's (1996) rather emotive argument is based on the premise that rational models of risk management lead us to overlook the impact that human actions and attitudes can have on the risk of major disasters.

23 Rational behaviour can be quite hard to define (see Sugden 1986, 1989). However, for the purposes of this section it can be considered to be the maximisation of some objective function (e.g. profit, growth or utility) with full information and unlimited powers of reasoning.

24 For two good recent reviews of this area see Pidgeon et al (1992) and Shiller (1997).

which a risk is understood by a decision maker). More heuristics have since been identified (most of which again based on experimental observations) dealing with issues such as the influence of past actions (Tversky & Kahneman 1974), framing effects (Schoemaker & Kunreuther 1979, Hershey & Schoemaker 1980, Tversky & Kahneman 1981) and even the media (Slovic 1987, Nelkin 1988).

Given the quite large number of empirical studies it is hard to deny that heuristics will not colour at least to some extent the real world decision making processes of either influential individuals (e.g. MacCrimmon & Wehrung 1986 & 1990, March & Shapira 1987, Lypney 1993, Mitchell 1995) or even certain groups within firms (see Pidgeon 1991, Pidgeon et al 1992, Turner 1994, Yardley et al 1997). However, despite this fact rational economic models of risk management are far from redundant (although some might like to see it that way, for example, Clarke 1992). As Schoemaker (1993) points out rational economic models have an important role to play in our understanding of a wide range of corporate behaviour. In particular, rational models keep the analysis tractable, enabling the consideration of complex issues such as the strategic interdependence of firms (see Chapter 6). Moreover, although the risky decisions of certain individuals and groups may depend on heuristics it is hard to believe that the firm as a whole will not in some way be influenced by rational criteria such as profit maximisation (Hay & Morris 1991, p292-296) - particularly when senior management remuneration is closely tied to profits (see Agrawal & Mandelker 1987, Lypney 1993, Tufano 1996)[25]. Indeed, as will be shown in Chapter 6, in the corporate context certain heuristics could actually be used as part of a rational strategy to increase profits.

Thus it is without any further apology that the analysis proceeds with the assumption that firms are rational expected profit maximisers. Despite this assumption, however,

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25 Although some would dispute this view (e.g. Mitchel 1995).

it will be demonstrated that even an apparently risk neutral firm is rarely going to be completely indifferent to risk or risk management. This concern originates out of two main observations that have been made in the general "economics of uncertainty" (Hey 1979) literature. The first is that risk can, on occasion, represent a "pure penalty" (Martin 1981) to the firm, which either raises its operating costs or lowers its revenues[26]. The second is that firm behaviour under risk can sometimes very closely mimic that of a risk averse or even risk preferring individual when it is influenced by what are commonly termed "technological non-linearities" in its profit function (see Aiginger 1987, Ch. 4 or Driver & Moreton 1992, Ch. 4)[27].

3.2 *Risk as a pure penalty*

In order for risk to represent a pure penalty for the firm the profits arising out of each possible state of nature can be no better than would occur in a world of certainty and must also sometimes be worse (Martin 1981). Hence, profit under certainty represents the upper bound of profit under risk meaning that a firm cannot benefit in any way (at least directly - see Chapter 6) from its exposure. The presence of risk will, therefore, cause an unambiguous reduction in the firm's expected profits, which it is likely to try to control through risk management.

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26 Theoretically it is also possible that risk could confer a pure benefit onto a firm (see Nickell 1978, p72-74), however, Driver & Moreton (1992, p46-47) argue that such an eventuality is much less likely in practice.

27 Aiginger (1987) makes a third observation that where a risk neutral firm is given some form of costly ability to alter their decision variable(s) ex-post (i.e. once the final state of nature is known) they may also cease to be indifferent to risk. However, as he himself recognises in almost all cases of ex-post flexibility the fundamental drivers of firm behaviour are pure penalties and technological non-linearities (for example, see Turnovsky 1973, Hartman 1976, Bernanke 1983, Ghosal 1995).

A classic example of risk as a pure penalty is the price rigidity model for a profit maximising, perfectly competitive firm under demand risk described in Aiginger (1987, Ch. 4) and Driver & Moreton (1992, Ch. 4). In this model a perfectly competitive firm is assumed to make its output decisions (q) based on a fixed market price (p) but before random consumer demand for its product is known (as denoted by the random variable X)[28]. The aim of a profit maximising firm is then to achieve optimum profits by maximising the difference between total revenue (r) and total costs (c).

Before proceeding further consider the certainty case in which a firm's revenue and costs will simply be a function of the only non constant variable: q. The profit maximising firm will, therefore, attempt to maximise its profits according to the following conditions:

$$\pi = r(q) - c\,(q), \tag{8}$$

$$\pi' = r'(q) - c'\,(q) = 0, \tag{9}$$

$$\pi'' = r''(q) - c''(q) < 0. \tag{10}$$

Noting that $p = r'(q)$ for a perfectly competitive firm (given the fact that it faces a perfectly elastic demand curve - see for example, Gravelle & Rees 1992, Ch. 10) this then yields the standard result - that an individual firm will maximise its profits at the level of q which equates the market price with its marginal costs. However, when exposed to demand risk the firm's behaviour is likely to change since in maximising

28 A prime example of this approach is the classic "newsboy" problem, in which a newspaper seller faced with a fixed cover price and random consumer demand must decide how many papers to purchase from his or her central distributor.

its profits it will not only need to consider how a change in q may affect its marginal revenues and marginal costs but also the possible values (x) that X could take. The reason for this is the fixed market price that prevents supply and random consumer demand from always being in equilibrium. This then forces the firm to resolve a new dilemma between raising output to make the most of high demand states or lowering it to reduce the possibility that produce will be wasted when demand is low.

Given that even in a world of risk a firm should seek to produce a level of output that equates the fixed market price with its marginal costs it should attempt to resolve this dilemma by assuming that its sales will be equal to the minimum of production or demand (see Aiginger 1987, Ch. 4)[29]. More formally this results in the following profit maximising condition:

$$\pi = min[r(X), r(q)] - c\ (q), \qquad [11]$$

or

$$\pi = Z - c\ (q), \qquad [11a]$$

where

$$Z\begin{cases} r(X) & \text{when } X < q \\ r(q) & \text{when } X > q \end{cases}.$$

Assuming that $f(x)$ is the probability distribution function of X with the cumulative distribution function $F(x)$, such that:

$$F(x) = prob\ (x \leq q),$$

29 It is worth noting that where the firm does not follow the standard marginal cost pricing assumption of perfect competition (e.g. where price is determined by a fixed mark-up) the results of this model may change (see Driver & Moreton 1992, Ch. 4).

$$1\text{-}F(x) = prob\ (x > q),$$

then from [11a] the expected value of Z will be:

$$E[Z] = r(X)F(x) + r(q)(1\text{-}F(x))$$

and

$$\mathrm{d}E[Z]/\mathrm{d}q = r'(q) - r'(q)F(x).$$

Thus the first and second order conditions for the firm's profits to be at a maximum are:

$$\mathrm{d}E\pi/\mathrm{d}q = r'(q) - r'(q)F(x) - c'(q) = 0 \qquad [12]$$

$$\mathrm{d}^2E\pi/\mathrm{d}q^2 = r''(q)[1\text{-}F(x)] - r'(q)f(x) - c''(q) < 0. \qquad [13]$$

Compared to [8] equation [12] has one additional negative term ($-\ r'(q)F(x)$) that (since $r'(q) > 0$, $F(x) > 0$) serves to directly reduce the expected marginal revenue and hence output of the firm. This term represents the tangible pure penalty element of risk. In this case the pure penalty comes from the positive potential[30] for unsold (i.e. wasted) production in low demand states (where $x \leq q$) coupled with the fact that when demand is high the fixed market price prevents the firm from doing any better than it would in a world of certainty[31].

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30 Since under the axioms of probability: $0 \leq F(x) \geq 1$.

31 To see this remember that no perfectly competitive firm can do better than produce the level of q that ensures $p = r'(q) = c'(q)$ (the profit maximising condition in a world of certainty). Any increase in q above this level will simply reduce the profits of the firm - since it will be producing where $p = r'(q) < c'(q)$).

In the above example the fixed price induced pure penalty has effectively caused a downwards (or more specifically right-wards) shift in the marginal revenue function of the firm. More generally, however, pure penalties can have an adverse affect on either the marginal revenue or marginal cost function of the firm. The broad effects of both are detailed in figures 1 and 2.

Figures 1 and 2 about here

Figures 1 and 2 illustrate the impact of revenue and cost related pure penalties respectively. In figure 1 the impact of a pure penalty has resulted in a downward (right-wards) shift in the perfectly competitive firm's marginal revenues. This adverse shift has then caused output (which falls from qc to qr) and profits to fall (where ABqcO > CDqrO). On the other hand figure 2 shows the impact of a cost related penalty. In this case the penalty causes the firm's marginal cost function to shift upwards (left-wards), however the net result is the same: output and profits will both fall (where in this case ACqcO > ABqrO).

In addition to the supply and demand dis-equilibrium model examined above several other possible causes of cost and revenue related pure penalties have been identified in the economics literature. In fact as a limited amount of recent research has shown many of the agency and transactions costs put forward by the modern finance approach to risk management can also be considered as pure penalties in an economic context. Most notable perhaps are the works of Greenwald & Stiglitz (1993) and Schneider (1992)[32] who explore the economic impact of bankruptcy costs[33] and

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32 See also Parry & Parry (1991) and Di Mauro (1994) who undertake a similar analysis to Schneider. However, their work relies much more heavily on the existence of risk aversion.

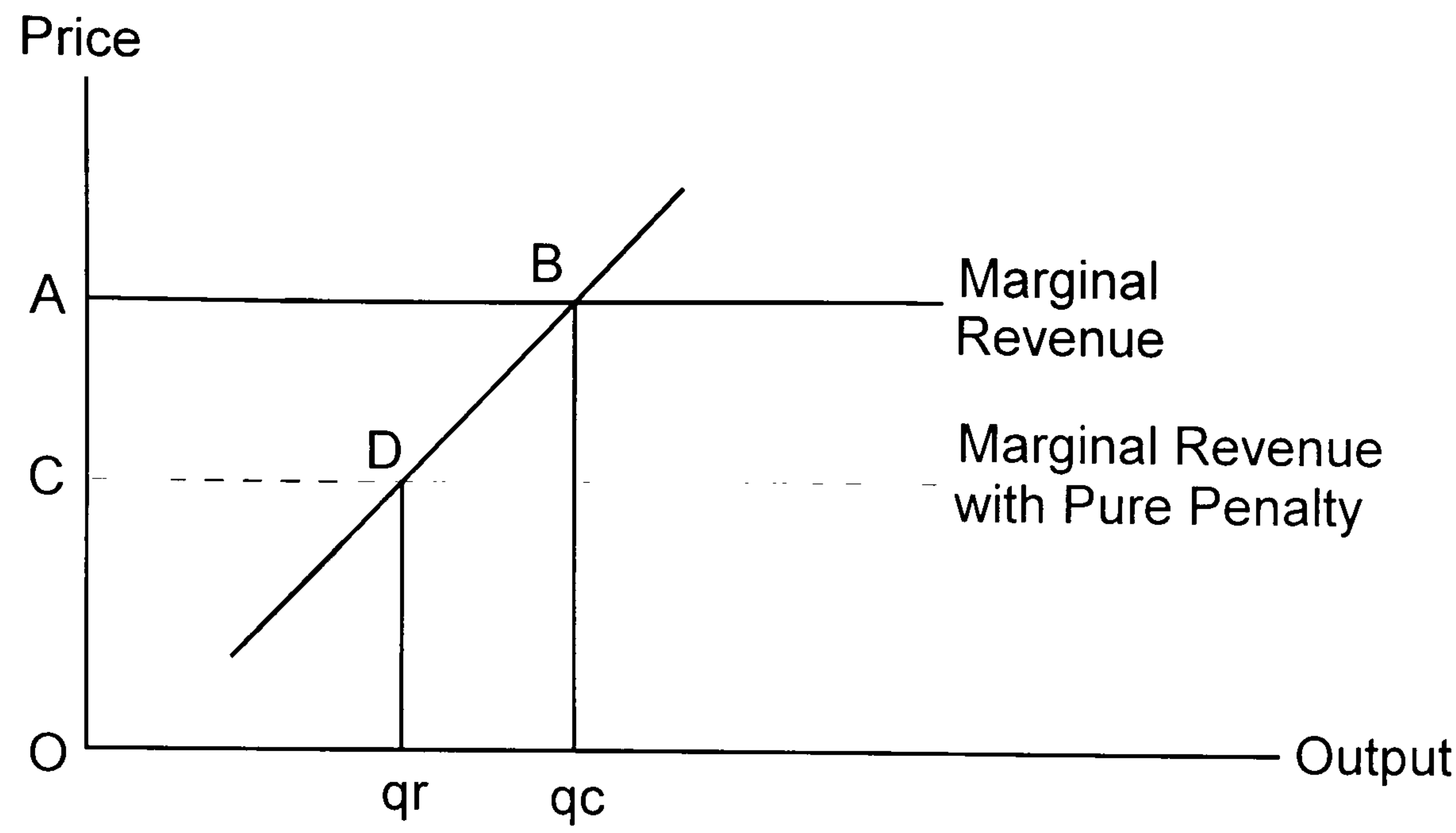

Figure 1: The Impact of a Pure Penalty on Marginal Revenue

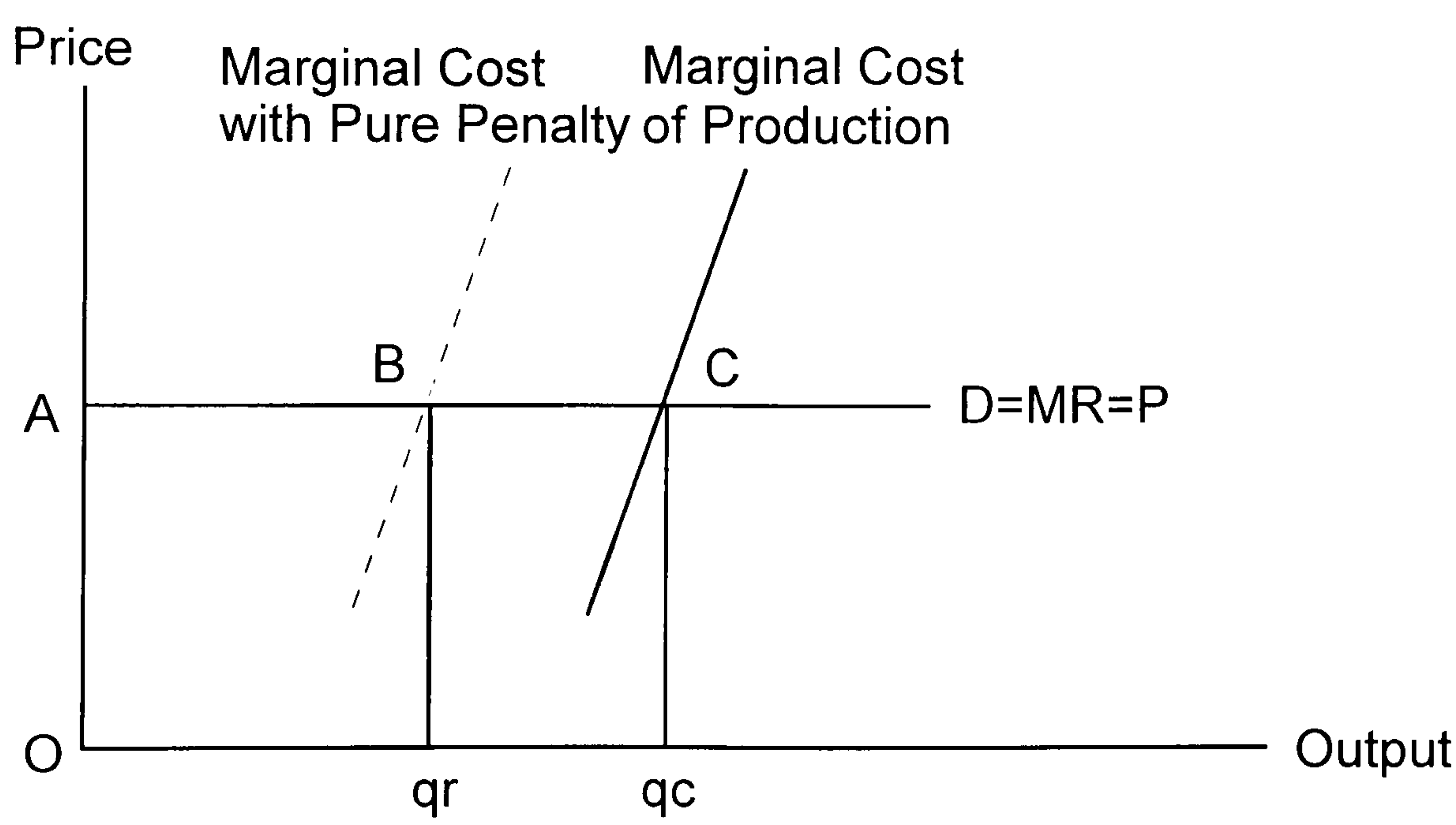

Figure 2: The Impact of a Pure Penalty on Marginal Costs

employee compensation claims/productivity respectively. In each case it is demonstrated that the presence of risk can serve to directly increase a perfectly competitive firm's marginal costs, thereby, providing a possible incentive for investment in risk management. However, while the predictions of the modern finance approach can be used to provide a number of interesting pure penalty based economic justifications for risk management, other equally attractive additional possibilities exist. For example there is the case of random output in the face of fixed demand (Aiginger 1987, Chung 1990) or the impact of a single unreliable input in a two factor fixed coefficient production process (Roodman 1972, see also Martin 1981 for a similar model). Moreover, whenever a firm is exposed to a "pure" risk (i.e. a risk whose outcomes are always negative - see Chapter 2, section 2) it is likely to experience some form of cost or revenue related pure penalty (McKenna 1986).

3.3 *Technological Non-Linearities.*

Where the presence of a particular risk leads to a reduction of profits in every state it is not difficult to see how its presence should motivate an expected profit maximising firm to invest in risk management. However, exposure to many risks can lead to not only adverse but also beneficial states of nature in which the firm's profits are higher than they would be in a world of certainty. Thus in order for the presence of such risks to affect the risk management decisions of a firm it will generally be necessary to prove that the losses associated with adverse states will be either greater or less than the gains in beneficial ones[34]. Of course one way to do this is to rely on expected

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[33] Note that depending on the specification of a model the possibility of costly bankruptcy could also create a technological non-linearity (Smith & Stultz 1985, Greenwald & Stiglitz 1993).

[34] Perhaps because of its roots in pure risk (see Chapter 2, section 2) most of the academic research into risk management has assumed that it will only be used to reduce a firm's exposure to risk. However, more recently it has been suggested that risk management may have a role to play not just in decreasing risk but also in profitably increasing it as well (e.g. Doherty & Smith 1993, Stultz 1996).

utility theory and risk averse or risk preferring utility functions. However, if (see section 2 above) it is accepted that expected utility theory is not an appropriate basis on which to model the behaviour of firms an alternative explanation will be required.

One more appropriate, way of expressing the apparent risk averse or risk preferring preferences of a firm is to make use of technological non-linearities (see Aiginger 1987, Ch. 4 or Driver & Moreton 1992, Ch. 4). Technological non-linearities can affect the behaviour of a profit maximising firm when two elements are present. First the firm must make its price and or output decisions ex-ante (i.e. before the state of the world and hence its final profits is known) - this forces it to maximise expected rather than actual profits. Second the presence of a technological non-linearity must cause the firm's total and or marginal profit function to become strictly concave or convex in the random variable(s) faced[35]. The situation is then analogous to that of a expected utility maximising individual (von Neumann & Morgenstern 1944, Pratt 1964, Arrow 1965), the only difference being that a firm's behaviour is firmly rooted in its desire to maximise profits (or more specifically, expected profits) rather than utility.

In order to fully understand the impact of technological non-linearities on a profit maximising firm assume that its profits are a function of a decision variable Y and a stochastic variable X, i.e.:

$$\pi = \pi(X,Y)$$

35 Note that strict non-linearity in a firm's total profit function is sufficient to show that the presence of risk will affect its expected profits. However, in order to show that the presence of risk will influence a firm's price/output decisions (as is generally case under risk aversion) a strictly non-linear marginal profit function is also necessary (see Nickell 1978, Ch. 5).

The formal condition for the firm's apparent indifference, aversion or preference for risk then depends on there being a linear, strictly concave or strictly convex relationship between the response of profits to a small change in the decision variable (*Y*) and the stochastic variable (*X*). In other words[36]:

If π_Y is concave, $\pi_{YXX} < 0$, Y is lower under risk than in a world of certainty.
If π_Y is convex, $\pi_{YXX} > 0$, Y is higher under risk than in a world of certainty.
If π_Y is linear, $\pi_{YXX} = 0$, Y is the same under risk than in a world of certainty.

Formal proof that the strict convexity or concavity of the profit function of an expected profit maximising firm will influence its decisions can be derived using Jensen's Inequality (see Aiginger 1987 Ch. 4 or Eeckhoudt & Gollier 1992 Ch. 3). Jensen's Inequality essentially states that for any strictly concave (convex) function of a random variable the expected value of that function will always be below (above) its equivalent value in a world of certainty. Specifically this implies that:

If π_Y is a strictly concave (convex) function of the random variable *X* then:

$$E[\pi_Y(X)] < \pi_Y[E(X)] \quad (E[\pi_Y(X)] > \pi_Y[E(X)])$$

Figure 3 about here

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36 Interestingly the formal requirements for an expected profit maximising firm to lose its indifference to risk comes from the Rothschild & Stiglitz condition for the optimal value of a decision variable to be smaller under uncertainty than the optimal value under certainty for any risk averse decision maker (Rothschild & Stiglitz 1970 & 1971). Indeed, as Aiginger (1987) points out it is quite a trivial exercise to modify the Rothschild & Stiglitz condition to illustrate the impact of technological non-linearities.

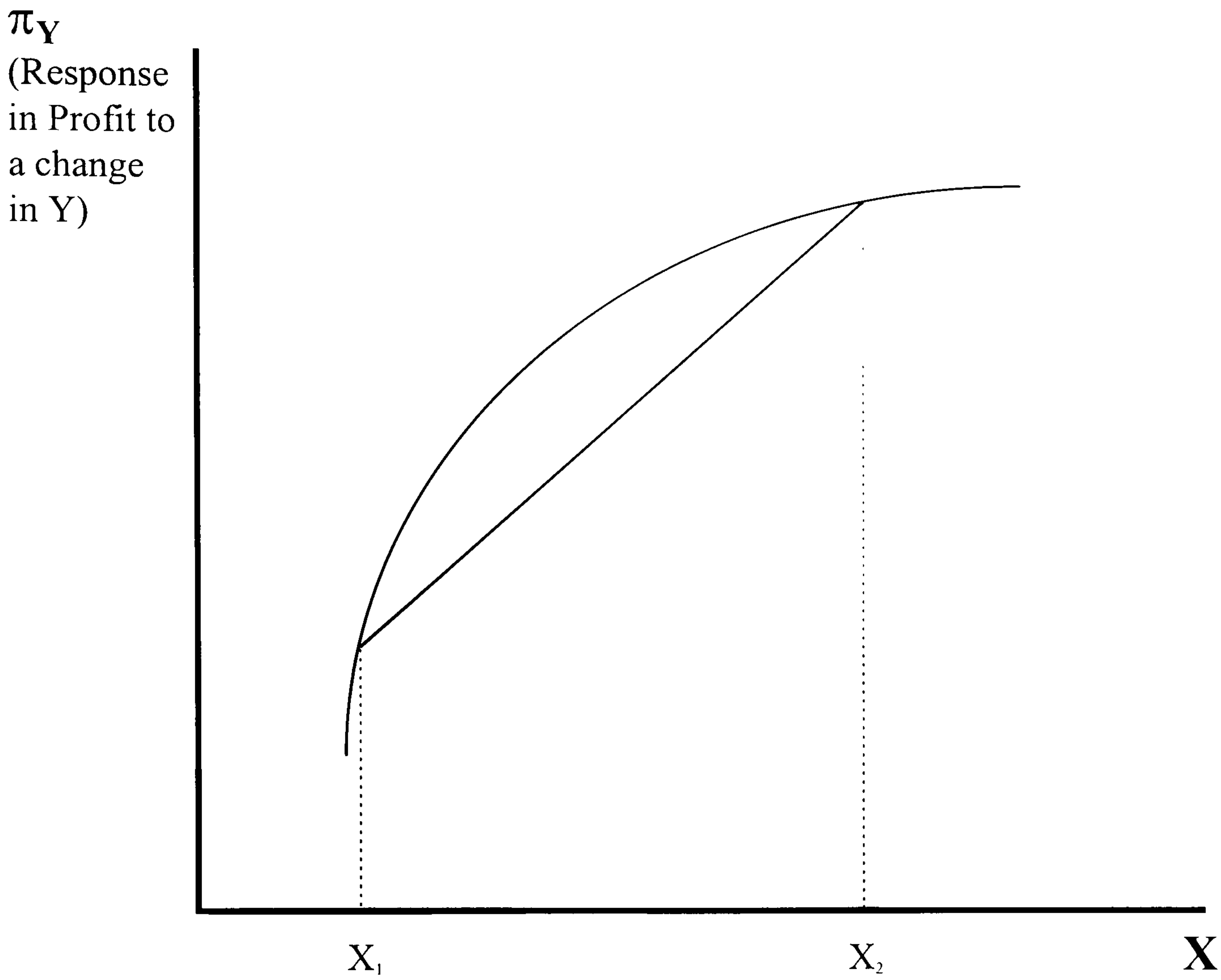

Figure 3: Impact of a Mean Preserving increase in Risk When π_Y is Concave in Y

To see this result more clearly consider the graphical example of the impact of a negative technological non-linearity (i.e. one that reduces the expected profits of a firm) illustrated in Figure 3. Here the firm's marginal profit function (π_Y) is assumed to be strictly concave in the random variable X (i.e. $\pi_{YXX} < 0$). Any value of π_Y associated with a certain value for X will then be greater than the expected value of π_Y corresponding to any possible random X values (i.e. X_1 and X_2) obtained in a mean preserving spread (Rothschild & Stiglitz 1971). Marginal (and indeed total) profits are, therefore, lower in a world of risk causing the point of zero marginal profit to be reached sooner than under certainty and thus reducing the firm's demand for Y.

In the corporate context technological non-linearities will generally arise where circumstances conspire to cause concavities and convexities in a firm's revenue, cost or production functions[37]. For example, all things being equal, a concave revenue function should cause a firm's profits to become more concave, while a convex production function (in which productivity increases with input use) will do the opposite. Many different factors have already been identified that could cause a firm's revenue, cost or production function to become strictly concave or convex, however, it should be noted that most research has focused on the impact of negative technological non-linearities[38]. Some causes of negative technological non-linearities have even been considered by authors within the modern finance approach to to justify investment in risk management - such as a progressive tax function (see chapter 2 section 3.3 and especially Eeckhoudt et al 1997), the risk of costly

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37 Even the "attitudes'" of individuals towards risk may be influenced by technological non-linearities. For example, the investment decisions of managers may be more due to concavities and convexities in their remuneration structure than a basic psychological liking or disliking for risk (e.g. see Lypney 1993).

38 Although, see Oi (1961) for an interesting and rather enlightened discussion of a positive technological non-linearity.

bankruptcy (Smith & Stutlz 1985) or an increasing marginal cost of credit (Froot et al 1993). Yet, other interesting possible causes of technological non-linearities remain to be properly considered in the risk management literature[39]. For example, one prime cause of a negative technological non-linearity identified in the economics literature is imperfect competition and the effect that this can have on the structure of a firm's revenue function (e.g. Leland 1972, Nickell 1978, Turnbull 1986, Klemperer & Meyer 1986, 1989). Indeed as will be shown in Chapters 5 and 6 the presence of risk in an imperfectly competitive industry can generate some quite surprising predictions regarding both a firm's production and risk management decisions. Moreover another interesting cause of a technological non linearity is the case of multiple unreliable inputs explored by Ratti & Ullah (1976). In Ratti & Ullah's model a firm uses two inputs (i.e. K and L) to produce its final output. Unfortunately the services rendered by these inputs are assumed to be random (where $\tilde{K} = uK$ and $\tilde{L} = vL$ and u, v are random variables with a unit mean) meaning that final output fluctuates. Then assuming that the elasticities of the marginal product curves are non-increasing functions of factor services and the two inputs compliment each other less and less as the productivity of one or other increases Ratti & Ullah demonstrate that exposure to two randomly productive inputs will create a technological non-linearity that reduces expected profits since the firm is forced to utilise inefficient combinations of $\tilde{K}$ and $\tilde{L}$[40].

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39 See Aiginger (1987) for a comprehensive review of the role of technological non-linearities in economic models of firm behaviour under risk.

40 Note that Pope & Just (1977) do criticise Ratti & Ullah's result and assumptions.

4. Conclusion

In many respects the conclusions of this chapter appear contradictory. On the one hand it was argued that a firm's decisions are not motivated by "human-like" concerns such as risk aversion, while on the other it was shown that an apparently risk neutral, expected profit maximising firm is still unlikely to be indifferent to risk. However, the crux issue is that risk - even speculative risk - can have a tangible and often negative impact on both a firm's revenue and cost functions. In short the presence of risk can often complicate corporate decision making, thereby, increasing the chance that a firm will make a mistake and often reducing its profitability.

Viewed under a framework of pure penalties and largely negative technological non-linearities risk management would appear to be an important investment for a firm, adding value by directly increasing the profitability of its operations. However, what has not yet been determined is the exact relationship between a firm's exposure to risk and its demand for risk management. Each type of risk (e.g. demand, cost or technological risk) is likely to influence a firm in rather different ways - affecting both the type of risk management tool that is chosen and the extent to which it is used. Moreover the economic environment in which a firm finds itself in (such as the extent of a firm's market power or its cost conditions for example) is likely to have a significant effect on its preferred risk management strategy. It is these important issues that are discussed in the next two Chapters.

Chapter 5:
Risk Management and the Theory of the Firm

1. Introduction

To some the title of this Chapter might appear to indicate that its contents are merely an attempt to reinvent the wheel. It was in fact Cummins (1976) who first used this title twenty years ago for his seminal paper on firm behaviour under risk (see Chapter 2, section 2 for more information). However, although stressing the need for a risk management decision framework that incorporates the global objectives of a firm Cummins's use of this phrase is somewhat misleading. What Cummins was actually proposing was a framework for corporate risk management decisions based upon the Capital Asset Pricing Model (CAPM) not the neo-classical economic theory of the firm that is applied here.

A major problem with just using the CAPM (or its derivatives such as Levy's 1978 Generalised CAPM - see Chapter 2) as a means to predict/explain corporate risk management behaviour is that it gives a rather one-dimensional view of the world. The trouble is that although CAPM based risk management models can be used to investigate the impact of risk on the long term market value of a firm, they are much less effective in evaluating shorter term concerns such as a given risk's influence on (expected) profits. In particular one point that has been largely overlooked by both Cummins and much of the subsequent CAPM based "modern finance" research into risk management is that increases in risk may not always be followed by a rise in a firm's short run expected returns[1]. Indeed, as discussed in Chapter 4, a considerable

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1 Admittedly some of the research (although this does not include Cummins) into the modern finance approach for risk management has recognised that tax or bankruptcy effects may lead to a negative relationship between risk and expected profits. However, these are only two reasons out of the many discussed in Chapter 4, moreover empirical studies have shown that the real world significance of tax or bankruptcy related costs in motivating risk management (especially those related to tax) is often quite small (see Chapter 3).

body of economics based research has already demonstrated that increases in risk will often represent a tangible and immediate cost to a firm. Using this insight the current Chapter goes onto demonstrate that it is possible to explain corporate risk management expenditure without having to resort to the assumption adopted by most modern finance based risk management models - that some of the firm's stakeholders are (or at least act as if) risk averse.

Integrating risk management into the neo-classical economic theory of the firm can also extend our understanding of corporate risk management decisions in other ways. For example, one major benefit is that the relationship between a firm's primary operational decisions (i.e. how much to produce, what inputs to use or price to charge, etc.) and its expenditure on risk management can be more firmly established. Modern finance based risk management research has never really addressed the impact that a firm's operational decisions can have on the size or nature of its risk management expenditure. Admittedly authors such as Shapiro & Titman (1985), Smith & Stultz (1985), MacMinn (1987), Cho (1988) and Froot et al (1993) have considered how the size of a firm's cash flow fluctuations, bankruptcy costs or leverage may affect the scale of its risk management operations, however, in none of these cases has a formal link between risk, risk management and a firm's price, input or output decisions ever really been made. This Chapter, therefore, attempts to provide an answer to this question, by showing how risk management can have a direct and significant influence on a firm's operational decisions.

Finally (as will primarily be argued in Chapter 6) economic theory can be used to aid our understanding of the strategic role of risk management. For example, industry commentators have already suggested that real world firms consider their rivals derivatives strategies when devising their own hedging plans (Bank of America 1995, Bishop 1996, Lawless 1997), however, what is lacking is a formal theoretical framework to explain the such behaviour.

Unfortunately, economic models of firm behaviour under risk are not without their complications. One major issue is that the predictions of a particular model are highly dependent upon the rather large number of specific assumptions that need to be made. Changes in the nature of the firm (i.e. its cost conditions or whether it is a price or quantity setter), its competitive environment and the form of risk that it will face (Aiginger 1987 Chs. 5-7) can all have a significant impact on the final outcome. Consequently, the analysis in this Chapter is necessarily restricted to only a small number of cases. In particular, it will focus on examining the planned output and risk management decisions of firms that face what is commonly termed technological risk (e.g. Walters 1960, Gravelle & Rees 1992, Ch. 21). Using this basic framework the behaviour of firms operating within three different market forms will then be considered, those of perfect competition, monopoly and oligopoly.

Section two commences with a brief critical discussion of the work of previous authors who have attempted to explain how the presence of risk may influence the behaviour of both expected utility and expected profit maximising firms. In particular it is argued that no one has yet properly considered a firm's incentive to actively control its exposure to risk in an economic context. Section three then attempts to address this problem by outlining a model in which an expected profit maximising firm must decide whether or not it wants to directly control the variance of random fluctuations in its production capacity. Section four provides some solutions for this model using the three selected market forms of perfect competition, monopoly and oligopoly. Under perfect competition it is shown that since each firm faces a perfectly elastic (constant) demand function the presence of firm specific output fluctuations will not affect the expected profits of such firms (although industry wide risks may still have an effect). This yields the standard result of the modern finance literature -

that a risk neutral firm will not generally purchase risk management unless it alleviates either agency or transactions costs. However, in what follows it is argued that perfect competition is simply a special case of a more general model. For example, in both monopoly and oligopoly markets a firm's marginal profit function may become concave in its exposure to output fluctuations, this can then cause output and expected profits to fall prompting investment in risk management.

2. Integrating Risk Management with the Theory of the Firm Under Risk.

The purpose of this section is to briefly review a number of previous attempts at explaining how the presence of risk may influence the behaviour of both expected utility and profit maximising firms. A key feature of this research is the suggestion that firms will not generally be indifferent to risk, moreover, it appears to be widely accepted that most firms (even expected profit maximisers in some cases) should wish to control their exposure. However, despite these observations only a very small number of papers have actually explicitly examined the economic impact of risk in a formal corporate risk management context. In particular what remains to be fully explored is an expected profit maximising firm's incentive to endonegously (i.e. internally) control its underlying exposure to risk.

Surprisingly, in much of the earliest economic based research into the behaviour of firms under risk it was assumed that risk was exogenous and that a firm would be unable to alter the underlying distribution of the random parameter(s) that it faces (e.g. Walters 1960, Oi 1961, Tisdell 1969, Sandmo 1971, Leland 1972, Ratti & Ullah 1976, Applebaum & Katz 1986, Gravelle & Rees 1992, Ch 21). The practice of formal risk management is, therefore, effectively assumed away. Indeed the only way that a firm can influence its exposure to risk (if at all) in these highly simplistic models is to adjust its primary operational decisions - such as by altering its preferred output or price level[2].

Recent research has attempted to more fully examine a firm's incentive to control its exposure to risk in an economic context. Take, for example, the pioneering research of Pope & Kramer (1979) and the subsequent related research by MacMinn & Holtmann (1983) and Ramaswami (1992). The crucial insight of these papers is that the randomness of output does not simply rely upon the number of inputs demanded (as in the standard multiplicative case with exogenous risk) but also on the specific nature of an input and whether it serves to increase or decrease a firm's exposure to risk[3]; i.e.

$$\tilde{q} = z + hz\varepsilon; E(\varepsilon) = 0.$$

The above formulation is taken from Pope & Kramer, however, it aptly (if simplistically) describes the approach followed by the two later papers. Random output, as denoted by $\tilde{q}$, is determined by the quantity demanded of the single input z and the random variable ε. The term h is then used to denote whether the input is risk

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2 Note that a prime example of an exogenous risk model is outlined in Chapter 4 (section 2). Here a risk averse perfectly competitive firm was exposed to multiplicative technological risk (of the form $\tilde{q} = f(z)\varepsilon$) and forced to make its input decisions before final output is known (as denoted by z and $\tilde{q}$ respectively). Given multiplicative risk it was then demonstrated that the risk averse firm can beneficially lower its exposure to output fluctuations by reducing its demand for inputs. However, the variance of ε and hence the level of risk surrounding the ex-post productivity of z is unalterable.

3 Common examples of risk decreasing inputs given in the literature include fertiliser and irrigation. However, there are many other non-agricultural possibilities (for example, safety training, machine maintenance, sprinkler systems etc.).

increasing or decreasing. Specifically when h is positive an input is said to be risk increasing, conversely when negative it is risk decreasing.

Unfortunately, although the research of Pope & Kramer, MacMinn & Holtmann and Ramaswami recognised that a firm can actively control its exposure to risk, their approach's capacity to explain corporate risk management decisions remains extremely limited. One particularly undesirable characteristic of all these models is that the firm is assumed to be risk averse. The trouble with risk aversion is that it places limits on the assumptions that can be incorporated into economic models of the firm[4]. Indeed in each model the impact that a risk increasing or reducing input can have on output variability had to be quite closely defined. The upshot being that even in the most general framework by Ramaswami (1992) it is still not possible to incorporate the fact that changes in risk could influence a firm's mean profits .

Similarly, although each model does allow the firm to face both risk increasing and risk decreasing inputs at the same time, the level of one of these inputs is typically fixed. This reflects a major simplification since in a true endogenous risk model a firm should be able to choose its desired level of both conventional risk increasing inputs (such as labour and capital) and risk decreasing risk management ones at the same time. Admittedly Pope & Kramer do at least consider (in passing) the case where a firm may simultaneously employ different levels of both a risk increasing and a risk decreasing input. However, their work is not very general and they are unable to predict firm behaviour in all but a few simple cases[5]. Moreover, Pope & Kramer did not allow for any real interaction between risk increasing and risk decreasing inputs,

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4 For a general critique on the use of risk aversion in economic models see Chapter 4, section 2.

5 For example Pope & Kramer predict that where inputs are substitutes the firm is likely to switch from risk increasing to risk decreasing inputs. However they are unable to make a similar prediction in the case where inputs are compliments.

instead a change in input use could only affect the overall distribution of possible output states and in no way affected the reliability of other inputs[6].

Another interesting attempt to more fully endogenise the impact of risk has been the now quite established research into the economic value of risk financing arrangements[7]. Many different tools have been discussed from the use of derivatives markets (Newbery & Stiglitz 1981, Anderson & Danthine 1983, Britto 1984, MacMinn et al 1989, Froot et al 1993, Bowden 1995, Moschini & Lapan 1995, Haruna 1996) and mutual insurance groups (Newbery & Stiglitz 1981, Martin & Yu 1990) to capital and product diversification (Diamond 1967, Newbery & Stiglitz 1981, Bowden 1995) and inventories (Newbery & Stiglitz 1981, Aiginger 1987, Ch. 6, Bowden 1995). However, whatever the mechanism used the basic result is the same, surplus income is stored in favourable (e.g. high output) periods and then used in more adverse states, the net result being a more stable income stream.

The primary advantage of the risk finance based literature is that a firm is usually allowed to select both conventional operational and risk management inputs at the same time. This has yielded some interesting results, perhaps the most notable of which is that when risk financing tools are purchased a firm will often increase its demand for profitable risk increasing inputs (such as labour or capital). Yet, there are still problems with this research. One is that the results tend to be highly tool

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6 For example, it is generally accepted that investment in risk control devices will directly increase the reliability of the firm's other inputs (see Feller 1957, p416-421). Thus if the firm was to invest in say regular machine maintenance this should reduce the probability of future breakdowns and help to stabilise output. However, in Pope & Kramers' model such interaction is not possible.

7 For a definition of risk financing see Appendix 4.

specific[8]. Thus just because some model predicts that a firm may use futures to control the effects of one type of risk (e.g. commodity price fluctuations) does not mean that it will use options or insurance in the same context. Moreover, perhaps even more disturbing is the fact that although models incorporating risk financing tools allow the firm to shift income between states it is still not allowed to directly control the underlying distribution of the risks that it faces.

Currently perhaps the best attempts to endogenise risk have come from the traditional economics of insurance literature. Of particular relevance is the work of authors such as Ehrlich & Becker (1972), Dionne & Eeckhoudt (1985), Briys & Schlesinger (1990), Briys et al (1991), Parry & Parry (1991) and Sweeney & Beard (1992). Importantly these authors observed that it is possible to directly influence the underlying distributions of many risks (both in terms of the mean and variance of a random parameter). By incorporating this assumption into their models they then concluded that economic decision makers are likely to invest a positive amount in what they define as the major risk management tools of: insurance, "self insurance" and "self protection"[9].

However, despite the explicit recognition in the economics of insurance literature that it is possible to directly control risk the applicability of these models to the corporate context is severely limited. One major problem is that almost all of the literature's

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8 The only real exceptions to this are Moschini & Lapan (1995) who considered the demand for both futures and options and Bowden (1995) who investigated the interaction between futures use, diversification and inventories. However, both papers focused on risk averse firms, moreover Bowden failed to consider the case of output induced price fluctuations (see section 4 below).

9 The term "self insurance" is an unfortunate one since it refers to the financing of retained losses, which are, by definition, uninsured. However, despite the theoretical objections it remains in common usage (see Williams et al 1995, p200). "Self protection" is used to describe physical loss control tools such as sprinkler systems or regular machine maintenance.

predictions are derived through the use of risk aversion (see Chapter 4 for a discussion of the problems associated with using risk aversion in the corporate context)[10]. Moreover, in not one of these models has there been any attempt to understand how the combined presence of risk and risk management may influence other important business/operational decisions such as the demand for productive inputs.

Admittedly some attempt to address these criticisms has been made by Schneider (1992)[11]. Schneider explicitly considered the interrelationships between the labour and self protection decisions of a profit maximising, perfectly competitive firm in the face of both cost and technological risk. Interestingly what Schneider revealed was that in the face of cost risk (where the compensation claims of employees are random) labour and risk management will tend to be complements, while under technological risk (where the productivity of employees varies) they can be substitutes.

However, while insightful, Schneider's predictions are still based on a number of rather undesirable assumptions. For example, one issue is Schneider's rather simplistic assumption that a firm's exposure to cost and or technological risk can only result in the creation of pure penalties (see Chapter 4, section 3.2). Indeed all Schneider considered was a firm's exposure to the risks that labour compensation claims would be higher and productivity lower than in a world of certainty. Yet, in the real world there may be states of nature in which the costs or productivity of a firm's labour force

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10 The only work to explicitly consider the actions of a firm is by Parry & Parry (1991). However, all they really consider is the purchase personal liability insurance for risk averse employees. As such risk is not fully endogenised in their model.

11 See also Di Mauro (1994) for a similar approach. However, Di Mauro's results rather unfortunately rely on risk aversion.

(or indeed any other input) actually improve - due perhaps to some unforeseen technical advancement, macro-economic factors or the whim of employees.

Furthermore, no attempt was made by Schneider to extend his work into the monopoly or oligopoly cases, even though such market forms could change his model quite considerably. The trouble is that where the market price is not constant but instead influenced by the operational or risk management decisions of a firm a rise in either the level of risk or its related costs will not necessarily reduce a firm's profits[12]. This could then lead to a situation in which a given increase in risk could cause either an increase or a reduction in the demand for risk management - the exact result depending on the relationship between marginal cost, the market price and a firm's profits (for more on ideas such as this see Chapter 6).

Thus it would appear that research into economic relationship between risk and risk management has some way to go. While it can predict how the presence of risk may affect the firm's production decisions it is not yet totally clear how this relationship may be influenced by risk management. The next two sections attempt to respond to this problem by presenting a more comprehensive model of the interaction between a firm's business and risk management decisions than has yet been attempted.

3. An Economic Model of Corporate Risk Management Behaviour

Before proceeding further a number of assumptions need to be made clear. These assumptions are important in that they keep the analysis reasonably tractable and will hopefully lead to some unambiguous results. However, it is with caution that many of these assumptions are made. In a world of risk the behaviour of a firm can be very

12 For a discussion of the benefit of cost increases see especially Salop & Scheffman (1983) and Seade (1985).

sensitive to the exact specification of a model. Relaxing or changing the following assumptions could lead to significant changes in the model's predictions.

For convenience the assumptions of the model will be grouped into two sections:

3.1 Assumptions about the type of risk faced.

3.2 Assumptions about firms and the nature of competition.

3.1 *Assumptions about the type of risk faced.*

3.1.1 Firms face technological risk.

In what follows it will be assumed that the primary source of risk faced by firms is technological (see Walters 1960, Diamond 1967 & 1980, Roodman 1972, Ratti & Ullah 1976, Newbery & Stiglitz 1981, MacMinn & Holtmann 1983, Martin & Yu 1990, Haruna 1996). Technological risk arises where the output that results from a given level of inputs is uncertain (for example: the weather may affect crop yields, strikes many hinder production or machines breakdown). In its most general form it can be described as:

$$\tilde{q} = f(z, \varepsilon) \quad where\ z = (z_1, z_2, \ldots\ldots\ldots, z_n)$$

Where $\tilde{q}$ denotes output as a constant linear function of a vector of inputs z (e.g. labour, machinery, land, etc.) and the state of nature as described by the random parameter ε. Note that the tilde is used to indicate that q is now a random variable (see Newbery & Stiglitz 1981, Chs. 5 and 10).

It is worth noting that output fluctuations caused by technological risk are distinct from those that may arise out of random changes in a firm's costs (which could be due to fluctuations in input prices or financing costs, for example)[13]. The primary difference is that firms experiencing technological risk are forced to make their production decisions (i.e. decide on their chosen level of *z*) before the state of the world and hence their final output is known (ex-ante); while those facing cost related risks are usually able to make their input/output decisions after their actual costs are known (ex-post)[14]. This difference significantly alters the decisions that a firm is likely to make. Under cost risk the firm can be confident that the inputs it uses will generate a certain level of output and hence is able to maximise actual profits. However, under technological risk the firm must decide on its input level before it knows what its final output and hence profits will be. This forces the firm to maximise expected rather than actual profits, subjecting it to the predictions of Jensen's inequality (see Chapter 4, section 3.3).

3.1.2 Technological risk is in the form of capacity fluctuations

Technological risk may either directly affect the total capacity of a firm (i.e. its possible final output) or the productivity of a specific input or combination of inputs. For simplicity and clarity this Chapter will focus on the capacity case and as such assumes that each firm effectively uses only one input - *z* (e.g. Newbery & Stiglitz 1981, MacMinn & Holtmann 1983, Haruna 1996). This allows the analysis to focus on the direct relationship between technological risk and output rather than on the impact that input specific fluctuations in reliability may have on the technical

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13 For an explanation of how random cost fluctuations may affect the behaviour of firms see, Gal-Or (1986), Shapiro (1986) and Sakai (1990 & 1991), Diacon (1991), Schneider (1992), Di Mauro (1994).

14 Note that this may not apply to cost fluctuations which are caused by liability suits or fines. Such costs take time to be realised, consequently it is entirely possible that a firm will have made its production decisions (and perhaps even sold the finished output) before it knows for certain the number and size of any liability claims or fines it is required to pay (e.g. see Schneider 1992, Di Mauro 1994).

efficiency of production (see, Walters 1960, Roodman 1972, Ratti & Ullah 1976 and Turnbull 1986 for examples of the input specific approach).

3.1.3 Technological risk is multiplicative.

A further important assumption regards the type of technological risk that the firm will face. Unfortunately in its most general form: $\tilde{q} = f(z,\varepsilon)$ the introduction of technological risk does not provide unambiguous results, consequently it is necessary to specify whether it is additive or multiplicative[15].

Additive risk is typically of the form:

$$\tilde{q} = f(z) + \varepsilon$$

Where ε is a random increment to output of mean zero. In the presence of additive risk the reliability of a firm's input(s) is not affected by the volume of inputs (i.e. planned output) chosen, for example, a flood might destroy a constant amount of crops (since only those on the flood plane will be affected), irrespective of the number of seed sown.

Multiplicative technological risk is of the form:

$$\tilde{q} = f(z)\varepsilon$$

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15 For example, Feldstein (1971) investigated the impact of technological risk in its most general form, however, he failed to provide any clear results, revealing that the demand for risky inputs by both a risk averse and risk neutral firm may be either greater or less than it would be in a world of certainty.

Where $\varepsilon \geq 0$ is a random variable with a mean standardised to 1 and variance $\sigma^2 \geq 0$. Thus what multiplicative risk implies is that the variability of a firm's final output increases with its planned level of production.

Note that the exact specification of technological risk (i.e. whether it is assumed to be additive or multiplicative) can have quite a significant effect on the results of a model - particularly in terms of the impact of technological risk on a firm's input decisions (e.g. see Newbery & Stiglitz 1981, Gravelle & Rees 1992, Ch. 21). However, multiplicative risk is generally thought to be the more realistic case and as such will be the specification used here. Indeed as Newbery & Stiglitz (1981, Ch. 5) point out additive risk is at best a simplification, since it is difficult to see how the level of output risk will not increase with planned input use in most cases[16].

3.1.4 The level of technological risk is endogenous.

One of the most unique features of the model in this Chapter is that a firm is directly able to influence the reliability of the inputs that it uses. As shown in Section 2 numerous authors have already investigated a firm's ability to influence its exposure to risk. However, only the literature on individual risk management decisions has ever really attempted to fully endogenise risk. In what follows, therefore, it is this literature which is adapted to explore how an expected profit maximising firm might attempt to manage its underlying exposure to technological risk.

Following the work of Briys et al (1991) expenditure on risk management is assumed to influence the variability of the *i*th firm's final output in the following way:

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16 For example, imagine that a factory uses machines that possess a 10% probability of failure. Thus if it increases the number of machines it has from 100 to 110 it is realistic to expect that the expected number of broken machines in any period will increase from 10 to 11. However, under additive risk the machine failure rate would have remained at 10.

$$\sigma_i^2(m_i) = \sigma_i^2 \exp(-\beta_i m_i)$$

Where, σ_i^2 denotes the variance of the firm's random parameter ε_i, m_i is the level of investment in risk management and the efficiency of risk management (i.e. the degree to which one unit of risk management reduces the firm's output fluctuations) β_i is assumed to be constant.

Figure 1 about here.

Further note that for analytical convenience the relationship between m_i and σ_i^2 is assumed to be exponential. As shown in figure 1 such a relationship implies continuous but decreasing returns to risk management[17]. A firm is, therefore, faced with choosing a level of m_i between the two extremes: $\sigma_i^2(\infty) = 0$ and $\sigma_i^2(0) = \sigma_i^2$, allowing the rate of change of $\sigma_i^2(m_i)$ to be expressed as the partial derivative:

$$\frac{\partial \sigma_i^2(m_i)}{\partial m_i} = -\beta_i \sigma_i^2(m_i)$$

The primary advantage of this approach is that it can be applied to any risk management tool that reduces the variability of a firm's final output. Admittedly this does not apply to all risk management tools. For example, hedging on the futures market will have no effect on the variance of a firm's output (although it will help to stabilise any resultant price fluctuations). However, this model does cover all physical risk control tools (as in Briys et al 1991) and certain aspects of a number of risk financing ones[18].

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17 Thus the more the firm invests in m_i the lower will be the resultant change in σ_i^2.

18 While it may not seem immediately obvious that the purchase of risk financing tools will help to reduce σ_i^2 this is in fact possible. Take, for example, a standard property insurance

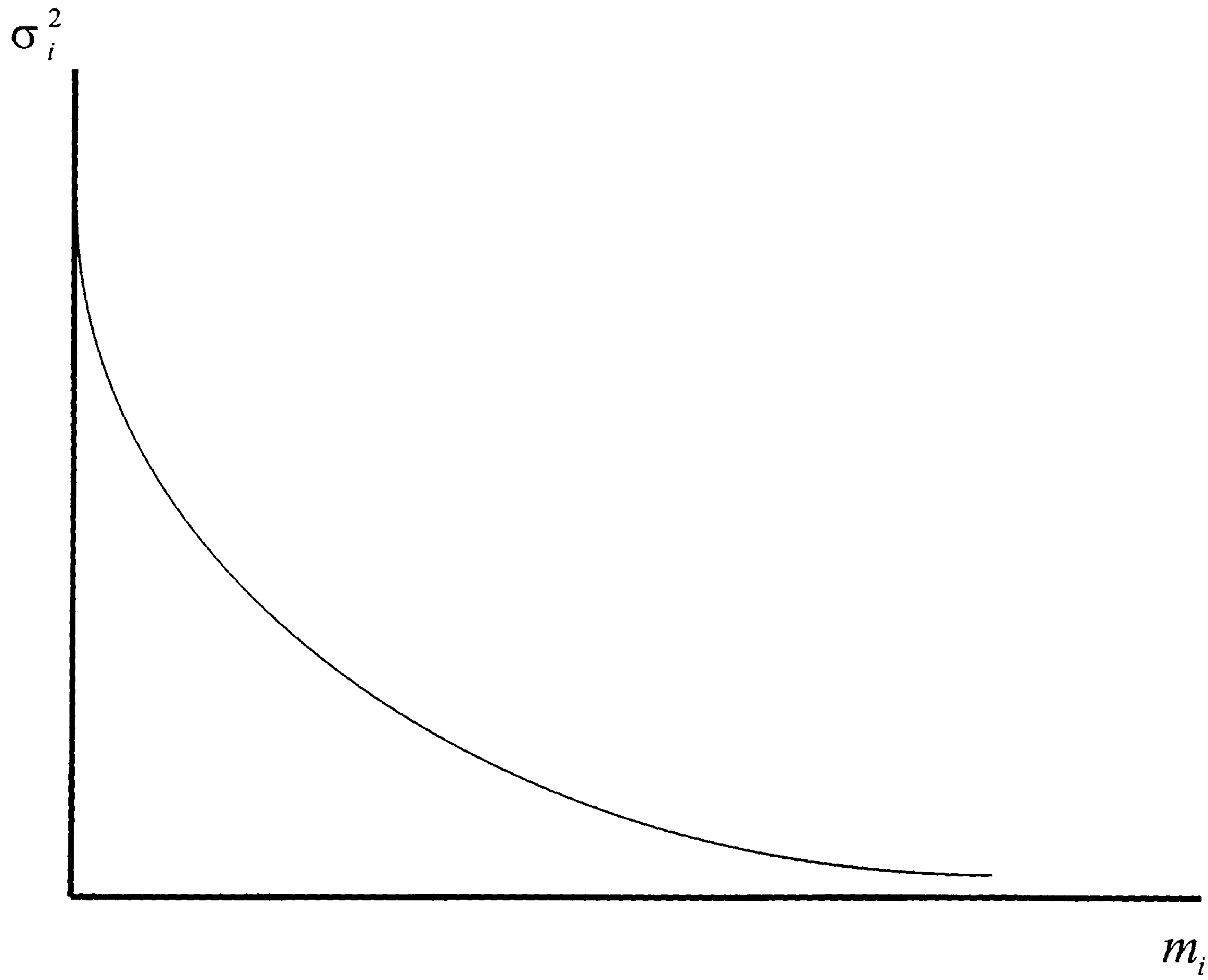

Figure 1: An Exponential Relationship Between σ_i^2 and m_i

3.2 *Assumptions about firms and the nature of competition.*

3.2.1 All decision makers are risk neutral.

Most economic models of firm behaviour under risk have assumed that they (or rather their owners and managers) are primarily risk averse (see Sandmo 1971, Leland 1972, Newbery & Stiglitz 1981 and even more recently: Gravelle & Rees 1992, Haruna 1996, Karagiannis & Gray 1996). Typically this yields the standard result that the presence of risk will cause a firm to make sub-optimal price or output decisions. The simple rationale for this is that a risk averse decision maker dislikes risk, consequently the argument goes that he or she will - even at the expense of a reduction in expected wealth - almost always attempt to reduce the variability of their income.

However, in the light of the strong theoretical and practical objections to corporate risk aversion outlined in Chapter 4 it will be assumed that all firms are risk neutral. Consequently, a firm will be indifferent to risk unless it represents either a pure penalty or reduces mean profits through the influence of technological non-linearities.

3.2.2 All firms are input (quantity) setters in the final goods market.

Under perfect competition this is a trivial assumption since firms are, by definition, price takers. However, because of their market power monopolistic and oligopolistic firms who are exposed to technological risk may select either the input z[19] or price as their primary operational decision variable. Yet, despite this possibility it will be

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contract. This can provide firms with a variety of risk reduction services from free risk management advice to the rapid provision of funds post loss - a move that should help the firm to quickly repair or replace lost assets and thus stabilise its output.

19 Remember that under technological risk final output is uncertain. Thus a firm can only adjust its planned output level by altering its use of z.

assumed, at least for now, that all firms are input (or rather planned/expected output setters). The main reason for this is to assist in the comparison of the current analysis against that of previous research into technological risk - most of which has adopted this assumption[20]. However, this does mean that the results of the model are unlikely to be applicable to price setting firms.

In the case of technological risk the main difference with price setting firms is that the market they operate in may end up in dis-equilibrium. Take the conventional Bertrand (1883) model of price setting behaviour in which the firm sets a price and is then supposed to accurately supply all that the market demands at that price (i.e. the firm acts as a quantity taker). The problem is that when faced with technological risk such a firm can no longer be confident that it will be able to accurately meet consumer demand. Instead in many states the firm may well find itself left facing the costly implications of either unsold production or unsatisfied customers. Firm behaviour (in terms of their price and or risk management decisions) will now depend not just on the combined costs of these eventualities (which is effectively a marginal revenue related pure penalty) but also on any differences between their associated costs. For example, where the costs of unsold production (disposal, storage costs, etc.) exceed those associated with unsatisfied customers (such as a permanent loss of market share) the optimum price level may be less than in a world of certainty. On the other

20 The paucity of research in the case of price setting firms under technological risk is, however, not reflected in the case of demand risk. See, for example, Leland (1972), Klemperer & Meyer (1986, 1989), Aiginger (1987) and Gradstein et al (1992) for detailed discussions of how price setting firms may behave when faced with the possibility of random fluctuations in consumer demand.

hand the optimum price level might be expected to rise as the costs associated with unsatisfied customers increase[21].

3.2.3 Production capacity is fully variable and purchased at a constant positive price.

This implies that the relationship between a firm's input demand (z_i) and the price of inputs (c) is simply:

$$cz_i, \text{ where, } c > 0$$

Admittedly this assumption is not wholly realistic (primarily since an increase in a non perfectly competitive firm's demand for z_i might usually be expected to bid up its market price), however, it does simplify the analysis considerably. Indeed it has been adopted by almost all of the current models of firm behaviour under technological risk (see, for example, Walters 1960, Roodman 1972, Ratti & Ullah 1976, Pope & Kramer 1979, Newbery & Stiglitz 1981, MacMinn & Holtmann 1983, Martin & Yu 1990, Ramaswami 1992, Karagiannis & Gray 1996).

3.2.4 Assumptions about the firm's production function.

In the monopolistic and oligopolistic cases the standard simplifying assumption (see Shapiro 1989a, Martin 1993, Ch. 2) that the *i*th firm's final output is a constant function of its input use is adopted, i.e.:

$$q_i = z_i \varepsilon_i .$$

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21 For a discussion of these issues in fixed price but perfectly competitive markets see Aiginger (1987, Ch. 5), Chung (1990), Driver & Moreton (1992, Ch. 4).

However, such an assumption is not generally desirable under perfect competition. In this case the presence of constant returns to z_i means that a firm's optimum choice of inputs is likely to be indeterminate.

In order to see this note that with constant returns to z_i a perfectly competitive firm operating in a world of certainty would simply maximise:

$$E[\pi_i(z_i)] = pz_i - cz_i$$

This then yields the following first and second order conditions:

$$\frac{\partial E}{\partial z_i} = p - c = 0,$$

$$\frac{\partial^2 E}{\partial z_i^2} = 0.$$

Unfortunately these conditions say very little about the behaviour of a firm. While the first order (marginal profit) condition approximates the standard result under perfect competition, that a firm will maximise its profits at a level of z_i that causes the market price to equal its marginal costs the non-existence of a second order condition means that the exact level of z_i that will yield this result is indeterminate. In short any level of z_i could be an optimum.

Thus when examining the case of perfect competition the standard assumption that a firm's production function will be both differentiable and strictly concave is adopted (see Newbery & Stiglitz 1981, Ch. 4, Gravelle & Rees 1992, Chs. 7 & 21), i.e.:

$$q_i = f(z_i), \text{ where } f' > 0, f'' < 0.$$

An individual firm's profit maximising choice of z_i can now be determined, for example in a world of certainty it will now be:

$$\frac{\partial E}{\partial z_i} = pf'(z_i) - c = 0,$$

$$\frac{\partial^2 E}{\partial z_i^2} = pf''(z_i) < 0.$$

3.2.5 Assumptions about market demand.

Throughout this Chapter it will be assumed that market demand is characterised by the following well behaved inverse function:

$$p = a - bQ, \quad a,b > 0$$

Where p denotes price and Q total industry output.

The advantage of using a linear, downward sloping demand function is that it makes it much easier to achieve unique solutions for z and m (indeed without these assumptions it would frequently be impossible to do so). However, it should be noted that the results achieved below may not carry over to less restrictive demand specifications. For example relaxing the linearity assumption could well lead to significant changes in the behaviour of a firm (see Newbery & Stiglitz 1981, especially Chs. 10 & 18). Moreover these differences are likely to be especially acute in the rather more realistic case of oligopolistic markets - more on this in Chapter 6.

3.2.6 There exists a rational expectations equilibrium.

A market or regional economy is in a rational expectations equilibrium if the optimal plans of producers and consumers are compatible in each state and generate a state distribution of prices that is consistent with the distribution they anticipated when making these plans (e.g. see Newbery & Stiglitz 1982, Gravelle & Rees 1992, p659-662).

Broken down this implies the existence of three inter-related assumptions:

- That all firms possess full knowledge about the distribution of the random parameter ε. This means that a firm will be able to reliably calculate the relationship between its mean output, profits and input use.

- That firms are fully aware of the impact that their input decisions and subsequent output fluctuations may have on the market price and behave accordingly (see Muth 1961).

- The market price will adjust to ensure that consumers will buy all that is supplied (i.e. the market will clear).

Although these are common assumptions in the literature (e.g. Sandmo 1971, Leland 1972, Ratti & Ullah 1976, Newbery & Stiglitz 1981) they are, admittedly, quite strong. One issue is that if markets do not clear (i.e. where there is the potential for dis-equilibrium) then it is possible that additional pure penalties (or perhaps even pure benefits) may arise to change firm behaviour (see Chapter 4, section 3.2)[22]. Moreover, in the absence of sufficiently reliable information about ε (or its eventual impact) a firm's expectations regarding future prices are unlikely to be consistent with the final realised distribution (see Aiginger 1987, Ch. 2 and Driver & Moreton 1992, Ch. 4 for reviews of this literature). This can then have serious consequences for the final

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22 Although the inclusion of additional pure penalties would probably serve to simply increase the benefits of risk management and the circumstances in which it would be of value.

predictions of the model according to both the strength and direction of the bias (i.e. whether and to what extent the impact or risk is over or under estimated).

However, despite the strength of these assumptions it would be difficult to generate a meaningful and unambiguous model without them. For example, expectations bias can occur in many ways and be due to many different factors (managerial hunches, information availability and framing effects, etc.) a fact which is likely to require some additional and rather "ad hoc" assumptions (Newbery & Stiglitz 1981, p136-137). Similarly the absence of market clearing could give rise to many different and potentially conflicting pure penalties and or benefits depending on the factors involved (sticky or fixed prices, market form, etc. - see Aiginger 1987).

3.2.7 One period model

Throughout this Chapter it will be assumed that firms only operate for one period. Hence all equilibrium outcomes are for the short run - meaning that when exposed to risk a firm can only adjust its use of risk management or demand for inputs and may not choose to enter or leave the industry. This is the most common assumption in models of firm behaviour under risk, however, it should be noted that in the perfectly competitive case a number of long run equilibrium models do exist (e.g. Applebaum & Katz 1986, Haruna 1996).

3.2.8 Firms move simultaneously.

Thus no form of communication is possible. In an oligopolistic market this also rules out the possibility of a sequential equilibrium (for more on this see Chapter 6).

4. The Behaviour of Firms Within Different Market Forms.

4.1 *Perfect Competition*

Before proceeding with the rather more realistic cases of monopolistic and oligopolistic markets it is worth reviewing the impact that technological risk can have on perfectly competitive firms. Whether explicitly or implicitly financial models of risk management behaviour have usually assumed perfect competition in the output market (see, for example, Doherty 1985, Shapiro & Titman 1985, Mayers & Smith 1987, MacMinn 1987 and Cho 1988). Indeed in what follows it is demonstrated that, in the current model at least, perfect competition largely supports the hypothesis that a firm is only likely to invest in risk management if it helps to alleviate the impact of capital/financial market imperfections such as agency and transactions costs.

A perfectly competitive market is one in which there are many small producers and consumers, none of whom are able to influence the market price. All firms are generally assumed to be identical both in terms of their production technology and the characteristics of the product that they sell. There are also zero entry and exit costs, allowing firms (at least in the long run) to come and go at will. The primary implications of these assumptions is that individual firms are price takers that each face a perfectly elastic (i.e. horizontal) demand function (although the industry demand function is typically downward sloping). As such, in a world of certainty anyway, a firm's choice of profit maximising output is said to depend on purely its input costs and production considerations (i.e. the technical efficiency of its combination of inputs), its marginal revenue being fixed at the market price.

One implication of a fixed market price in a single input model is that a firm's profits would appear to be a constant linear function of its capacity decisions[23]. As such risk

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23 Although in a two input model a perfectly competitive firm's profits function may well become concave because of the adverse effect that sub-optimal combinations of these inputs

management would seem to offer no direct economic value in a perfectly competitive market since technological risk will not directly affect the profits of a risk neutral firm (see Pope & Kramer 1979, MacMinn & Holtmann 1983, Ramaswami 1992, Gravelle & Rees 1992, Ch. 21, Eeckhoudt & Gollier 1992, Ch. 11). However, it is important to note that the clarity of this result rests on the assumption that each firm experiences independent random output fluctuations. Where firms face positively correlated output fluctuations the irrelevance of risk management is much less clear. In this case it is shown that both a firm's profits and its choice of z may be affected by technological risk (see for example, McKinnon 1967, Newbery & Stiglitz 1981, Anderson & Danthine 1983, Britto 1984, Moschini & Lapan 1995, Haruna 1996) providing a potential rationale for risk management. Yet despite this fact it is argued that a perfectly competitive firm will still often not invest in risk management. This supposition rests on the basis that it is the fluctuations in the market price that result from positively correlated output fluctuations which reduces a firm's profits, not the variance of its individual output.

Dealing first with the case of independent output fluctuations, a risk neutral firm (as denoted by the subscript "i") operating in a perfectly competitive industry will (since $E[\varepsilon_i] = 1$) maximise:

$$E[\pi_i(z_i)] = pf(z_i) - cz_i - rm_i \qquad [1]$$

Where r denotes the industry wide unit cost of risk management. Note that because firm i is operating in a perfectly competitive industry the price that it will receive is independent of its own choice of z_i but will be influenced by the aggregate demand for z since this will affect expected industry output. However, given that each

may have on the technical efficiency of production (see Walters 1960, Roodman 1972, Ratti & Ullah 1976).

individual firm's output fluctuations will not be sufficient to affect the market price it is assumed, for simplicity, that p is exogenously determined.

It then simply follows that:

$$\frac{\partial E}{\partial z_i} = pf'(z_i) - c = 0, \qquad [2]$$

Proposition 1. *Providing that* $E[\varepsilon_i] = 1$ *both expected profit and the level of output produced in a perfectly competitive industry will be unaffected by the presence of independent technological risk*[24]. *Firms will not, therefore, find it profitable to manage their exposure to firm specific risk unless it helps to reduce either agency or transactions costs.*

Figure 2 about here

Figure 2 provides a simple illustration of this result. Imagine that the profit maximising level of certain output for any perfectly competitive firm is q^* (as represented by the point of intersection between the demand and supply curves: $P(q)$ and s respectively)[25]. However, instead the firm experiences multiplicative

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24 Given that $\frac{\partial E}{\partial m_i} = r = 0$ the second order condition for [2] to be at a maximum is:

$$\frac{\partial^2 E}{\partial z_i^2} = pf''(z_i) < 0$$

Which requires that $f'' < 0$.

25 Note that for convenience the subscript i has been dropped for this example.

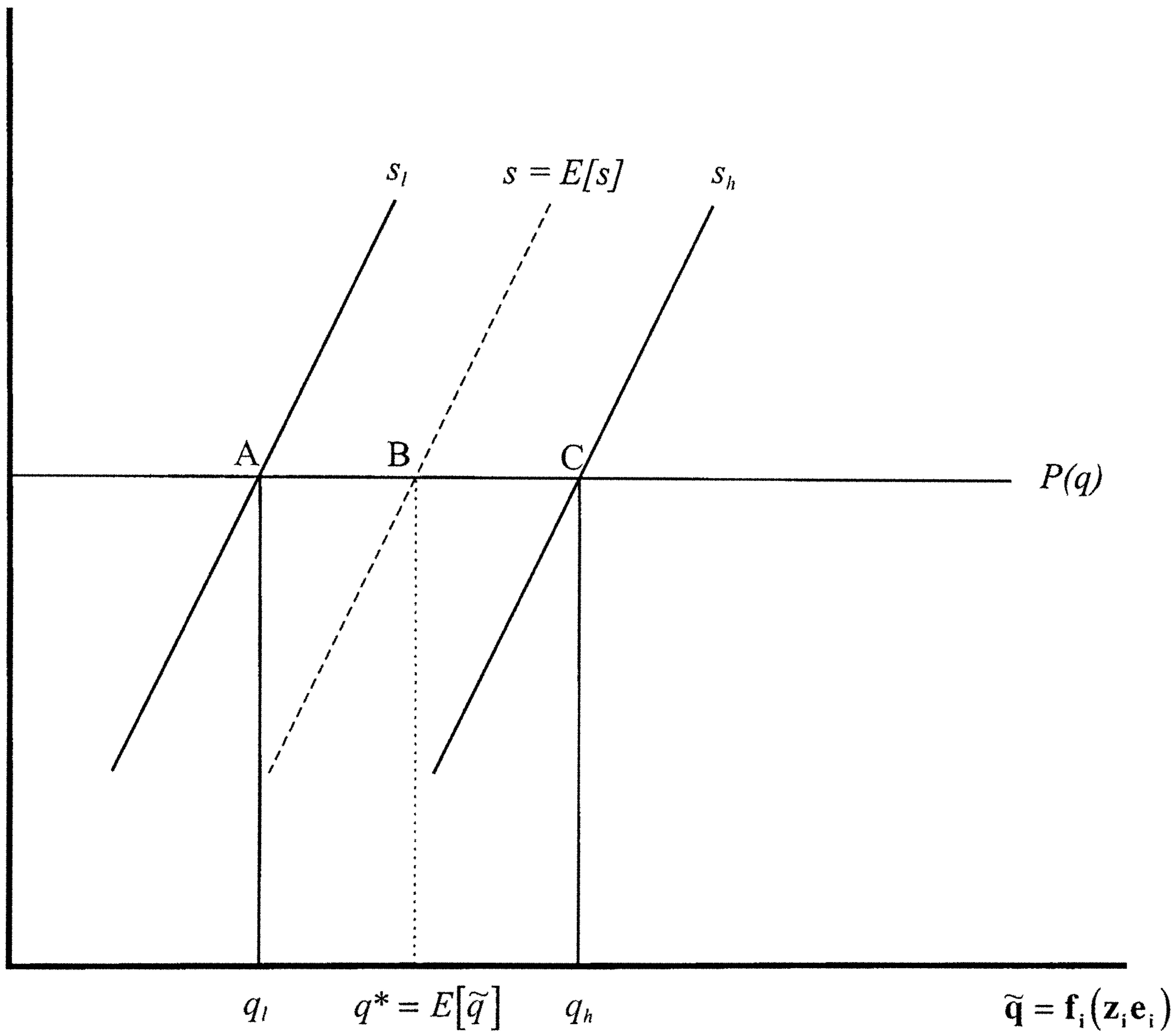

Figure 2: The Perfectly Competitive Firm Under Independent Technological Risk

technological risk of the form $\tilde{q} = f(z)\varepsilon$, $E[\varepsilon]=1$ and for the same level of z that would produce q* units under certainty faces an equal chance of one of two states of nature arising: s_l in which q_l units are produced and s_h where the firm is able to produce q_h units. At first glance such uncertainty might seem to be undesirable since the firm can no longer be sure how much it is going to be able to produce in any one period. However, since the price that it receives for its product is unaffected by its output a risk neutral firm will be indifferent to the presence of technological risk. This can be proven by comparing the loss in revenue that is associated with the adverse state of nature (as illustrated by the area: ABq^*q_l) against the gain accrued in the beneficial one (BCq_hq^*). Holding price constant it is simple to show that since $E[\varepsilon]=1$: BCq_hq^* - ABq^*q_l = 0, meaning that the gains and losses associated with the presence of technological risk will exactly off-set one another. Expected revenue will, therefore, remain the same as it would be in a world of certainty and the firm will derive no economic benefit from either altering its input decision or investing in risk management.

Where the output fluctuations of all the firms in the industry are positively correlated the behaviour of each individual (ith) firm could change. In order to see this consider the simple case of perfectly positively correlated output fluctuations (see especially Newbery & Stiglitz 1981, Ch. 10)[26]. Here the output of each firm is assumed to depend on its input level z_i and the value of its random variable ε_i[27]. However, the value of ε_i in each state is assumed to be precisely the same for all firms, causing not only an individual firm's output to fluctuate but the aggregate industry level of output

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26 Less than perfect positive or even negatively correlated output fluctuations could also be modelled in a similar way. However, these possibilities have not received much attention in the literature.

27 Possible examples of random factors that could affect an industry as a whole include the weather and general strikes.

as well. A firm with rational expectations (see section 3.2.6) should, therefore, expect market supply to also become random according to the following expression:

$$\tilde{Q} = \left(\sum_i f(z_i) \right) \varepsilon.$$

Where:

$$E[\varepsilon] = \frac{1}{n} \sum_i E[\varepsilon_i] = 1$$

$$\sigma^2 = \frac{1}{n} \sum_i \sigma_i^2 \geq 0$$

and n denotes the number of firms in the industry.

Then assuming that the final goods market clears (see section 3 above) fluctuations in market supply will have a knock on effect on the market price causing it to also vary. In the current context with an inverse demand function of the form $p = a - b(Q)$ this will imply that (see MacMinn et al 1989):

$$p = a - b(Q) = \sum_i f(z_i) \varepsilon$$

As market supply fluctuates the market price will adjust in order to ensure that supply is equated with consumer demand. Thus in a world with perfectly positively correlated output fluctuations it will not only be final industry output that varies with ε but also the market clearing price, i.e.:

$$\tilde{p} = a - b\left(\sum_i f(z_i) \varepsilon \right).$$

Given the presence of randomness in both aggregate output and the market price the ith firm will now maximise:

$$E[\pi_i] = \tilde{p}f(z_i)\varepsilon_i - cz_i - rm_i \qquad [3]$$

$$= \left(a - b\left(\sum_i f(z_i)\varepsilon\right)\right)f(z_i)\varepsilon_i - cz_i - rm_i.$$

Rearranging and noting that $\varepsilon_i = \varepsilon$, and $E[\varepsilon^2]=1+\sigma^2$ this can then be rewritten as:

$$= \left(a - b\sum_i f(z_i)(1+\sigma^2(m))\right)f(z_i) - cz_i - rm_i$$

or

$$= \left(p - b\left(\sum_i f(z_i)\right)\sigma^2(m)\right)f(z_i) - cz_i - rm_i \qquad [4]$$

where,

$$\sigma^2(m) = \frac{1}{n}\sum_i \sigma^2(m_i).$$

Differentiating [4] then yields the following first order condition for a firm's choice of z_i[28].

$$\frac{\partial E}{\partial z_i} = \left(p - b\left(\sum_i f(z_i)\right)\sigma^2(m)\right)f'(z_i) - c = 0 \qquad [5]$$

[28] The second order condition necessary for [5] to be a maximum is:

$$\frac{\partial^2 E}{\partial z_i^2} = \left(p - b\left(\sum_i f(z_i)\right)\sigma^2(m)\right)f''(z_i) < 0$$

which again requires that $f'' < 0$.

Proposition 2. *Where the output fluctuations of a perfectly competitive firm are positively correlated with those of all other firms in the industry it will no longer be indifferent to the presence of technological risk. Instead marginal profits and the optimal level of* z_i *will be lower than in a world of certainty*[29].

In order to see this result more clearly rewrite equation [5] to get:

$$pf'(z_i) - c = b\left(\sum_i f(z_i)\right)\sigma^2(m)$$

Since $b\left(\sum_i f(z_i)\right)\sigma^2(m)$ should be positive a comparison of [5] against [2] reveals that:

$$pf'(z_i) - c > 0$$

Providing proof that the presence of positively correlated output fluctuations should reduce both the optimal level of z_i and expected profits[30].

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29 Note that this result is not robust in a long run equilibrium model. In this case, some firms will probably leave the industry, meaning that those remaining may not suffer from a loss in expected marginal profits (e.g. see Applebaum & Katz 1986, Haruna 1996).

30 Note, however, that in the case of a positively sloped demand function (as might be the case for giffen or veblem goods) this result would be reversed. With a positively sloped demand function: $p=a+b(Q)$, consequently equation [5] would be rewritten as:

$$\frac{\partial E}{\partial z_i} = \left(p + b\left(\sum_i f(z_i)\right)\sigma^2(m)\right)f'(z_i) - c = 0$$

Hence the presence of positively correlated output fluctuations would actually benefit a firm.

The rationale behind this result stems from the fact that positively correlated output fluctuations create a technological non-linearity (as denoted by the term: $-b\left(\sum_i f(z_i)\right)\sigma^2(m)$) between each firm's marginal profit function and total industry output. The primary cause of this technological non-linearity is the presence of a linear, downward sloping industry demand (and hence revenue) function. To see this remember that the point elasticity of demand on a downward sloping linear demand curve will vary from relatively more elastic over higher prices to relatively more inelastic over lower ones. Hence, the percentage increase in the market price that will accompany low output states will be less than the associated decrease in high ones. Then given multiplicative risk[31] marginal industry profits will be concave in Q causing each firm's expected share of these profits and their resultant demand for z_i to fall (see Chapter 4, section 3.3 for a detailed discussion about the nature of technological non-linearities).

Given the adverse effects of positively correlated output fluctuations it would seem reasonable to suppose that firms will invest in risk management. Yet, this is still unlikely. Under perfect competition an individual firm's investment in m_i will not have a significant impact on the variance of total industry output. Hence risk management would seem to be of little value to an individual firm. However, it is worth noting that the optimum level of risk management for the industry as a whole is not zero. Instead if firms could agree to jointly invest in risk management the aggregate level of m would be:

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31 The presence of additive technological risk would reduce the total profits earned by the industry but would have no effect on marginal profits. This is because each firm's exposure to output fluctuations (and hence its expected marginal profits) is invariant to its demand for inputs (see Newbery & Stiglitz 1981 Chs. 5, 10).

$$\frac{\partial E}{\partial m} = b\beta\sigma^2(m)\sum_i f(z_i) - r = 0 \qquad [6]$$

Of course public good problems aside (since each firm that contributes towards increasing m will not only reduce its own exposure to price fluctuations but also the price fluctuations faced by all the other firms in the market) perfectly competitive firms can not, by definition, act together. By jointly agreeing to invest in risk management perfectly competitive firms would actually raise the market price for their product. However, this would then imply that such firms are capable of exhibiting strategic behaviour which in perfectly competitive market is not possible[32].

Thus it would seem that whether perfectly competitive firms face independent or positively correlated output fluctuations they are unlikely to invest in risk management unless it can reduce the impact of agency and transactions costs. However, a couple of important qualifications do need to be made clear. Firstly by changing the assumptions of the model (e.g. the market clearing conditions - Chung 1990 or the number of inputs - Roodman 1972, Ratti & Ullah 1976, Pope & Just 1977) additional, firm specific, pure penalties and technological non-linearities could be created which might be reducible through personal investments in risk management. Secondly, it should be remembered that while perfectly competitive firms may not unilaterally attempt to improve the reliability of their inputs they might still invest in certain risk financing tools such as futures or government price stabilisation schemes. These tools can help to directly stabilise price fluctuations and will, therefore, reduce an individual firm's (rather than the entire industry's) exposure to the adverse effects of positively correlated output fluctuations (Newbery & Stiglitz 1981, Anderson & Danthine 1983, Britto 1984, MacMinn et al 1989, Haruna 1996).

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32 Such agreements would not be possible in a one period simultaneous move model anyway.

4.2 *Monopoly*

In the monopoly case there is only one firm operating in the industry. Firm output and industry output are, therefore, the same thing meaning that in the current model (from section 3.2.5) the monopolist faces a downward sloping demand curve.

The fact that a monopolist will face a downward sloping demand curve can have a significant affect on its behaviour when it is faced with technological risk. As such it is surprising that very little research has been done in the area. Indeed the only author to really consider this possibility is Turnbull (1986) and even he focused on the rather straightforward and unrealistic case of a cost based pure penalty related to a positive threat of a total loss in the supply of a specific input. In what follows, however, the analysis of a monopolist under technological risk (as in a world of certainty) is treated as a natural extension of the standard perfectly competitive model used above.

Being the only firm in the market a monopolist's choice of z and m will be set to maximise:

$$E[\pi(z)] = (a-c)z - b(\sigma^2(m)+1)z^2 - rm \qquad [7]$$

where the second term of the right hand side is simply the expected value of $b\tilde{q}^2$.

Remembering that for a monopolist $\frac{\partial\sigma^2(m)}{\partial m} = -\beta\sigma^2(m)$ (see assumption 3.1.4) the first order conditions for [7] to be a maximum are as follows[33]:

33 Given that the monopolist is utilising two variables (z and m) three second order conditions are required: one for z,

$$\frac{\partial^2 E}{\partial z^2} = -2b(\sigma^2(m)+1) < 0,$$

one for m,

$$\frac{\partial E}{\partial z}=(a-c)-2b\left(\sigma^2(m)+1\right)z=0 \qquad [8]$$

$$\frac{\partial E}{\partial m}=b\beta\sigma^2(m)z^2-r=0 \qquad [9]$$

Then assuming that the second order conditions are satisfied equations [8] and [9] can be used to generate the following two results:

Proposition 3. *Under multiplicative technological risk the optimum level of input demand for a monopolist will decrease as* $\sigma^2(m)$ *increases.*

In order to see this result more clearly rewrite [8] to get:

$$(a-c)-2bz=2bz\sigma^2(m), \qquad [8a]$$

then, note that in a world of certainty [8a] will simply reduce to[34],

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$$\frac{\partial^2 E}{\partial m^2}=-b\beta^2\sigma^2(m)z^2<0$$

and the joint condition,

$$\left(\frac{\partial^2 E}{\partial z^2}\right)\left(\frac{\partial^2 E}{\partial m^2}\right)-\left(\frac{\partial^2 E}{\partial z\partial m}\right)^2>0.$$

Note that since,

$$\left(\frac{\partial^2 E}{\partial z\partial m}\right)^2=2b\beta\sigma^2(m)z>0$$

the joint condition will be satisfied when $\sigma^2(m)<1$.

34 Since $\overline{Q}=z$.

$$\frac{\partial E}{\partial z} = (a - c) - 2bz = 0 .$$

Finally assuming $\sigma^2(m) > 0$ it is possible to show that a profit maximising monopolist experiencing multiplicative technological risk should choose a level of z that satisfies the following inequality:

$$(a - c) - 2bz > 0. \qquad [8b]$$

Equation [8b] then proves that input demand will be lower than in a world of certainty.

As in the case of positively correlated output fluctuations under perfect competition the explanation behind this result rests on the presence of a demand/revenue induced technological concavity ($\sigma^2(m) + 1$) in the monopolist's marginal profit function. Because the monopolist is the sole supplier in a market as its final output varies so will the market price for its product. Then given the combined effects of a downward sloping linear (or indeed concave) demand function and multiplicative risk the presence of output induced price fluctuations will (via Jensen's Inequality) cause the expected marginal profits of the monopolist to fall. The returns on the monopolist's investment in extra capacity are, therefore, lower than they would be in a world of certainty prompting it to reduce its demand for z.

Proposition 4. *Even when risk management is costly (i.e. $r > 0$) an expected profit maximising monopolist is likely to want to invest in a positive level of m.*

The proof of this proposition follows from rewriting [9] as:

$$b\beta\sigma^2(m)z^2 = r$$

The left hand side of this equality denotes the marginal benefit of risk management, the right its marginal cost. In a world of certainty, where $\sigma^2 = 0$ the left hand side would fall to zero indicating that no profit maximising firm will rationally invest in risk management, however, whenever a firm is exposed to technological risk (i.e. $\sigma^2 > 0$) the marginal benefits of risk management will become positive. It then follows that a firm should invest in *m* up to the point where the marginal benefit of risk management (in terms of the efficiency with which risk management can reduce the costly effects of technological risk) is equal to its marginal cost.

Given the first order conditions [8] and [9] it is also possible to examine the effect that changes in the exogenous parameters (such as σ^2 and *r*) may have on the behaviour of a monopolist. Following Dixit (1986) let θ denote the change in an exogenous parameter. By using Cramer's rule it then follows that:

$$\frac{\partial z}{\partial \theta} = \frac{|H_1|}{|H|} \qquad [10]$$

$$\frac{\partial m}{\partial \theta} = \frac{|H_2|}{|H|} \qquad [11]$$

where $|H|$ is the determinant of the second order direct and cross partials for [8] and [9], i.e.:

$$|H| = \begin{pmatrix} \frac{\partial^2 E}{\partial z^2} & \frac{\partial^2 E}{\partial z \partial m} \\ \frac{\partial^2 E}{\partial m \partial z} & \frac{\partial^2 E}{\partial m^2} \end{pmatrix}$$

and $|H_1|$ is the determinant of $|H|$ with the first column replaced by the column vector $\left[\frac{-\partial^2 E}{\partial z \partial \theta}, \frac{-\partial^2 E}{\partial m \partial \theta}\right]^T$ and $|H_2|$ is the corresponding determinant with the column vector in the second column of $|H|$.

Using [10] and [11] now assume that there is an exogenous change in the maximum possible level of risk (i.e. $\theta = \sigma^2$) that a firm can face so that[35]:

$$\frac{-\partial^2 E}{\partial z \partial \sigma^2} = 2bz\varepsilon^{-\beta m} > 0$$

and

$$\frac{-\partial^2 E}{\partial m \partial \sigma^2} = -b\beta z^2 \varepsilon^{-\beta m} < 0.$$

A little computation then yields:

$$\frac{\partial z}{\partial \sigma^2} = 0 \qquad [10a]$$

$$\frac{\partial m}{\partial \sigma^2} = 2\left(1 - \sigma^2(m)\right) > 0, \text{ so long as, } 1 > \sigma^2(m). \qquad [11a]$$

What [10a] and [11a] indicate is that an exogenous change in the maximum possible level of technological risk (i.e. σ^2) faced by the monopolist will *only* affect its choice of m. Thus when a firm is able to invest in risk management its input decisions would seem to be independent of the level of σ^2. At first glance this result might appear surprising, however, it is consistent with the Separation Theorem outlined in the

35 For example in the real world exogenous increases in risk could be the result of factors such as global warming or changing technology.

futures literature (e.g. Anderson & Danthine 1983, Haruna 1996)[36]. Moreover, it is also intuitively appealing. A firm that attempts to control its exposure to risk by reducing its demand for inputs is likely to produce less and as a result suffer a substantial opportunity cost in terms of forgone sales. But by investing in risk management no sales are lost meaning that it should be the preferred risk control option[37].

However, altering σ^2 does not give the full story, what also needs to be considered is how a change in the unit cost of risk management may affect z and m.

Letting $\theta = r$ will imply that:

$$\frac{-\partial^2 E}{\partial z \partial r} = 0$$

and

$$\frac{-\partial^2 E}{\partial m \partial r} = 1.$$

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36 The Separation Theorem effectively states that a firm's planned output level will only depend on the non-stochastic futures price and as such is independent of both a firm's attitude towards risk and the probability distribution of the spot price.

37 It is also interesting to note that this result is largely consistent with one of the claims made by the "traditional" risk management literature (e.g. see Carter & Crockford 1974, Mehr & Hedges 1974) - that the role of risk management should be to free managers from non-core distractions (such as having to worry about the risk of fire or machine breakdowns) thus allowing them to concentrate on their main business activities (deciding what and how much to produce etc.). In fact it is possible that this traditional motive for risk management arose out of an implicit awareness of the economic impact of technological risk. See also Stultz (1996) for an interesting modern take on traditional risk management views that would seem to support this hypothesis.

Consequently, the values for both $\frac{\partial z}{\partial r}$ and $\frac{\partial m}{\partial r}$ are negative which means that a marginal increase in the unit cost of risk management has the effect of decreasing both the demand for z and (as might be expected) the monopolist's utilisation of m.

This result not only illustrates the importance of cost effective risk management but also provides evidence that z and m are complimentary goods[38]. For example, as the unit cost of risk management increases the budget constrained monopolist will be forced to reduce its demand for m, thereby, increasing its exposure to technological risk. Increased exposure to risk will, however, reduce the value of z causing the firm to lower its planned output. Conversely as r falls the firm is able to increase its investment in m thus reducing its exposure to risk and enabling it to raise expected output.

In the light of these comparative statics it would seem that technological risk can have a significant adverse effect on the expected profits of a monopolist. Such firms are, therefore, likely to invest considerable amounts in risk management. However, it is important to remember that the cost of risk management is also crucial. If the unit cost of risk management is too high the monopolist may be forced to reduce its demand for m. This is then likely to have a serious knock-on effect on both planned output and expected profits.

4.3 *Oligopoly*

An oligopoly can be loosely defined as a market in which a few large firms dominate (e.g. see Gravelle & Rees 1992, Ch. 12, Martin 1993, Ch. 2). One major characteristic of these small numbers is that any one firm's behaviour will not only affect its own profitability but also that of its rivals. Because of this interdependence oligopolists

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38 Note that this result contradicts that of Schneider (1992). However given that Schneider focused on pure risk this is not surprising.

face a strategic situation where the optimal decisions of one firm are influenced by those of all the other firms in its industry.

Despite the analytical complexity presented by the introduction of strategic considerations, economic models of oligopolistic behaviour under risk do exist[39]. However, with the exception of a few disparate papers (e.g. Dekel & Scotchmer 1990, Young & Bolbol 1992, Jensen 1992, Stenbacka & Tombak 1994[40]) the impact of technological risk and indeed risk management has been largely neglected. Instead most authors have focused on how the presence of demand risk may influence the price, output and longer term investment (such as advertising) decisions of firms (e.g. see Sherman & Tollison 1972, Harris 1986, Klemperer & Meyer 1986, 1989, Paraskevopoulos et al 1991, Gradstein et al 1992, Wong 1995). The purpose of the current section is to begin to redress this imbalance. However, because of the complexity associated with oligopolistic models of firm behaviour this section will primarily focus on analysing the productive input decisions of oligopolists exposed to technological risk (although it will show that they are unlikely to be indifferent to managing their exposure to risk). The next Chapter will then explore the wide range of factors that may influence the strategic risk management decisions of oligopolistic firms in more detail.

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39 As Driver & Moreton (1992) point out:

"Most of the literature on uncertainty deals with either perfect competition or monopoly. The interdependence of decision making means that oligopoly is a much more difficult object of study.".

40 The form of technological risk investigated by Jensen (1992) and Stenbacka & Tombak (1994) is not the same as that considered here. Instead these authors focused on an oligopolist's incentive to adopt untried (but potentially profitable) new technologies, the efficiency of which could not be determined ex-ante.

Although oligopolistic markets can contain quite a large number of heterogeneous firms it will be assumed that there are only two identical firms operating within the industry. This is a common approach, its primary advantage being that the results of such a model can be shown relatively simply and clearly[41]. Admittedly these results may not easily generalise out of the homogeneous duopoly case, however, it does provide a useful starting point for subsequent research.

Taking into account the strategic nature of oligopolistic decisions the profit maximising condition for the ith duopolist under technological risk is:

$$E[\pi_i(z_1 z_2)] = (a-c)z_i - b(\sigma_i^2(m_i)+1)z_i^2 - b\{\rho\sigma_1(m_1)\sigma_2(m_2)+1\}z_i z_j - rm_i, \text{for } i,j=1,2; i \neq j \quad [12]$$

Note that equation [12] contains an additional term to the perfectly competitive and monopoly cases. The term: $b\{\rho\sigma_1(m_1)\sigma_2(m_2)+1\}z_i z_j$ (which arises from taking the expected value of $(-b\tilde{q}_1\tilde{q}_2)$) represents the impact that a rival's input decisions will have on the residual demand curve and subsequent market price faced by a firm. As such it illustrates two important effects. Firstly it recognises that in a world with technological risk rival output is also likely to fluctuate, meaning that the proportion of total consumer demand available to a firm will vary. This implies that in a world of technological risk a duopolist will face two sources of risk rather than just one: random output fluctuations caused by unreliability in its own inputs and random fluctuations in its residual demand curve caused by the unreliability of its *rival's* inputs. Secondly the term recognises that rival output fluctuations may be positively or negatively related (as the correlation coefficient ρ is positive or negative respectively) with those of the ith firm - a fact which could further influence the degree to which the market price for a firm's product will vary.

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41 For proof of the dominance of this approach see Shapiro (1989a) or Martin (1993).

Equation [12] then yields the following first order conditions for z_i and m_i:

$$\frac{\partial E}{\partial z_i} = (a-c) - 2b\{\sigma_i^2(m_i)+1\}z_i - b\{\rho\sigma_1(m_1)\sigma_2(m_2)+1\}z_j = 0 \qquad [13]$$

$$\frac{\partial E}{\partial m_i} = b\beta_i\sigma_i^2(m_i)z_i^2 + b\left(\frac{\beta_i}{2}\right)\rho\sigma_1(m_1)\sigma_2(m_2)z_iz_j - r_i = 0 \qquad [14]$$

From equations [13] and [14] it should immediately become clear that, just as in the monopoly case, duopolistic firms are unlikely to be indifferent to either the presence of technological risk or investment in risk management. However, a comparison with the optimisation conditions of a monopolist reveals that the motivations behind the behaviour of a duopolistic firm are likely to be somewhat more complex. Moreover as they stand equations [13] and [14] do not reveal any specific details about either the nature or extent of these motivations. Because they are competing in a duopoly the decisions of one firm will affect those of the other, consequently, in order to get the complete picture it is necessary to see how firm *i*'s decisions about *z* and *m* will affect *j*'s choices and vice-versa.

Given the rather complex interactive nature of a duopolist's decisions it is instructive to first consider how technological risk will influence its selection of z_i when risk is exogenous. The equilibrium level of z_i in the industry (z_i*) can then be found by solving the following simultaneous equation:

$$\frac{\partial E}{\partial z_i} = (a-c) - 2b\{\sigma_i^2+1\}z_i - b\{\rho\sigma_1\sigma_2+1\}z_j = 0$$
$$\frac{\partial E}{\partial z_j} = (a-c) - 2b\{\sigma_j^2+1\}z_j - b\{\rho\sigma_1\sigma_2+1\}z_i = 0$$

Some tedious computation (in which the expression for firm i's reaction function is substituted into j's first order condition) then yields[42]:

$$z_i^* = \frac{\frac{(a-c)}{b}.\left[2\left(\sigma_i^2+1\right)-\left(\rho\sigma_1\sigma_2+1\right)\right]}{4\left(\sigma_1^2+1\right)\left(\sigma_2^2+1\right)-\left(\rho\sigma_1\sigma_2+1\right)^2} \quad \text{for } i \neq j \qquad [15]$$

Given identical firms the second order conditions for a maximum require $\frac{\partial^2 E}{\partial z_i^2}$ to be negative and the Hessian determinant $|H| = \left(\frac{\partial^2 E}{\partial z_1^2}\right).\left(\frac{\partial^2 E}{\partial z_2^2}\right) - \left(\frac{\partial^2 E}{\partial z_1 \partial z_2}\right)^2 > 0$. From [13] we have:

$$\frac{\partial^2 E}{\partial z_i^2} = -2b\left(\sigma_i^2+1\right) < 0$$

and

$$\frac{\partial^2 E}{\partial z_1 \partial z_2} = -b\left\{\rho\sigma_1\sigma_2+1\right\},$$

so that the final second order condition is satisfied when the denominator of [15] is positive.

As should now be obvious from equation [15] it is quite difficult to specify the exact impact that technological risk will have on a duopolist's optimal demand for z_i. The trouble is that instead of being simply influenced by the impact of its own exposure to

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42 A useful check to test the validity of any model of firm behaviour under risk is whether or not it reduces to the standard result under certainty. In fact this is indeed the case, when $\sigma^2 = 0$, [15] becomes,

$$z_i = \frac{\frac{a-c}{b}}{3}$$

which is the standard Cournot result in a world of certainty.

technological risk a duopolist must also consider the implications of its rival's exposure as well. This gives rise to several, potentially conflicting, effects:

1. *Own risk effect*

Firstly a duopolist's demand for z_i will, just as in the monopoly case, be influenced by a technological non-linearity between its marginal profits and random output. Again given that the duopolist faces a linear, downward sloping demand curve, fluctuations in final output should serve to reduce its expected marginal profits, thereby, lowering z_i*.

In order to see this result more clearly remember that where each firm is exposed to an identical level of risk and $\rho = 1$ equation [15] will reduce to:

$$z_1 = z_2 = \frac{(a-c)}{3b(\sigma^2+1)}$$

In short equation [15] produces the standard Cournot result - that expected industry output ($\overline{Q} = z_1 + z_2$) will be exactly 1/3rd greater than that of a monopolist. The only difference being that in this case expected industry output is 1/3rd greater than that of a monopolist experiencing multiplicative technological risk.

2. *Rival risk effects*

Interestingly the impact of increased rival exposure to risk is rather mixed. On the one hand the presence of firm j's risk in the denominator of [15] would seem to indicate that as the value of σ_j^2 increases z_i* should also rise. Intuitively this is not very surprising - given the technological concavity between a firm's marginal profits and its final output increased exposure to technological risk will, logically, cause the expected marginal profits of firm j to fall. This should then induce j to lower its output, providing firm i with an opportunity to increase its market share[43]. However, the presence of the term $4(\sigma_1^2+1)(\sigma_2^2+1)$ in the denominator indicates that increases in a rival's exposure to risk can also serve to reduce z_i*. The rationale behind this rather counter-intuitive result stems from the fact that firm j's output fluctuations will be translated into fluctuations in the residual demand curve of i. Such fluctuations can then increase the extent to which the market price for i's product will vary across different output states, thereby, potentially intensifying the technological non-linearity effect between marginal profits and final output (for more on ideas such as this see Chapter 6, section 2.3).

3. *Correlation coefficient effects*

Where the correlation coefficient $\rho \neq 0$ the behaviour of a duopolist will be influenced by several effects. For example, as might be expected in the case where $\rho > 0$ the demand for inputs in the industry as a whole will reduce under technological risk (since this will increase the degree to which the market price fluctuates). Moreover, increases in the standard deviation of either a firm's own *or* its rival's output fluctuations will serve to intensify the adverse effects of a positive correlation coefficient. However, rather less expectedly its presence in the denominator means that where firms are exposed to different levels of risk it may also (despite being non-linear) serve to widen the gap between firm's input levels[44]. Thus a low risk firm may gain an additional *relative* advantage over its rival by becoming increasingly

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43 A standard characteristic of (Cournot type) duopoly behaviour is that firms' optimum output levels are negatively related - thus as the optimum output level of one firm increases its rival's optimum output level should fall and vice-versa. In a world of technological risk this result would, therefore, seem to still stand. However, in the current example a duopolist's optimum output is not simply determined by known demand, cost or production conditions but also the extent of its exposure to technological risk.

44 That is, if $(z_i - z_j) > 0$ then it is increasing in ρ.

dominant (in terms of being able to produce a higher level of expected output than its rival) as the correlation between ε_1 and ε_2 increases. Note that these results will be precisely reversed on the case where $\rho < 0$.

Thus it would seem that the impact of technological risk on z_i* will depend critically on whether firms are exposed to the same or different levels of risk. In the case where each firm is exposed to the same amount of technological risk its presence will, just as in a monopoly, cause an unambiguous reduction in z_i*. In fact to the extent that the correlation coefficient is positive (i.e. $\rho > 0$) the adverse impact of technological risk on the marginal profits of a duopolist would appear to be relatively greater than for a monopolist. However, in the case where firms are exposed to different levels of risk (either by default or through the deliberate management of risk) the impact of technological risk is much less clear cut. On the one hand higher output and price fluctuations mean lower optimum output levels for a duopolist, providing its rival with an opportunity to dominate the market. Yet, on the other hand one firm's exposure to technological risk could also serve to increase its rival's exposure to price fluctuations, creating a potential competitive advantage.

Having shown that a duopolist is unlikely to be indifferent to risk the next step is to examine the relationship between this concern and its investment in risk management. However, given the somewhat conflicting effects that a unilateral change in a duopolist's exposure to risk may have on z_i* (and ultimately its profits) it is hard to achieve any precise predictions as to the optimal level of risk management in duopolistic industries. In fact the joint solutions for z_i* and m_i* would require equations [13] and [14] to be solved for four unknowns (z_i and z_j as well as m_i and m_j). Unfortunately this involves extremely complicated and often ambiguous multiple solutions, which need to be checked against the second order conditions to determine which, if any, are true maxima. Therefore, a more detailed analysis of this problem is left to the next Chapter where game theory is used to help simplify and clarify this issue by modelling the interaction between duopolists' risk management decisions as a two-by-two risk management game.

5. Conclusion

The purpose of this Chapter has been to show that even in a world with perfect capital markets and where every stakeholder is risk neutral a firm may still invest in risk management. Indeed this result appears to be quite general. Except in the limited case of perfect competition with independent output fluctuations a risk neutral firm should actually be able to increase its expected profits if it can reduce its exposure to technological risk.

Of perhaps most interest is the case of Cournot duopoly since this more accurately represents the behaviour of real world firms. Here it was argued that where duopolists are exposed to different levels of (technological) risk its presence can have either a positive and negative effect on their profits. This is largely due to the impact that technological risk can have on a duopolist's ability to compete since any enforced reduction in its (mean) optimum output level will enable its rival to capture an increased market share and dominate the market. Thus it would seem that duopolists are, a-priori at least, likely to be particularly keen to invest in risk management, however, due to its analytical complexity a more detailed examination of this proposition is left until the next Chapter.

Chapter 6:
A Strategic Framework for Risk Management

1. Introduction

In the last chapter a number of specific examples were developed to show that even an expected profit maximising firm is likely to want to control its exposure to (technological) risk. The main driving force for this lack of indifference was imperfect competition, where both monopolists and duopolists could suffer greatly from the adverse impact that unpredictable random output fluctuations may have on the prevailing market price for their product and subsequently expected revenues. In particular, duopolists appeared to have the most to gain from controlling their exposure to technological risk. However, the strategic nature of a duopolist's decisions meant that its exact reaction - in terms of its risk management and input decisions - was unclear. This was largely due to the conflicting effects that technological risk could have on both its own and its rival's ability to compete. Higher output and price fluctuations meant lower optimum output levels for a firm, providing its rival with an opportunity to dominate the market. Yet, conversely one firm's exposure to technological risk could also have an adverse effect on its rival's ability to predict the demand for its product, thereby, creating a potential competitive advantage.

The purpose of this chapter is to provide some rather more specific predictions as to a duopolist's (or indeed oligopolist's) preferences regarding risk and risk management. Admittedly models examining the impact of risk on the strategic behaviour of firms are nothing new. Yet, with the exception of a few disparate pieces of research (Dekel & Scotchmer 1990, Eldor & Zilcha 1990, Allaz 1992 and perhaps Young & Bolbol 1992[1]) no one has yet developed a significant strategic role for risk management. In

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1 Young & Bolbol do not explicitly consider the corporate demand for risk management, however, their model could be easily adapted to do so.

particular, it will be confirmed that risk management is likely to be of considerable importance to strategically interdependent firms. However, this may not always stem from risk management's ability to confer a competitive advantage. Instead, depending on the exact specification of the game to be played, a number of further interesting possibilities could arise.

The analysis begins in a simplified and effectively static environment in which identical but self interested duopolists are required to simultaneously decide on their exposure to risk. This exposure is then allowed to condition the nature of competition played out in the final output market and hence the exact payoffs of each firm. Using such a framework many different outcomes are possible, however, particular attention is given to several interesting symmetric Nash equilibrium solutions[2] that could be attained. These include both "*Risk Wars*" and "*Certainty Wars*" in which firms respectively expose themselves to excessive degrees of risk and certainty and also potentially costly Co-ordination Equilibria where either Pareto inefficient levels of risk or certainty could arise.

The analysis is then extended to incorporate rather more dynamic interactions between duopolists. In particular the possibility that self interested duopolists may become aware of and attempt to control their tendency to select jointly Pareto inefficient outcomes is explored. The theoretical basis for this analysis is that of a multi stage game with "closed-loop" equilibria (e.g. see Fudenberg & Tirole 1986, Shapiro 1989a, Slade 1995). The essential characteristics of such games is that at each stage firms are able to fully remember and make *strategic* decisions conditioned on what has gone before. A firm may, therefore, make commitments to its rival to either

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2 A Nash equilibrium can be defined as an equilibrium from which no firm would unilaterally wish to deviate (for a good discussion of this topic see Rasmusen 1994, Ch. 1).

punish it for engaging in inefficient, non-cooperative, behaviour or rather more interestingly to punish itself if it was to do the same. Using this insight it is then argued that some of the tools which firms can use to control their exposure to risk (such as external insurance, captive insurance, physical risk control devices etc.) may be employed as commitment devices in "risk games". As such risk management may be more than a simple internal control device (in a similar manner to non-executive directors) but could also be used to improve a firm's external relations with its competitors as well.

The next section commences by developing a static two-by-two risk management game in which non-cooperative firms may expose themselves to Pareto inefficient levels of risk (both too little and too much). Section 3 then extends the analysis to the rather more realistic case of multi-stage closed-loop games and examines how certain risk management tools (in particular insurance and risk sharing arrangements) could be used to improve on the equilibrium solutions reached in static games. Finally section 4 rounds the Chapter off with a brief conclusion.

2. Risk Management as a Static Two-by-Two Game

Before proceeding it is worth reconsidering equation 12 in Chapter 5 (section 4.3), the profit maximising condition of the *i*th (quantity setting) duopolist facing technological risk:

$$E\left[\pi\left(z_i z_j\right)\right] = (a-c)z_i - b\left(\sigma_i^2(m_i)+1\right)z_i^2 - b\left\{\rho\sigma_1(m_1)\sigma_2(m_2)+1\right\}z_i z_j - rm_i, \quad i \neq j$$

What this equation demonstrates is that technological risk can impact upon a duopolist in three mains ways: first, *i*'s expected profits are decreased by its own output variations via the term $\sigma_i^2(m)_i$, second expected profits are decreased by the covariance term to the extent that ρ is positive, and third profits are affected by the technological risk and expected output of its rival.

Given equation [12] it is not difficult to see how the behaviour of even a seemingly risk neutral duopolist will be influenced by the presence of risk[3]. However, what is rather less obvious is the extent or even direction of this influence on the $i$ths duopolist's choice of z_i and m_i. The cause of this ambiguity flows from the strategic interdependence of duopolists' decisions. On the one hand a firm's own exposure to technological risk (and or any correlation with this and its rival's exposure to technological risk) causes it to reduce its demand for inputs (and thus expected output), thereby, providing its rival with a competitive advantage. However, on the other hand variability in a firm's own output will hinder its rival's learning processes and expose them to the potentially costly effects of a fluctuating residual demand curve (so called demand risk). In short a duopolist's (or indeed oligopolist's) exposure to technological risk need not necessarily be a bad thing: while it may decrease its revenues, it can - by preventing its rival(s) from making the right production decisions - harm its competitor(s) as well.

As already stated in Chapter 5 (section 4.3) the rather conflicting effect that (technological) risk may have on the relative fortunes of a duopolist (or indeed oligopolist) makes it almost impossible to achieve a unique, all encompassing prediction regarding its behaviour. The trouble is that even in the highly specific and simplified world exemplified by equation [12] several different Nash equilibrium solutions are possible - a firm's choice between different levels of risk or certainty depending on how the precise values of the given variables in a model (for example the nature of the industry demand curve, the value of ρ or the cost of risk management) influence the costs and benefits of each possible strategy. What is

3 For formal proof of this proposition see Chapter 5, section 4.3.

needed, therefore, is an analytical framework that helps to both structure and interpret the multiplicity of possible results. The framework proposed here is game theory.

Developed initially by von Neumann & Morgenstern (1944) game theory is a widely accepted framework for the analysis of strategic interdependence in economics based duopoly and oligopoly models (see Schmalensee 1988, Shapiro 1989a&b, Martin 1993, Ch. 19). Although it does have its detractors (for example, Geroski 1988, Pelzman 1991) it remains an invaluable tool for describing the complex strategic behaviour of firms. In the words of Shapiro (1989b):

"Game theory has emerged as the predominant methodology for analysing business strategy. Much of the work of the new I.O. [Industrial Organisation] involves specifying a game among competing firms and solving that game in extensive form using the non-cooperative solution concept of Nash equilibrium or one of its refinements......At this time game theory provides the only coherent way of logically analysing strategic behaviour."

		Firm 2	
		Certainty	*Risk*
Firm 1	*Certainty*	(C,C)	(A,B)
	Risk	(B,A)	(R,R)

Payoffs to: (Firm 1, Firm 2)

Table 1: A Static 2x2 Risk Management Game

Using the methodology of game theory table 1 illustrates the duopolist's conflict between risk and certainty as a non-cooperative game of complete symmetric information with identical firms. Note that although the game is treated as being static, this is something of a misnomer. The essential feature of this game is that each firm makes a (simultaneous) decision regarding its exposure to risk *before* it selects its optimum input/planned output (or indeed price) level. As such there is a degree of dynamism in this model that would not be present in a conventional Cournot (quantity setting) or Bertrand (price setting) duopoly game. However, despite this dynamism two-stage games such as in table 1 are often treated as being static (see, for example, Spence 1977b, Dixit 1980, Fudenberg & Tirole 1984 & 1986, and Shapiro 1989a or Martin 1993 for a review). The rationale behind this comes from the simplifying assumption that a firm will behave naively, taking both the first stage (strategic) and second stage (tactical) decisions of its rivals as given[4]. Thus in the current context this is achieved by assuming that each duopolist takes both its rival's exposure to risk and resultant input decision as given. As such a firm cannot pro-actively influence in any way the strategic risk management decisions of its rival.

A further simplifying assumption to be adopted in this section is that each firm is restricted to choosing between only two discrete levels of risk (Risk and Certainty). This approach differs from the continuous risk case used for perfectly competitive and monopolistic firms in Chapter 5 and is much less realistic. However, having only two discrete levels of risk will substantially improves the tractability of the analysis while still allowing the consideration of the same equilibria that could arise in a game where a firm's choice of risk is taken to be continuous.

In addition to focusing on only two discrete levels of risk a further difference with Chapter 5 is that much of the discussion in this section will be kept quite general. The main reason for adopting a higher level of generality is to allow a firm's payoffs (A, B, C or R) to be influenced by the widest possible variety of factors (such as the

4 More formally this is known as an "open-loop" strategy (e.g. see Fudenberg & Tirole 1986, Slade 1995). Such a strategy is admittedly unrealistic, however, it is commonly used to simplify models with multiple dependent variables. Moreover, as will be demonstrated the equilibria that are derived from open loop strategies can also arise in more complex games (Fudenberg & Tirole 1986).

impact of demand, cost or technological risk related pure penalties and technological non-linearities or even expected utilities - if required). However, for the sake of continuity with Chapter 5 (and the majority of the little past research that does exist) the subsequent analysis will focus primarily on the case of price taking duopolists producing substitute products (i.e. the case of strategic substitutes). Moreover, a technical appendix (Appendix 3) is provided at the end of the thesis in order to provide a more specific insight into the behaviour of a quantity setting duopolist faced with a linear inverse demand function and technological risk.

One corollary associated with the level of generality assumed in this analysis is that a rather large number of Nash equilibrium strategies are possible[5]. For reasons of space the analysis is, therefore, restricted to several interesting symmetric games from which can be derived the following pure strategy alternatives[6]:

2.1 "*Certainty*" Equilibrium

A "*Certainty*" equilibrium will arise if C>B and A>R so that each firm will earn a higher payoff by choosing Certainty no matter what the choice of its rival. Thus

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5 Guyer & Hamburger (1968) note that, in general, there are 726 distinct 2x2 games.

6 A pure strategy arises where a player decides to always choose the same action whenever a game is played (i.e. in this context a firm adopting a pure strategy would select either Risk or Certainty instead of randomly mixing between both).

A symmetric game is one in which each player has the same number of pure strategies and the payoff to any strategy is independent of the player to which it is applied to (i.e. in the case where one firm selects risk and the other certainty it does not matter whether it is firm 1 or 2 which selects risk as the payoff received by each would be exactly the same - B) - see Weibull (1995) for a good discussion of symmetric games.

Certainty is the dominant strategy for each firm, meaning that the prevailing Nash equilibrium will also be (Certainty, Certainty)[7].

A "*Certainty*" equilibrium is perhaps the most straightforward and least contentious outcome for a two-by-two risk management game. Indeed whenever the presence of risk (whether it be technological, demand or cost related) can be shown to have a significantly adverse impact on the profits earned by a duopolist such an equilibrium is likely to arise. However this outcome relies on the fact that available risk management instruments are sufficiently cost effective. Moreover, in other industries the strategic benefits of risk (in terms of an increased competitive advantage) may well outweigh its associated costs. In such environments other equilibrium outcomes are possible.

2.2 "*Risk*" Equilibrium

A "*Risk*" equilibrium will arise if B>C and R>A. As such it is the inverse of the "*Certainty*" case - Risk is the dominant strategy for each firm meaning that the Nash equilibrium will be (Risk, Risk).

In a "*Risk*" equilibrium neither firm will find it profitable to control or remove its exposure to risk. While such a result may seem surprising it is worth bearing in mind that where risk management is expensive or inefficient it is entirely possible. However, the existence of a "*Risk*" equilibrium does not necessarily mean that each firm will always *prefer* Risk to Certainty, merely that Certainty is currently too

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7 A dominant strategy is a firm's strictly best (i.e. most profitable) response to any strategy that its rival might pick. Note also that a dominant strategy equilibrium will, by definition, be a Nash equilibrium (although not all Nash equilibrium are dominant). For a good discussion of this subject see Rasmusen (1994, Ch. 1).

expensive to achieve. Therefore, if a firm could find some way to improve the cost effectiveness of its risk management programme it might well do so[8].

2.3 "*Risk War*"

A "*Risk War*" equilibrium outcome can arise if B>C>R>A. However, although the dominant/Nash equilibrium solution will be the same as in the "*Risk*" equilibrium case (Risk, Risk), there is a major difference between the two.

The difference is that in a "*Risk War*" the chosen equilibrium outcome (Risk, Risk) is actually Pareto inferior to that of (Certainty, Certainty). In fact both firms could be made better off if they switched to a joint "*Certainty*" equilibrium. However, in the absence of an enforceable co-operative agreement such a switch is not possible. The problem is analogous to the classic Prisoners' Dilemma problem in game theory (e.g. see Rasmusen 1994, Ch. 1). Consider, for example, firm 1. Firm 1 knows that if both it and its rival were to choose Certainty joint profits would be at their highest. However, firm 1 also knows that if firm 2 was to choose Certainty it could do better by selecting Risk (since B>C), moreover, it should realise that if firm 2 was to select Risk and it had selected Certainty its payoff would be the lowest possible (A). In short, the dominant individual strategy for firm 1 is to expose itself to risk since whichever strategy 2 then chooses it cannot do worse than if it had selected Certainty. It then follows that since the game is symmetric, firm 2's reasoning should be exactly the same, leading to the conclusion that the dominant strategy equilibrium is, rather unfortunately, (Risk, Risk).

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8 It is, however, worth noting that in the case of strategic complimentary (i.e. price setting firms producing substitute products or quantity setting firms producing complimentary products) firms may directly benefit from exposing themselves to risk. This is because it encourages them to set a higher (and more profitable) price for their product (see Gradstein et al 1992).

Interestingly the possibility of a "*Risk War*" has already been considered in the mainstream industrial economics literature. Perhaps the best known (and seminal) example is that of Brander & Lewis (1986)[9]. What they suggest is that an incorporated quantity setting oligopolist may try to strategically exploit its exposure to certain risks (such as multiplicative demand or cost risk) by purchasing debt[10]. The reasoning behind this is based on the debt agency conflict outlined by Jensen & Meckling (1976) (see also Chapter 2, section 3.1). A firm that purchases debt becomes relatively less concerned about the effects of adverse (i.e. low demand/high cost) states because of the limited liability effect of equity capital[11]. Effectively debt serves to increase the convexity of a firm's marginal profit function providing leveraged firms with an incentive to increase their exposure to risk by say (ex-ante) raising their output (as in the case of multiplicative demand or cost risk). This fact can then be exploited by an oligopolist since by purchasing debt it can provide itself with a credible[12] means to raise its output and dominate the market. However, if all firms follow suit (as is likely if they want to avoid losing market share) the perceived benefits of the strategy will soon disappear. Instead the whole situation could degenerate into what is essentially a

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9 See also Fershtman & Judd (1987) and Rotemberg & Scharfstein (1990) who reach very similar conclusions but explore a firm's ability to exploit rather different agency relationships - such as those between managers and shareholders.

10 Brander & Lewis also claimed that their argument could apply to price setting firms, however, Showalter (1995) has since shown that this is not generally the case.

11 The argument being that a higher level of output should increase the expected benefits of favourable (i.e. high demand/low cost) states while having a much less significant effect on the expected costs of adverse ones (since the worst that can happen is that shareholders will lose their initial stakes when the firm goes bankrupt).

12 Without altering its second stage payoffs no firm would rationally increase its output above the standard Cournot duopoly or oligopoly level (e.g. see Shapiro 1989a).

"*Risk War*", where non-cooperative firms purchase excessive levels of debt, driving risk and output up but industry profits down.

Yet, as Brander & Lewis largely admit the type of "*Risk War*" they discuss (where a firm uses its own exposure to risk to directly increase its output) may not occur in every oligopolistic market. The problem is that Brander & Lewis' result relies on the assumption that higher draws of a random variable leads to an increase in the firm's marginal profits. However, there are many situations in which the opposite may in fact be the case.

Take, for example the case of identical duopolists facing multiplicative technological risk and a linear downward sloping demand function as examined in Chapter 5 (section 4.3)[13]. Here it is not difficult to show that a strategically motivated firm which purchases debt will rationally try to decrease rather than increase its exposure to technological risk. To see this re-write equation [13], the first order condition for z_i (i.e. the level of input utilisation of the *i*th firm), as follows[14]:

$$\frac{\partial E}{\partial z} = E\left[(a-c) - 2bz_i\varepsilon_i\right] - bz_j = 0, \text{ for } i,j = 1,2; i \neq j \qquad [13]$$

What equation [13] reveals is that since demand is downward sloping the marginal benefit (in terms of increased revenue) received through the use of an additional input will be negatively correlated with the realised values of the random variable ε_i. As

13 Other examples include the case of price setting firms facing demand and cost risk (Showalter 1995) and competition through advertising (Brander & Lewis 1986). See also Bolton & Scharfstein (1990) for a similar discussion in relation to the strategic exploitation of bankruptcy risk.

14 Remember $b\left(\sigma_i^2(m_i)+1\right)z_i^2 = b\left(z_i\varepsilon_i\right)^2$ and note for simplicity the assumption that $\rho = 0$.

such the firm will find that in high output states its profitability can be improved by demanding *fewer* inputs, while in low output states it would be better off increasing its demand for z_i. Thus when a firm (or rather managers acting in shareholders' interests) purchases debt its aim will be to reduce its demand for z_i since doing so will enable it to more fully exploit "good" (high final output) states of nature while the costs associated with such a strategy (lower profits in low output states due to insufficient input use) will be attenuated by its ability to declare bankruptcy in "bad" states of nature and make creditors the residual claimants. In short the purchase of debt will, in the face of technological risk, actually commit a firm to compete less aggressively, thus providing its rival(s) rather than itself with the ability to dominate the market.

Even though a Brander & Lewis' type "*Risk War*" can not occur where higher draws of the random variable decrease a firm's marginal profits another type of "*Risk War*" could. The rationale behind this stems from the fact that the adverse consequences of one firm's exposure to risk may also expose its rival(s) to additional risk related pure penalties or technological non-linearities. Consequently, where rival risk related costs are relatively high it may well be profitable for a firm to increase its own costly exposure to risk.

The possibility that one firm's exposure to risk might be translated into additional risk related costs for its rival(s) has not been well treated in the literature. In fact the only real piece of work in the area is that by Young & Bolbol (1992)[15]. Using the dominant firm model of oligopoly they investigated the incentives of a large (quasi-monopolist) incumbent firm in an industry to deter the entry of a competitive (i.e. price-taking) fringe of rivals by exposing them, via random fluctuations in its own output, to

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15 See also Dekel & Scotchmer (1990). However, there is no potential for risk wars in their model. Instead they argue that firms may actually benefit from joint increases in technological risk. For more on this see sections 2.4 and 3.2 below.

demand risk. By assuming that fringe firms make their (irreversible) entry decision ex-ante but their output decisions ex-post (i.e. after the random market price for the product was revealed - see Oi 1961) Young & Bolbol were able to show that such firms would, in the face of a strictly convex cost function, rationally reduce choose not to enter[16]. Then providing that the costs associated with a fringe firm's exposure to demand risk outweigh those related to output risk they argued that it should be in an incumbent firm's interests to deter entry in this manner.

Unfortunately, although explicitly dealing with an oligopolist's strategic incentive to expose both itself and its rivals to risk, Young & Bolbol's research does not explain how this might translate into a "*Risk War*". Indeed as in much of the research into entry barriers the dominant firm's incentive to expose itself to output fluctuations largely stems from the fact that it has various special advantages over its rivals (i.e. the ability to influence the prevailing market price and make its production decisions ex-ante)[17]. However, despite this oversight there are situations when even completely identical duopolists or oligopolists may find that one firm's exposure to risk can have a disproportionately costly effect on that of its rival(s). It is this observation that can then be used to explain the existence of what from now on is termed a Young & Bolbol type "*Risk War*".

Take the case of identical duopolists who via their own exposure to technological risk can expose their rival to fluctuations in its residual demand curve (i.e. demand risk). Here the preconditions for a Young & Bolbol type "*Risk War*" stem from the fact that technological and demand risk can each have a quite different impact on a firm. For

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16 Young & Bolbol (1992) also considered the case where fringe firms are risk averse. However, such an eventuality is much less plausible (see Chapter 4).

17 For an excellent review of this literature see Martin (1993, Chs. 3-4).

example it may be that each firm is exposed to the risk of costly bankruptcy, the probability of which is positively related to their profit fluctuations. Given the existence of a such a pure penalty any increase in risk (whatever the source) would appear to have a deleterious effect on the final profits earned by these firms. However, with a downward sloping demand function the penalty associated with increased exposure to technological risk is likely to be less than that of a similar increase in the variability of demand. Where movements in price and output are negatively related a high level of output will be associated with a low price and vice versa. This negative relationship means that *any* firm which exposes itself to technological risk should find that its income will remain fairly stable (or at least more stable than that of a firm facing a similar level of demand risk) because of the compensating movements in price. In short a firm which exposes itself to technological risk may be able to benefit from this natural hedge (see Appendix 4 for a definition) between price and output while significantly increasing the demand risk related profit fluctuations and hence expected bankruptcy costs of its rival[18]. In this context (and assuming that each firm is aware of the strategic benefits associated with increased output fluctuations) it is then not difficult to see how a "*Risk War*" equilibrium might arise.

More generally a Young & Bolbol type "*Risk War*" could arise whenever a duopolist is able to expose its rival to some risk related pure penalty[19]. In fact it is interesting to

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18 An interesting point worth noting is that the strength of this hedge will depend on the elasticity of demand. Where demand is more elastic, price will not be significantly affected by output thereby reducing the strength of any hedge that may exist between them, the opposite being the case for inelastic demand. However, while the costs associated with increasing output risk may rise when demand is elastic the benefits of such a strategy may also increase. Where demand for a product is elastic consumers tend to be very price sensitive, consequently, even a small change in the price of one firm's product is likely to have a significant affect on the demand for those of its rivals'. Hence with elastic demand a firm need only slightly increase its output fluctuations in order to expose its rivals to significant levels of demand risk.

note that many of the issues discussed in the modern finance approach to risk management (such as the attitudes of employees, creditors, suppliers etc. to profit fluctuations - see Chapter 2) can create pure penalties that could lead to "*Risk Wars*". As such when considering these issues it may be necessary to not just consider their direct impact on a firm's profits but also their strategic implications. For example, a firm that can improve its relationship with its stakeholders may not only be able to reduce their compensation claims but also place itself in a more dominant position in its industry (in terms of increased market share) by reducing its rival's ability to expose it to demand risk related pure penalties.

The following example illustrates these arguments rather more formally. Although highly simplified it does provide a clear justification for a Young & Bolbol type "*Risk War*". As before assume that there are only two identical duopolists in the industry, however, they now each have the ability to costlessly expose their rival to some risk related pure penalty ϕ, where: $\phi > 0$ [20]. When a duopolist is exposed to this pure penalty its profit maximising condition is therefore:

$$\pi_i(q_i, q_j) = (a - c - \phi)q_i - bq_i^2 - bq_iq_j \quad \text{for } i, j = 1,2; i \neq j$$

Immediately it should be obvious that the presence of the pure penalty ϕ (however large or small it is) will serve to reduce the total profits of a duopolist. However, what is also crucial is that the extent of the negative impact of ϕ is taken to be multiplicative in q_i. Without this assumption the presence of ϕ would simply serve to reduce the total profits of the ith firm and would have no impact on either its marginal

19 For a discussion of the types of pure penalty that could exist see Chapter 4 (section 3.2).

20 Note that providing the strategic benefits of creating ϕ were to exceed any associated costs, assigning a cost to this activity (probably in the form of some own risk related pure penalty or technological non-linearity) would not alter the predictions of the model.

profits or the optimum level of q_i. In this case the strategic benefits of exposing a rival to a fixed pure penalty would be very small, in fact a firm would only benefit from doing so if ϕ was sufficiently large to drive its rival out of the market altogether.

The first order condition for a firm exposed to some level of ϕ is then[21]:

$$\frac{\partial \pi_i}{\partial q_i} = a - c - \phi - 2bq_i - bq_j \ \text{ for } i, j = 1,2; i \neq j$$

Using this first order condition and that of a duopolist operating in a world of certainty the following two-by-two game can then be generated. Note that in this case the "Risk" action no longer corresponds to a firm's decision to expose itself to risk but rather its rival.

		Firm 2	
		Certainty (ϕ=0)	*Risk (ϕ>0)*
Firm 1	*Certainty (ϕ=0)*	$\left(\frac{1}{9}\left(\frac{(a-c)^2}{b}\right), \frac{1}{9}\left(\frac{(a-c)^2}{b}\right)\right)$	$\left(\frac{1}{9}\left(\frac{(a-c)^2}{b}\right) - \frac{4}{9}\left(\frac{\phi^2}{b}\right), \frac{1}{9}\left(\frac{(a-c+\phi)^2}{b}\right)\right)$
	Risk (ϕ>0)	$\left(\frac{1}{9}\left(\frac{(a-c+\phi)^2}{b}\right), \frac{1}{9}\left(\frac{(a-c)^2}{b}\right) - \frac{4}{9}\left(\frac{\phi^2}{b}\right)\right)$	$\frac{1}{9}\left(\frac{(a-c-\phi)^2}{b}\right), \frac{1}{9}\left(\frac{(a-c-\phi)^2}{b}\right)$

Payoffs to: (Firm 1, Firm 2)

Table 2: A Pure Penalty Risk War

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21 As in the no risk case the second order condition for a maximum is simply:

$$\frac{\partial^2 \pi_i}{\partial q_i^2} = -2bq_i < 0$$

By comparing the payoffs for each strategy it should become clear that although (Certainty, Certainty) is the Pareto superior equilibrium, (Risk, Risk) is the dominant strategy. As such it would seem that where each firm possesses the ability to expose its rival to a pure penalty a "*Risk War*" is quite likely (especially when ϕ is quite large). However, if a firm can find some way to prevent or at least attenuate its rival's ability to expose it to the pure penalty it may not only be able to prevent a "*Risk War*" but also increase its market share (and profits). For example, if firm 1 was to find some way to reduce the impact of the pure penalty (say by improving employee or consumer relations, etc.) it might then be able to achieve a payoff of $\frac{1}{9}\left(\frac{(a-c+\phi)^2}{b}\right)$ and become the dominant firm in the market.

Justifying a Young & Bolbol type "*Risk War*" on the basis of increased rival exposure to risk related technological non-linearities is rather less straightforward. Again consider, for example, a firm's use of technological risk to expose its rival to demand fluctuations[22]. Although it is possible to show that fluctuations in a rival firm's residual demand curve can reduce its expected profits there are only a small number of restricted cases in which this is likely to outweigh the costs associated with a firm increasing its exposure to technological risk. The trouble is that in this case the impact of residual demand risk depends on both the type of demand risk faced (i.e. whether risk is taken to be an additive or multiplicative function of a firm's position on its real or inverse demand curve) and the exact specification (linear, quadratic etc.) of the industry demand curve (see Newbery & Stiglitz 1981, Chs. 8 & 18, Aiginger 1987, Ch. 5). Indeed in certain cases it can be argued that fluctuations in a firm's residual

22 Young & Bolbols' own model also illustrates this problem quite well. In order for the dominant firm to strategically increase its exposure to output fluctuations fringe firms had to face a convex cost function and make their output decisions ex-post.

demand (or inverse demand) function will have no or even a positive effect on its expected profits/market share.

Figure 1a and 1b about here.

Figures 1a and 1b illustrate two possible cases in which a (quantity setting) firm's exposure to demand risk will have no effect and a positive effect on expected profits respectively. In each case firms are exposed to the risk of a discrete additive shift in their real (as opposed to their inverse[23]) residual demand function (D), consequently the precise form of risk can be defined as:

$$q_i = f(p) + \varepsilon, \quad E[\varepsilon] = 0, \quad Var\,\varepsilon = \sigma^2$$ [24]

Dealing first with 1a - the case of an additive shift in a linear demand function[25] - the presence of risk can be shown to have no effect on the expected profits of a firm. In this case (since $E[\varepsilon]=0$) the losses associated with producing too much in the low demand state (as denoted by the area: ABEF) will be exactly offset by the gains

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23 As Aiginger (1987, Ch. 5) points out neither demand specification is intuitively more plausible than the other (although real world markets may historically adopt one in preference for the other). In many ways this is rather unfortunate since each specification can yield quite different results. However, whichever specification is used risk wars could still arise - albeit under different circumstances.

24 As opposed to:

$$p = f(q_i) + \varepsilon, \quad E[\varepsilon] = 0, \quad Var\,\varepsilon = \sigma^2$$

in the inverse demand case.

25 Note that under additive risk it is the intercept of the demand function that varies rather than its slope (as would be the case for multiplicative demand risk).

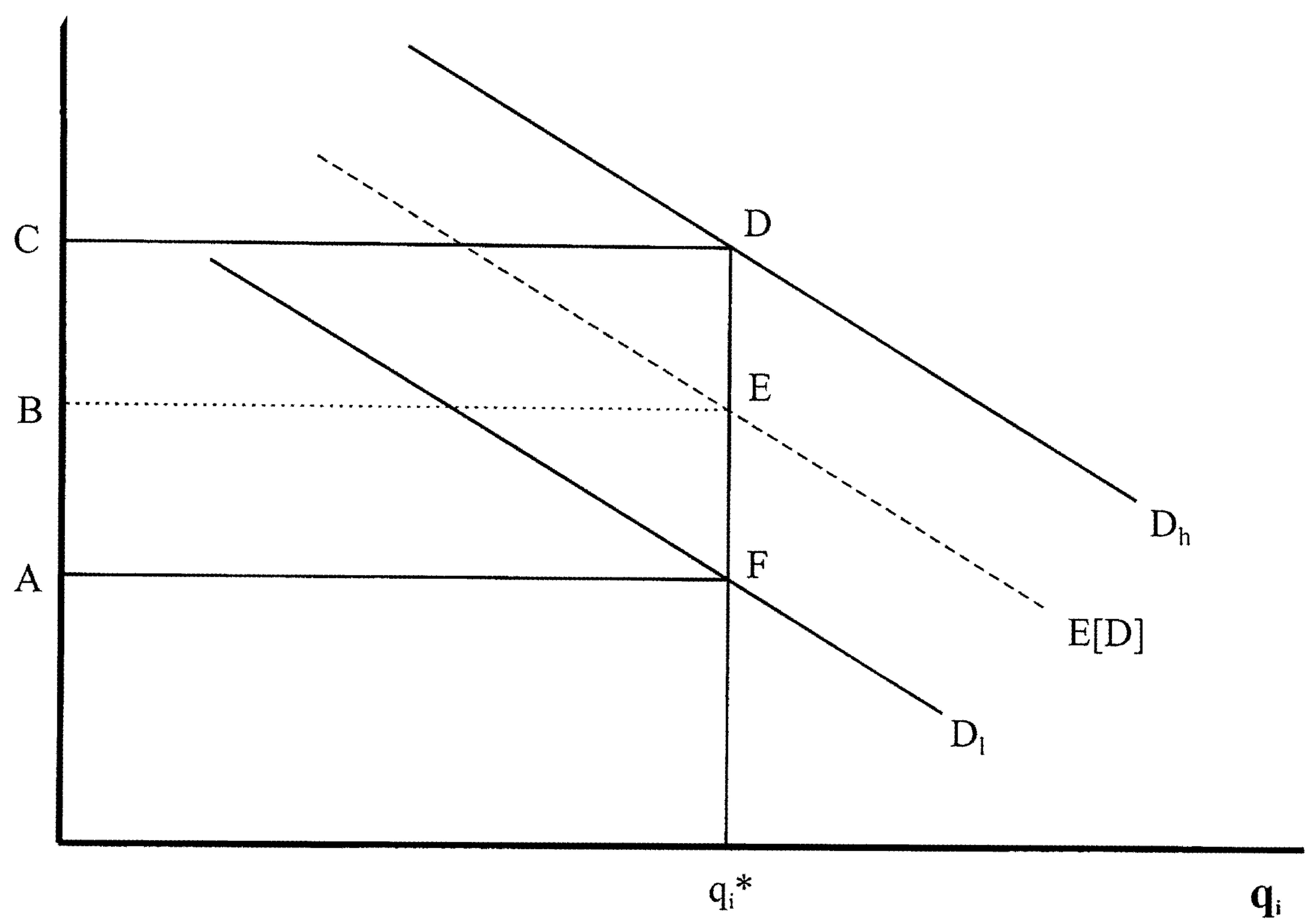

Figure 1a: Additive Fluctuations in a Linear Demand Function

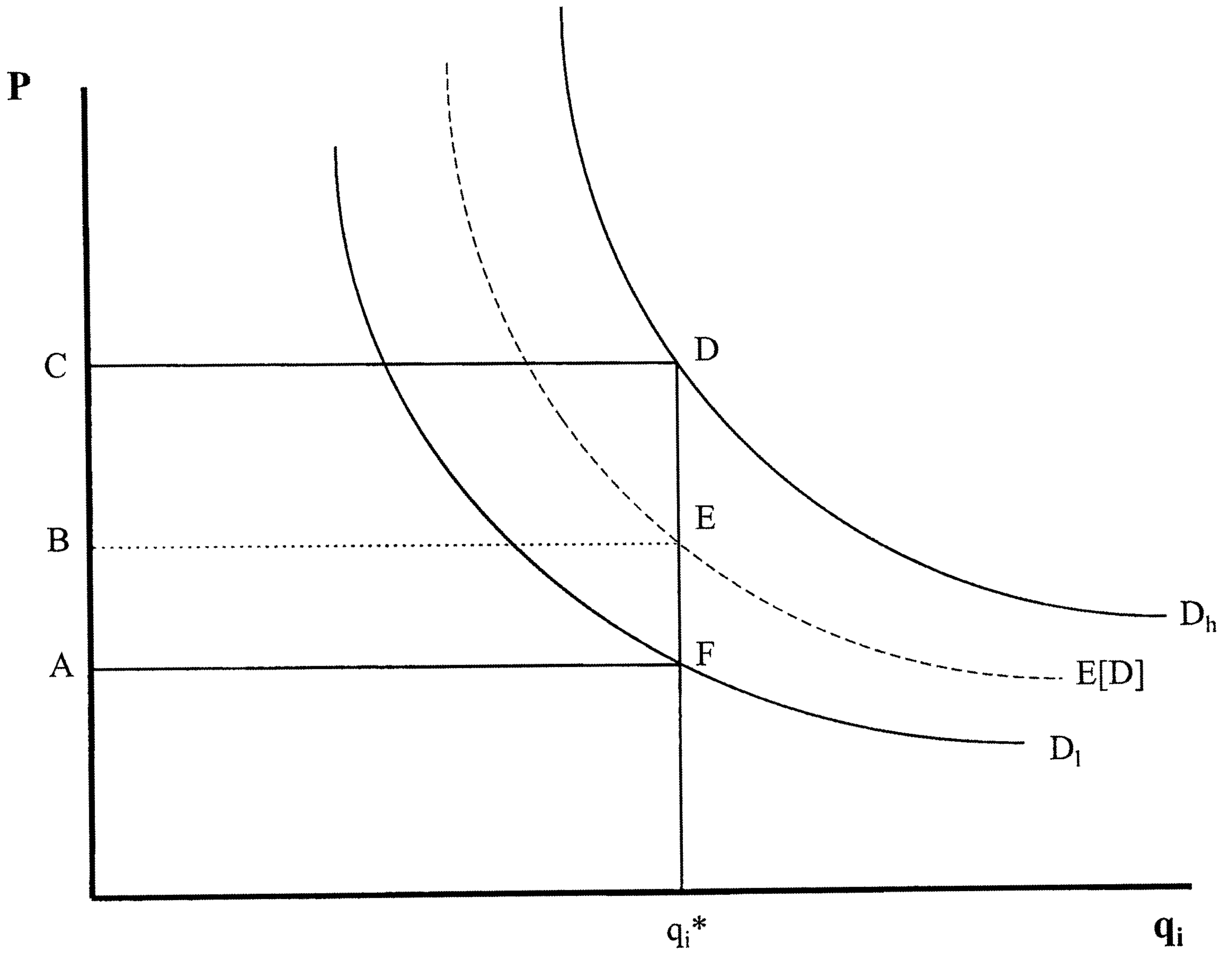

Figure 1b: Additive Fluctuations in a Strictly Convex Demand Function

associated with a greater than average price in the high demand one (the area BCDE). As such a firm will be indifferent to the presence of demand risk seeking neither to adjust its optimal output decision (as denoted by q_i*) or invest in risk management.

Alternatively in 1b the presence of demand risk will actually increase a firm's expected profits. The result flows from the fact that the firm's random demand function is now strictly convex. This causes the firm's total profit function to become convex in ε: such that the higher draw of ε (which creates the demand state D_h) will cause a larger gain (BCDE) than the loss (ABEF) associated with the equivalent low one (which creates the state D_l). It is then straightforward to show (via Jensen's inequality) that for any level of output (e.g. q_i*) an expected profit maximising firm will, paradoxically, benefit from increased exposure to demand risk[26].

Yet, despite the fact that increased exposure to demand risk need not necessarily be bad, there are certain circumstances under which it will have an adverse effect on a firm's profits and or behaviour. For example, in the case of additive shifts in a strictly concave real demand function, Jensen's inequality can be used to derive the reverse result to that described in 1b. Moreover, there are several cases in which both real and inverse multiplicative demand shifts can have an adverse effect on both the profits and output decisions of firm (see for example Nickell 1978, Ch. 5, Newbery & Stiglitz 1981, Ch. 18, Klemperer & Meyer 1986, 1989).

Figure 2 about here.

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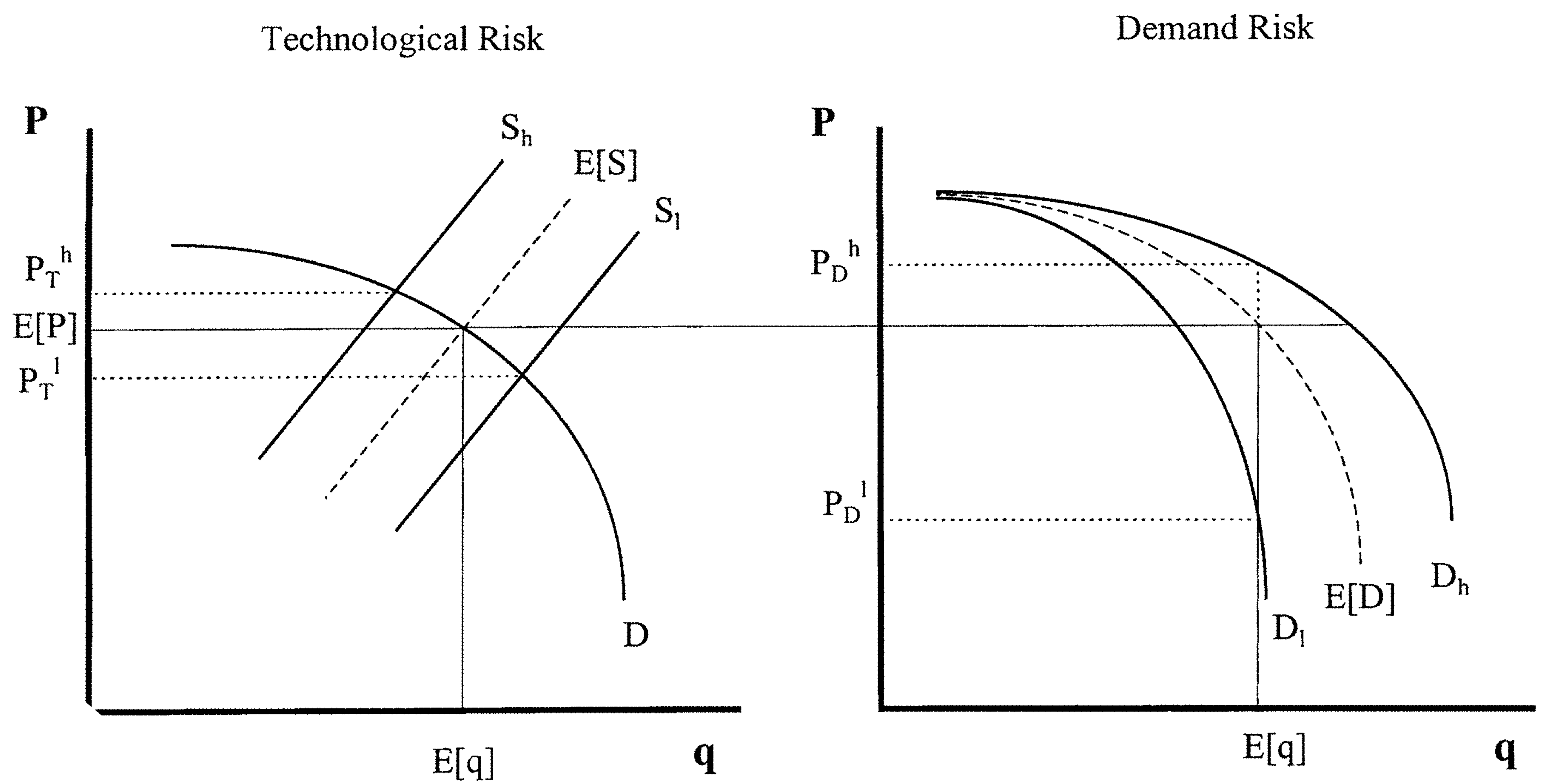
26 Note that in this case the result would be precisely reversed if the fluctuations were in a firm's inverse demand function (see Newbery & Stiglitz 1981, Ch 18).



Price Fluctuations Under Technological and Demand Risk Function

Figure 2 illustrates one case in which the adverse impact of technological risk induced multiplicative demand risk could be sufficient to create a "*Risk War*". Here demand fluctuations are described in multiplicative form as[27]:

$$q_i = f(p)\varepsilon, \quad E[\varepsilon] = 1, \quad Var\, \varepsilon = \sigma^2$$

The (real) market demand function for a firm's product is then assumed to be strictly concave in both random price and output fluctuations. Since this will cause each firm's total profit function to become strictly concave in these random fluctuations, it is not difficult to see (via Jensen's inequality) how the presence of either technological or demand risk will cause expected profits and generally output to fall[28]. What is then required for a "*Risk War*" is to show that the adverse impact of demand risk is greater than for technological risk and indeed this should be the case. The reason for this stems from the fact that under demand risk the output level of a quantity setting firm is fixed ex-ante. As such there is no natural hedge to help deflate the impact of any resultant price fluctuations. Consequently the price fluctuations faced by firms experiencing demand risk (such as P_D^h and P_D^l) are likely to be greater than for a similar level of technological risk (i.e. P_T^h and P_T^l), thereby, causing a larger drop in both optimal output and profits.

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27 Note that the impact of technological risk on output is defined as in Chapter 5 in multiplicative form:

$$q_i = z_i\varepsilon_i, \quad E[\varepsilon_i] = 1, \quad Var\, \varepsilon_i = \sigma_i^2$$

28 In order for the presence of risk to cause a reduction in income all that is required is that a firm's total profit function be strictly concave in the random variable faced. However, for risk to affect output a firm's marginal revenue function must also be strictly concave. Unfortunately, in the demand risk case this does not immediately follow, although, as Nickell (1978, Ch 5) points out it will occur for linear and quadratic real demand functions or for products where the elasticity of demand is constant and less than -1 (i.e. elastic).

2.4 "*Certainty War*"

A "*Certainty War*" will arise when A>R>C>B. This is effectively the opposite result of a "*Risk War*", but instead of (Risk, Risk), (Certainty, Certainty) ends up being the dominant but Pareto inferior equilibrium solution to the game.

As with a "*Risk War*" the rationale behind a "*Certainty War*" is based on the classic Prisoner's Dilemma. In this case the Pareto superior equilibrium is (Risk, Risk), however, this is not the dominant strategy for each individual firm. The problem is that a firm will not rationally choose to expose itself to Risk since doing so will yield lower (individual) payoffs than if it had chosen Certainty, no matter what action its rival chooses. However, since both firms are then likely to choose Certainty their joint profits will actually be lower than would occur if they both selected Risk. The two firms will, therefore, need to find some way to agree to increase their exposure to risk, unfortunately this will not be easy since no one firm will do so unless it can be sure that its rival will follow suit.

The possibility of a "*Certainty War*" arising out of an oligopolist's exposure to risk (whatever its source) has not been well treated in the literature. However, one or two interesting papers do exist. Take, for example, Dekel & Scotchmers' (1990) investigation of "*Certainty Wars*" in the technological risk case. Although they focused on the rather narrow case of accidental spills in the oil industry their model illustrates all the essential elements of a "*Certainty War*".

Dekel & Scotchmers' argument rests on the fact that oil spills can cause sufficient disruption in the supply of oil to raise its market price[29]. As such the impact of an oil spill is not all bad, since firms can (providing market demand is downward sloping

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29 For example it has been estimated that the Exxon Valdez disaster caused a 10% rise in the global price of oil (Lave & Quigley 1989).

and sufficiently inelastic) then benefit from a significant increase in revenues. Given this possibility it might seem to be in firms' mutual interests to increase their exposure to the risk of oil spills, however, self-interest may prevent this. In effect increased exposure to the risk of oil spills creates a positive externality - where the initiating firm will bear all of the costs (e.g. clean up and liability costs, reputational effects, etc.) but not all of the benefits associated with this strategy[30]. Thus, while a firm that is guilty of spilling oil may gain some benefit from any resultant price increase (see Doherty & Smith 1993), this is unlikely to be sufficient to encourage it to increase its exposure to risk to a level that maximises joint industry profits.

More generally the presence of technological risk could lead to a "*Certainty War*" whenever it is in a duopolist's or indeed oligopolist's individual interests to try to maintain a lower level of risk than its rival(s). Indeed *a-priori*, at least, such an eventuality would seem to be quite plausible. As was shown in Chapter 5 (see section 4.3) not only can increased certainty reduce the adverse consequences of a duopolist's own exposure to technological risk but it can also provide it with a significant competitive advantage over a riskier rival. This could then quite easily mean that duopolists will end up spending too much on risk management and expose themselves to a jointly inefficient (low) level of risk - since if one firm was to unilaterally increase its exposure it would lose market share[31].

Finally it is worth noting that Certainty wars could also arise out of a duopolist's or oligopolist's exposure to other sources of risk. Indeed the foundations have already

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30 For example, a firm that experiences an oil spill is unlikely, in the short run at least, to be able to supply as much oil at the new higher price as its rivals. In fact in their rather simplified model Dekel & Scotchmer assumed that the spilling firm would actually produce nothing at all for a time.

31 For a specific example of this see Appendix 3.

been laid for this possibility by Eldor & Zilcha (1990) who consider the use of futures to control common, industry wide fluctuations in consumer demand[32].

Although focusing on the case of risk averse oligopolists Eldor & Zilcha come up with a similar result to the one described here - that too much certainty can be a bad thing. In their model firms are assumed to be risk averse but can buy futures from an unbiased (i.e. actuarially fair) forward market in order to reduce their exposure to demand risk. However, purchasing futures may not always be jointly beneficial for firms. The exact result relies on two conflicting effects: a beneficial "reduction of risk" effect (in terms of increased psychological well-being) and a potentially costly "output" effect. The adverse consequences of the output effect stems from the fact that in the face of increased certainty about market demand risk averse firms should rationally choose to raise their output (as in Sandmo 1971, Leland 1972, etc.). However, if all risk averse firms in a market individually choose to purchase futures (which is likely since no firm should allow itself to loose market share to its rivals) this could then cause the market price and hence firms' joint profits to fall. In such a situation firms would be jointly better off by not buying futures, yet, as Eldor & Zilcha point out (Risk, Risk) is not a Nash equilibrium since each firm would then do better (through increased market share) by reducing their individual exposure to risk.

2.5 *Co-ordination Equilibria*

A Co-ordination equilibrium will arise if a game yields two (or perhaps even more) symmetric Nash equilibria. For example, from table 1 this could arise when C>B and

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32 See also Allaz (1992) who considers the strategic incentives of a risk neutral oligopolist to purchase futures. However, in Allaz's model it is not increased certainty that enables the firm to increase its future output (since a firm makes its output decisions after market demand has been revealed) but simply the fact that it is able to fix the price of its product.

R>A, leading to two equally plausible Nash equilibrium solutions (Certainty, Certainty) and (Risk, Risk).

In the context of risk management, co-ordination equilibria are perhaps most likely to arise when there is a strong negative (as opposed to positive in the case of risk wars) relationship between the extent of one firm's risk related pure penalties or technological non-linearities and its rival's exposure to risk. Indeed one possible cause - the case of strongly negatively correlated output fluctuations - is discussed in Appendix 3. However, more generally any natural hedge that could be created by the simultaneous exposure of duopolists or oligopolists to risk might well lead to co-ordination equilibria[33].

Another possible cause of risk management co-ordination equilibria is where the cost of risk management depends on the number of firms investing in it[34]. Take, for example, insurance. In general premium costs should decline as sales of a particular insurance product increases (because of administrative economies, improvements in underwriting, competitive pressures etc.), consequently, it may be that the attractiveness of a particular policy will increase as more firms purchase it. In the

33 For example, where an industry is exposed to demand fluctuations it may be that any resultant "stock outs" (i.e. where consumer demand exceeds supply) could lead to consumers permanently switching to an alternative product (e.g. from IBM compatible to Apple-Mackintosh computers). One solution to this problem might be to invest in risk management, however, another might be for firms to exploit negative covariances in their own personal demand fluctuations. If each specific firm experiences negatively correlated demand fluctuations then whichever firms have surplus production could use this to supply the consumers of firms experiencing high demand states. Although the firms experiencing high demand states might then lose potential customers all firms would benefit in the long run since consumers will have been prevented from switching to a rival product (see Balachander & Farquhar 1994, for a variation on this theme).

34 For an example of this phenomenon in the technological risk case see Appendix 3.

current duopoly model this could then lead to a situation where it is just in a firm's interests to purchase insurance if its rival follows suit, since only then will it provide a cost effective means of reducing risk.

Games with multiple Nash equilibria are often characterised by what Crawford & Haller (1990) term "strategic uncertainty" - whereby a firm needs to know exactly how its rival is going to act before it is able to determine its own best (i.e. most profitable) strategy. Take the case where C>B and R>A but C=R and B=A. In this context there are two solutions that are both Pareto superior and Nash equilibria (Risk, Risk) and (Certainty, Certainty), however, it is by no means certain that either one or the other will actually be achieved. The problem is that there is no dominant pure strategy for this game, in fact there isn't even a weakly or iterated dominant pure strategy[35]. Consequently, it is entirely possible that one firm will select Risk and another Certainty, causing them to earn lower payoffs than if they had each selected the same strategy.

One possible way in which firms could play co-ordination games is to adopt a mixed strategy (see Harsanyi & Selten 1988, Crawford & Haller 1990). When playing a mixed strategy a firm randomly alternates between two or more strategies, the frequency with which a given strategy is played depending on some prior determined probability. For example, in the case where C>B and R>A but C=R and B=A firms could, by independently selecting Risk or Certainty with equal probability, achieve a

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35 A weakly dominant equilibrium solution can exist if a particular strategy profile yields payoffs that are never lower and possibly better than some alternative strategy. An iterated dominance equilibrium is the strategy profile that remains when all weakly dominated strategies (i.e. a strategy which is never better but possibly worse than some alternative) have been successively deleted. For a more detailed discussion of these concepts see Rasmusen (1994, Ch. 1).

profitable Nash equilibrium 50% of the time (yielding expected profits of $\frac{1}{2}C+\frac{1}{2}B = \frac{1}{2}R+\frac{1}{2}A$). However, although authors such as Harsanyi & Selten (1988) have argued that a mixed strategy is the only rational[36] way to play a static, symmetric co-ordination game, there are other ways in which players can improve their expected profits. In fact, the interesting thing about co-ordination games is that seemingly irrational behaviour can often yield a more profitable outcome.

One of the first authors to suggest that seemingly irrational behaviour could benefit the players of co-ordination games was Schelling (1960). Schelling observed that in the real world the players of static co-ordination games would generally try to reach a mutually beneficial equilibrium by finding what he termed "focal points". They did this, he argued, by choosing strategies which they believed to be the most obvious or salient for both themselves *and* other players[37].

Salient strategies can arise for a number of different reasons. They may be the result of: psychological or cultural similarities between players, the context in which a game is played (such as the way actions are labelled) or even more tangible considerations

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36 "Rational" behaviour in game theory is defined in virtually the same way as it is in expected utility theory (in fact expected utility theory was largely developed with game theory in mind - see von Neumann & Morgenstern 1944). As such the usual axioms of Ordering, Contextual Independence, Equivalence, etc. (see Gravelle & Rees 1992, Ch. 19) must all apply if a player's decisions are to be deemed fully "rational".

37 Note that Schelling's definition of salience is not the only one that has been identified. Indeed it is entirely possible that a player may not consider what its rivals' are going to do and instead naively select the first strategy that comes to mind at the time (see Mehta et al, 1994). However, the advantage of Schelling's approach is that a player's search for a salient strategy is based on the (economically) rational pursuit of increased payoffs, as such it would seem to most appropriately describe the behaviour of an expected profit maximising firm.

such as Pareto optimality or the symmetry (i.e. fairness) of certain equilibria[38]. Indeed salient strategies could well arise in strategic risk management games. For example, if C>B and R>A but R>C expected profit maximising firms might well feel that the Pareto optimal equilibrium (Risk, Risk) is focal[39]. Moreover, in smaller or manager controlled firms human considerations such as risk aversion might also help them to achieve "*Certainty*" equilibria. However, perhaps the most common source of focal points for risk management games (at least in respect of widely held firms) is likely to be the influence of stakeholders.

Different stakeholders could affect the outcomes of co-ordination games in different ways. In an oligopolistic industry characterised by high levels of debt, for example, agency considerations might well lead to firms' concluding that "*Risk*" equilibria are focal (since they should each realise that it is in their rivals' interests to increase their exposure to risk - see Chapter 2, section 4.4). On the other hand in industries where the potential severity of loss is very high (e.g. Nuclear and Chemical industries) public and or government pressure might well lead to a feeling that Certainty is the more salient strategy. Similarly the influence of employees, suppliers, consumers or even shareholders might also help firms to co-ordinate their behaviour and achieve mutually beneficial equilibria.

Unfortunately, an important limitation of the applicability of Schelling's theory to oligopolistic games is that not all focal points are Pareto optimal. Moreover the existence of a clear focal point is not always guaranteed. Consequently, expected profit maximising firms are likely to want to find some rather more reliable means to

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38 In addition to Schelling (1960) see Sugden (1986) for a good discussion of the factors that may influence a strategy's salience.

39 Note that this could arise in the case of negatively correlated output fluctuations - Appendix 3 for an example of this possibility.

achieve co-ordination. However, given that this will generally require some kind of pre-game behaviour or interaction the possibility is effectively excluded in purely static games. As such a detailed analysis of co-ordination strategies and the possible role of risk management in helping strategically motivated firms to achieve them is left to the next section on more dynamic games.

3. Risk Management as a Dynamic Closed-Loop Game.

The above analysis was couched in an effectively static, one period framework in which the only strategic decision a duopolist needed to make was to choose between Risk and Certainty. Unfortunately, while providing simple, clear results static models limit the range of strategic options that may be open to duopolistic (or indeed oligopolistic) firms. In order to have a more complete picture of the behaviour of such firms under risk this section, therefore, considers the rather more dynamic case of multi-stage, closed-loop risk management games.

The essential feature of a multi-stage, closed-loop game is that its participants do not take the actions of their rivals as given, instead a player is allowed to both observe and predict the strategic decisions of his or her opponents and pro-actively respond to them (see Fudenberg & Tirole 1986, Shapiro 1989a, Slade 1995). This then opens up a huge gamut of interesting new strategic possibilities and equilibria. In the current model self interested firms could, for example, devise strategies that commit themselves to even more severe "*Risk Wars*" and "*Certainty Wars*". However, what is rather more likely is that firms will try to improve on the Pareto efficiency of static equilibria by finding ways to help co-ordinate their actions.

As was shown in section 2 one feature of many static, symmetric games is that strategically interdependent firms can end up experiencing Pareto inefficient equilibria (in the current framework this applies to "*Risk Wars*", "*Certainty Wars*" and co-ordination equilibria). Of course firms might well be expected to want to try and do something about this rather unfortunate situation, however, in a static game this will usually prove impossible. The basic problem is the absence of any means to generate a credible commitment to take mutually beneficial actions[40]. Duopolists may, for example, realise that it is in their joint interests to co-ordinate their risk management actions, yet when it comes to the crunch (i.e. the strategic decision making phase) they will not be able to reliably motivate themselves to behave in such a way. Due to the static, unsophisticated nature of the analysis what each duopolist lacks is a means to irrevocably modify either its own or its rival's behaviour. Without such a commitment there is, therefore, very little that the two duopolists can do in order to ensure that they do not (either deliberately or mistakenly) select a mutually undesirable level of risk[41].

Of course in the real world strategically interdependent firms can and do find ways to co-ordinate their actions[42] - multi-stage closed-loop games provide a way to examine this interaction. The idea is that by incorporating a greater degree of strategic

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40 Credible commitments are strategies that rival firms strongly believe will be carried out (see Schelling 1960, Dixit 1980, Shapiro 1989a).

41 Take for example the case of a "*Risk War*". Although each duopolist might agree that (Risk, Risk) is an undesirable equilibrium they will not be able to credibly commit themselves to doing anything about this. The trouble is that while each firm may be able to raise their joint profits if they agree to invest in Certainty, individually they can do better by cheating on such an agreement (since one requirement of a "*Risk War*" is that B>C) and increasing their exposure to risk. Therefore, in order to deter cheating firms will need to find some way to punish violators. However, since there is no way in which a firm can react to deviant behaviour in an effectively static model (either because competition lasts for only one period or firms are strategically naive) cheating cannot be punished.

42 For example, Porter (1983), Rotemberg & Saloner (1986) and Salop (1986) all report real world examples of co-operative arrangements between strategically motivated firms.

sophistication into game theoretic oligopoly models firms may be able to credibly commit themselves to mutually beneficial equilibria. In fact the literature on oligopoly theory is full of research into the possible ways in which strategically aware firms might attempt to jointly improve their payoffs[43]. The purpose of this section, however, is to explore one particular and potentially highly effective sub-set of these mechanisms commonly known as "Facilitating Devices" (Salop 1986)[44].

The function of a facilitating device is to directly alter the payoffs that each player receives in a game before it is played. As such they can transform situations like "*Risk Wars*" or "*Certainty Wars*" and co-ordination equilibria into games of mutual interest where firms automatically select the Pareto-superior outcome. Many things can be used as facilitating devices[45], however, in the current context the role of certain risk management tools (such as insurance, captive insurance and physical risk control devices like sprinklers) is explored. In particular four main possibilities are proposed:

(i) the use of specific risk management tools as devices for reducing risk,

(ii) the use of specific risk management tools as devices for increasing risk,

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43 See, for example, Shapiro (1989a) and Martin (1993) for two excellent reviews of this literature.

44 In the words of Salop (1986):

"The likelihood of successful co-ordination may be increased by the adoption of industry practices that increase oligopolists' incentives to co-operate and reduce their incentives to compete, despite their divergent interests."

45 See, for example, the work by Salop (1986) on "most favoured nation" and "meeting competition" clauses or Poitevin (1989) on the role of the banking structure of a duopoly.

(iii) the use of specific risk management tools as devices to facilitate communication between firms,

(iv) the use of risk management in general as a device to foster and signal a seemingly subjective dislike for risk amongst the stakeholders of strategically interdependent firms.

Two of these roles - those of reducing risk and facilitating communication - are largely uncontentious, at least in that they accord with the "accepted wisdom" of much current risk management research (e.g. see Chapter 2). However, in what follows it will be argued that these roles only represent a sub-set (although admittedly quite a large one) of possible real world motivations for investment in many risk management tools. The use of certain risk management tools as devices for increasing risk is perhaps the newest and most surprising assertion, yet in the context of "*Certainty Wars*" it will be demonstrated that such behaviour is not only possible but could also prove to be highly profitable for some firms. On the other hand the view that risk management can be used to both foster and signal a subjective dislike for risk could be seen as a highly traditional and out of date one (see Chapter 2, section 2.2). Indeed most of the recent literature on risk management (including in part this thesis) has been dedicated at discrediting it. Yet, when faced with certain co-ordination equilibria it will be shown that seemingly irrational and apparently risk averse behaviour can sometimes help a firm to directly increase its profits.

What follows is a discussion of the role of a number of specific risk management tools in helping to facilitate the prevention of "*Risk Wars*", "*Certainty Wars*" and certain Pareto inefficient co-ordination equilibria. Note that this section marks a further important departure from Chapter 5 by relaxing the assumption that all risk control and risk financing tools perform effectively the same function - to directly reduce a firm's exposure to the physical consequences of risk (whether this be demand, cost or output related). Instead it will be argued that in a strategic framework risk management tools may well be used for quite different reasons and applications. Some of the tools discussed below and their associated terms may be unfamiliar to the reader, therefore, a brief description of these concepts is provided in Appendix 4.

3.1 *Using Risk Management to Control "Risk Wars"*

In section 2.3 it was explained how a pair of duopolists competing in a static, open loop risk management game might achieve a Nash equilibrium (Risk, Risk) that is Pareto inferior to that which would arise if they had jointly opted for Certainty. The reasoning behind this outcome was based on the standard game theoretic problem of the prisoner's dilemma, in which self and mutual interest are in conflict. What firms need, therefore, is a way to reconcile this predicament, the purpose of this section is to explore how investment in certain risk management tools might help to facilitate this.

If a risk management tool is going to be of any use in preventing "*Risk Wars*" it will need to fulfil two requirements, firstly any expenditure on the tool must be irrevocable (i.e. once purchased it cannot be re-sold) and secondly it must eliminate a duopolist's personal incentive to choose Risk over Certainty. Remembering that from table 1 a "*Risk War*" occurs where B>C>R>A this can be achieved by reducing both B and R, the possible payoffs that a duopolist receives when it chooses Risk. A "*Risk War*" will, therefore, be prevented where pre-game expenditure on a particular risk management tool reduces B and R sufficiently to create a game of "*Certainty*" (where C>B and A>R)[46].

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[46] Note that a "*Risk War*" could be prevented by simply reducing the off-diagonal Risk payoff B (Salop 1986). However, while reducing B should prevent firms from choosing Risk there is no guarantee that this will actually occur. The problem is that simply reducing B (so that C>B>R>A) will effectively create a co-ordination game with two Nash equilibria (Risk, Risk) and (Certainty, Certainty). Then although (Certainty, Certainty) is the Pareto dominant equilibrium it is by no means certain that firms will actually select it (see section 2.5).

Not all risk management tools will meet the two criteria that are necessary for them to be able to help prevent a "*Risk War*". Moreover, depending on the parameters of the model even apparently good tools may become less effective. However, due to the rather large number of risk management tools that are currently available the subsequent discussion is necessarily restricted to a number of specific examples - although it is hoped that these examples will provide a good illustration as to how other tools might be used in practice.

3.1.1 Physical Risk Control.

One way to help prevent a "*Risk War*" might be for firms to jointly agree to invest in risk control devices (whether they be loss reduction or loss prevention tools - see Appendix 4) before they make their risk and input decisions in the competitive phase of the game. The rationale behind this strategy is that a firm which has already invested in risk control tools is going to be more likely to use them. One of the advantages of increased exposure to risk is that a firm can save on its risk management expenses, however, if the firm has already purchased risk control tools any decision to increase risk will necessitate the waste of already purchased resources (unless of course it can find a ready second hand market). Hence the benefits associated with increased exposure to risk are reduced, thereby, lowering the firm's incentive to deviate from the jointly profitable (Certainty, Certainty) equilibrium.

Unfortunately, however, a major problem with using risk control tools as a facilitating device is likely to be monitoring. Firms may agree in stage one of the game to purchase a set amount of risk control devices, but, given the advantages associated with unilateral increases in risk, an individual firm can never be sure that its rival(s) will do so. What a firm will need to do, therefore, is inspect its rivals' risk control purchases, investigating both the quantity and quality of their expenditure. However, such an inspection is unlikely to be easy. Accurate assessments of risk are expensive, moreover, the effectiveness of many risk control tools can often only be assessed ex-post (see Chapter 2, section 3.1). Thus it may not be until after the risk management game in table 1 is played that firms will realise that one (or more) of them has cheated - but by then it will be too late[47].

3.1.2 External Insurance

One potentially more effective risk management based facilitating practice is insurance. Insurance companies tend to have a comparative advantage in both monitoring and preventing risk seeking behaviour within firms (see Chapter 2, section 3.3). Thus any firm that purchases insurance and then decides to increase its exposure to risk should be quickly detected. Moreover, insurers have the ability to penalise firms which increase their exposure to risk by charging higher premiums[48] or cancelling cover without refunding the original premium.

The risk monitoring and prevention abilities of insurance companies are also often enhanced by the fact that they tend to have the law on their side. When purchasing insurance a firm is governed by all the same legal principles as individuals including those of "Utmost Good Faith" and "Warranty". Consequently, if a firm fails to provide accurate information about its planned exposure to risk or comply with contractual requirements (such as the installation of risk control devices/procedures) it may well have its claims refused or even face criminal proceedings[49].

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47 It is also worth noting that anti-trust authorities may become highly suspicious if oligopolistic firms are regularly visiting each other's factories.

48 Although in the case of experience rated policies (i.e. where the premium is determined by the *past* loss experience of the purchasing firm) such increases may arise too late.

49 See Birds (1993) for a good discussion of UK insurance law.

Despite the potential effectiveness of insurance as a means to prevent "*Risk Wars*" there are still some problems associated with its use. Perhaps the most obvious one is moral hazard (see Shavell 1979, Rees 1989). If an insurance company is unable to properly monitor the actions of a firm then insurance will not provide an effective deterrent against risk increasing activities[50]. In fact, in such circumstances the purchase of insurance could even increase the likelihood or severity of a "*Risk War*" - providing it serves to reduce the costs associated with increased exposure to technological risk.

Secondly, although it should be easier to determine the extent and quality of a firm's insurance cover than for the case of risk control devices, perfect monitoring is still not guaranteed. Seeking to gain the upper hand firms might then start purchasing substandard or insufficient insurance cover or even try to cancel it just prior to deciding on its exposure to risk. Whichever way firms' behave the strategic benefits of insurance are then likely to become seriously attenuated, a fact which could possibly lead to the re-commencement of a costly "*Risk War*".

Fortunately there are ways round these problems. One potential solution is for firms to use the same insurance company or broker. Since a common insurance company or broker would be responsible for all the firms in an industry it is likely to have both an increased incentive and ability (via its specialist knowledge of the industry) to control firms' moral hazard incentives[51]. Moreover, common insurers or brokers could even be used as an information transmission device, monitoring insurance purchases and

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50 This is especially likely for new or low frequency hazards that insurance companies do not have much information about (see Doherty & Smith 1993).

51 See Pointevin (1989) for a similar discussion on the use of common lenders to prevent a Brander & Lewis (1986) type risk war.

notifying a firm of reductions in its rival(s) chosen level of cover or of outright cancellations.

Finally it is interesting to note that duopolistic and oligopolistic firms could also exploit the fact that many insurance contracts are compulsory. Governments, creditors and suppliers all typically stipulate minimum insurance requirements for certain risks and could punish firms that refuse or are unable to purchase sufficient cover (because of their exposure to high levels of risk, for example) through the imposition of fines, refusal of firm specific inputs and greater interest charges or input prices (see Mayers & Smith 1982). However, compulsory insurance requirements do not cover all risks, and even when they are in place the penalties associated with non-compliance can often be small or imperfectly enforced[52].

3.1.3 Risk Sharing Arrangements/Joint Captives

One final interesting alternative worth noting is the use of a joint captive. The mechanisms by which a joint captive should help to prevent a "*Risk War*" are very similar to that of traditional insurance. However, joint captives are likely to have a number of further advantages. For example, where each firm in an industry is an owner of the joint captive they should be better able to monitor the quantity and quality of their rivals' insurance cover (since they will be directly involved in the procedure). Moreover, in industries characterised by unique or uncommon risks the specialist risk assessment expertise of firms may well exceed that of insurance companies, thereby, providing them with a superior ability to prevent moral hazard (e.g. see Doherty & Smith 1993).

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52 For example, few regulators, creditors and suppliers are likely to check the true extent of a firm's insurance cover until after a loss has occurred.

3.2 *Using Risk Management to Control "Certainty Wars"*

That risk financing tools such as insurance or joint captives could be used to help prevent a "*Risk War*" may seem unsurprising. As stated in Chapter 2 one important function assigned to numerous risk financing tools is the monitoring and control of a firm's exposure to risk, consequently the argument that they should help to prevent Pareto inefficient increases in risk is neither a particularly new or contentious one. Yet, in what follows it is argued that in the strategic context certain risk financing tools may also paradoxically be used to help prevent "*Certainty Wars*". The rationale behind this is actually very similar to the "*Risk War*" case - with firms making irrevocable investments in specific risk financing tools in order to influence their payoffs in the ensuing two-by-two risk management game. However, instead of using these tools to commit themselves to Certainty firms actually design them to do the opposite.

The main mechanism that firms could exploit to prevent "*Certainty Wars*" is moral hazard. Moral hazard is traditionally seen as a potential cost of both traditional insurance and joint risk sharing contracts (e.g. Shavell 1979, Rees 1989), however, when dealing with strategically motivated firms this need not be so. Moral hazard in insurance or risk sharing contracts is caused by the fact that the individual or firm that is purchasing such a contract (the insured) no longer has to bear the full financial consequences of their exposure to risk. As such the insured will tend to become much less concerned about reducing the adverse consequences of risk since this cost is now shared. In a "*Certainty War*" this should then have the beneficial effect of reducing a firm's incentive to select Certainty by restructuring its payoffs to create a more profitable "*Risk*" equilibrium (where R>A and B>C).

Any risk management tool that can be used to generate a moral hazard incentive might be able to prevent Pareto inefficient reductions in risk, however, as in the case of "*Risk Wars*" certain tools are likely to be more effective that others. To illustrate this idea the impact of two quite different tools are investigated: risk sharing arrangements and traditional insurance contracts.

3.2.1 Risk Sharing Arrangements

Interestingly some consideration of the strategic use of risk sharing agreements to profitably increase firms' joint profits already exists in the literature. In a rare synthesis of risk management and economics Dekel & Scotchmer (1990)[53] examine the incentives of oil companies to use joint risk sharing arrangements in order to increase their exposure to the risk of potentially profitable oil spills. In ensuring that firms no longer bear the full impact of their losses, risk sharing creates an incentive for firms to engage in moral hazard and reduce their expenditure on spill prevention. Spills disrupt the supply of oil and raise its price, so while each firm must bear a proportion of any clean up costs Dekel & Scotchmer argue that this should be more than offset by the associated increase in revenues - providing demand is sufficiently inelastic.

Although not explicitly framing their discussion in the context of "*Certainty Wars*" Dekel & Scotchmers' reasoning is consistent with that adopted here. They recognise, for example, that without a risk sharing agreement there would be too few spills, leading to a low oil price and Pareto inferior profits. Moreover they argue that when a firm joins a risk sharing agreement it will rationally increase its exposure to risk, since failure to do so (despite their individual incentive to cheat and maintain a low level of risk) would penalise the firm - in terms of its failure to exploit the moral hazard incentive. Indeed, Dekel & Scotchmer actually suggest that given equal risk sharing a firm's incentive to cheat should be eliminated.

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53 See also Balachander & Farquhar (1994) for a similar analysis in the case of price setting firms.

However, involvement in a risk sharing arrangement is no guarantee that a firm will not find some way to personally exploit the situation to the detriment of others. One major problem is likely to be contractual enforcement. As Coats & Ravallion (1993) point out the members of a risk sharing pool who have not experienced a loss should rationally seek to renege on their agreement in order to avoid sharing their good fortune with others. In the current context this could seriously attenuate the effectiveness of risk sharing agreements at preventing "*Certainty Wars*" - with member firms attempting to secretly reduce their own exposure to risk and then reaping the benefits but refusing to share in the losses of others. Of course the use of formal, legally binding, contracts might reduce the likelihood of such opportunism, however, even this is unlikely to be completely effective. It is frequently impossible or at best prohibitively expensive, for example, to either completely specify or legally enforce every desired future action in a contract. This can then allow its participants to exploit loop holes and still renege on the agreement (see Williamson 1985, Hart & Holmstrom 1987).

One way round the problem of contractual enforcement might be to create a risk sharing arrangement in which firms pre-commit a set level of funds to a neutral party. Indeed risk sharing arrangements such as the P&I clubs or joint captives (for example Oil Insurance Ltd in the oil industry or Energy Insurance Mutual for electric power stations) could be used for this reason. In effect this is akin to posting a hostage (e.g. see Schelling 1960, Williamson 1985, Raub & Keren 1993), whereby, a firm which reneges on its commitment to increase risk will then have to write off any premium payments that have already been made to the risk sharing pool. Thus rather than having to use rather more uncertain and expensive legal routes (such as litigation) to ensure compliance, opportunism can be instantly and costlessly punished. As such a firm should now (providing the level of pre-committed funds is large enough) have much less of an incentive to renege on the risk sharing contract.

However, the are problems with the pre-commitment of funds. Pre-commitment will require losses to be estimated ex-ante, something that may prove difficult especially given that a firm's exposure to risk should change after it has joined the agreement. Furthermore, even if the expected level of losses could be correctly predicted it is still possible that in bad years claims will exceed the financial capacity of a fund. Consequently in the face of very large or frequent losses the risk sharing pool may run dry, preventing full insurance for all losses and thus reducing a firm's incentive to engage in moral hazard. Extra cash could be demanded either ex-ante or ex-post, however, the former may lead to costly over payments (in terms of the opportunity cost of forgone alternative investments), while with the latter the original problem of reneging could be repeated.

3.2.1 External insurance.

The use of an external insurer could confer a number of advantages over joint risk sharing agreements. As already stated in the case of "*Risk Wars*" external insurers generally possess a comparative advantage (in terms of superior actuarial skills, lower information gathering and processing costs etc.) in assessing risks ex-ante. Moreover, their reserve capacity should be such that except in the most extreme cases they will have the necessary funds to compensate a firm for its losses. However, despite these advantages there are a number of problems which do rather question the strategic usefulness of external insurers in this context.

The big issue is whether an external insurer will be prepared to tolerate the presence of a high degree of moral hazard. An external insurer will simply face the costs associated with firms' moral hazard, consequently unless they can find some way to compensate it - say by offering retroactive premium payments, or by even making it a residual claimant - an insurer may actually require them to reduce their exposure to risk rather than increase it. Similarly other insurability issues could represent a problem. Factors such as adverse selection, whether a loss is measurable in monetary terms, the availability of reliable historical information or the uniqueness of an insured event may all influence whether an insurer is prepared to offer cover or not (see Schmit 1986). Admittedly these insurability issues could also hinder to operation of risk sharing pools, however, given that they are generally owned by their policy holders these issues should be less significant (see Bawcutt 1991, Ch. 1)[54].

3.3 *Using Risk Management to Help Co-ordinate Firms' Actions*

As stated in section 2.5 the basic problem with static risk management co-ordination games is that they are often characterised by a considerable degree of "strategic uncertainty" (Crawford & Haller 1990). Consequently, what firms are likely to want to try to do is find some way to resolve this uncertainty. In what follows two different possibilities are investigated. The first deals with the role of specific risk management tools as a means for facilitating communication between firms, while the second suggests that in some cases risk management could be used to help a firm establish a number of risk related strategic conventions.

3.3.1 Using Risk Management to Aid Communication in Co-ordination Games.

Engaging in pre-play communication is likely to be one of the best ways to ensure a Pareto optimal solution to a risk management co-ordination game. Effective communication will ensure that each firm can decide on its exposure to risk with full knowledge of how its rival is going to act. However, what firms will need to do is devise a mechanism to facilitate the exchange of information between them and it is here that certain risk management tools could be of use. Indeed a natural candidate for the role of communicator might well be a joint captive or insurer, or an insurance broker or risk management consultant that deals with several clients in the same

54 For example, Protection & Indemnity clubs have even been known to provide cover against fines incurred for intentionally criminal acts (Faure & Heine 1991).

industry[55]. What these devices could then do is collect data from all firms and help to co-ordinate their actions by establishing an industry norm for risk management practice and expenditure[56].

In addition to providing a medium for information exchange joint captives, brokers and consultants might also be able to improve the effectiveness of pre-play communication by acting as a form of translator. One particular problem with communication is that firms will need to establish a common language (Crawford & Haller 1990, Farrell 1993, 1995). For example, it may be that each firm has a different way of describing its exposure to risk[57]. Consequently if one firm was to say that it is going to reduce its exposure to risk by *x* units, its rival - who could define risk units somewhat differently - might take this to mean something completely different. By using a common insurer/captive, broker or consultant, however, the probability of this kind of misunderstanding could be reduced. Then when the actual co-ordination game is played there should be little danger that a rival firm will invest in either too little to too much risk management, resulting in an increase in expected payoffs for all firms.

Communication is also likely to very difficult where firms have an incentive to lie about their future behaviour (e.g. see Ziv 1993). Take, for example, the case where A>B>C≥R (or indeed B>A>C≥R). In this case the best possible outcome is to be the only player to choose Certainty. However if both firms choose Certainty they will

55 Given that communication will improve the payoffs of a co-ordination game firms should even be prepared to pay a premium for these services.

56 For a good general discussion of the role of joint communication devices in co-ordination games see Farrell & Saloner (1988).

57 Admittedly this is not a problem in the current model where firms can only choose between either full exposure to Risk or Certainty, however, it could occur in a model where the level of risk is continuous.

each be worse off than if one of them had instead chosen Risk. The problem now is to find some way for firms' to credibly communicate their behaviour since each of them will attempt to intimidate their rival by falsely claiming that what ever happens they are going to be the one to select Certainty[58]. When faced with such a communications deadlock[59] common insurers/captives, insurance brokers or risk management consultants could act as a mediator (Schelling 1960). The role of this mediator would be to assign an action to each firm. Then once assigned with an action no firm should have an incentive to deviate from it since doing so would make it worse off (see Schelling 1960, Sugden 1986, 1989)[60].

3.3.2 Using Risk Management to Help Establish Conventions.

Although often arising out of a particular focal point conventions provide a much stronger basis for co-ordination. A convention is a universally known and accepted way of playing a game (see Sugden 1986, 1989). Therefore, where it is convention that a duopolist or oligopolist should play a particular strategy its rival(s) will assume that this is the only strategy that will be played and act accordingly[61]. This should then have quite a stabilising effect on the outcome of a risk management co-ordination game since each duopolist will have a very definite idea as to how its rival is going to act.

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58 In game theoretic parlance this is known as the game of "Chicken". For more on this game see Sugden (1989) and Rasmusen (1994, Ch 3).

59 In many respects the repeated breakdown of the Northern Ireland peace talks are a result of the fact that the battle between Republicans and Unionists is a game of "Chicken".

60 For example, if a firm was told that its rival was going to select Certainty and that it should select Risk it would not rationally then decide to select Certainty since B > C.

61 For example, the convention in the UK that cars should pass each other on the left helps to co-ordinate the actions of motorists and avoid accidents.

It is usually assumed that conventions arise haphazardly rather than being deliberately chosen by the players of a game (e.g. Sugden 1986, 1989, Weibull 1995)[62]. In fact conventions are typically modelled as being the result of evolution, arising through an often lengthy process of quasi-biological natural selection in which less "successful" strategies are eliminated until only one remains[63]. This supposition does not, however, sit well with the current focus on closed-loop games in which firms are gifted with very superior powers of deductive reasoning. One problem is the time it can take for the players in an evolutionary model to establish a convention that ensures a stable equilibrium. Moreover even when a convention is established there is no guarantee that the ensuing equilibrium will be Pareto optimal. Instead as Sugden (1989) points out evolutionary success is more likely to be determined by analogy[64] and the ability of one particular strategy to do well against other competing strategies rather than concepts like Pareto efficiency.

Given the vagaries of natural selection it is, therefore, hard to believe that intelligent, expected profit maximising firms will allow themselves to succumb to the whims of evolution[65]. Instead it is argued that in the current context of closed-loop risk management games firms are far more likely to try to modify the process (just as a

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62 Consider, for example, the fact that cars in the UK drive on the left while those in France drive on the right. Random chance seems to have determined which side of the road cars are expected to pass each other.

63 See Sugden (1989) for an excellent discussion of this process.

64 The concept of analogy is very similar to Schelling's notion of salience. It refers to popular and widely agreed upon notions such as "first come first served" or "last in first out".

65 In defence of Sugden (1986, 1989) it should be noted that he focused on the behaviour of individuals who typically will possess (due to bounded rationality and lack of information) inferior reasoning abilities to large firms.

scientist might do working in the field of Genetics) in order to ensure that a universal convention is not only established quickly but that it is also Pareto efficient. Admittedly this assumption is at odds with the likes of Sugden (1989) who argues quite forcefully that "...conventions are not chosen; they arise by chance", however it does have a precedent in the game theoretic literature in the form of some recent work by Mark Casson (1991).

In his book, *The Economics of Business Culture*, Casson (1991) argues that the payoffs of many different types of game, including those of co-ordination, can often be manipulated by some form of leader. Leaders can either be distinct - such as a dominant firm, politician, or regulator - or a personification of the combined influence of a dispersed peer or stakeholder group. The purpose of this leader is then to consciously influence the payoffs received by players in order to create games of "Harmony" where they each automatically select the best (i.e. Pareto optimal) course of action.

Although Casson largely focused on the manipulation of human attitudes and emotions (and in particular our moral sensibilities) his work can be used to help explain the strategic risk management behaviour of even an expected profit maximising firm. In fact one of the key insights of Casson's and indeed much of the convention literature is that seemingly irrational or emotional behaviour can sometimes help to facilitate mutually beneficial equilibria in co-ordination games[66]. Admittedly the idea that "emotional" behaviour can be used to generate profitable equilibria is at odds with many of the traditional axioms of both game theory and economics (see Sugden 1986, 1989). However, the paradox is that where players face

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66 The basis for this insight is the same as in the original focal point literature - see section 2.5 above.

multiple Nash equilibria human emotions can enable them to achieve more profitable outcomes than if they were operating under the traditional axioms of game theory. As such it is hard to believe that intelligent, expected profit maximising firms will not choose to exploit potentially profitable conventions, even when they are based on subjective human concerns.

What follows is a discussion of how the risk management functions of duopolists or oligopolists might be used to establish profitable conventions for risk management games. Note that in this case it is not always specific risk management tools that are used to ensure a profitable equilibrium. Instead the suggestion is that firms may also use their entire risk management functions as a means to alter the behaviour of key decision making personnel (i.e. company directors and other senior employees).

3.3.2.1 Using risk management to help establish a convention of risk aversion.

As demonstrated in Chapter 2 (section 2) much of the early research into risk management was built around the premise of corporate risk aversion. In fact some authors (e.g. Mehr & Hedges 1974, Greene & Serbein 1983) even went as far as to suggest that risk management should help to promote risk aversion. This was on the grounds that unprofitable reductions in risk might be required in order to ensure that firms engaged in socially responsible behaviour[67]. More recently this view has been extensively criticised (see Chapters 2 and 4), with many academics voicing strong objections to both the theoretical and practical implications of using risk aversion to justify corporate risk management. Yet, in the strategic context the case against risk aversion becomes less clear cut, instead it can actually be argued that fostering a

67 Greene & Serbein (1983, p. 4) sum this idea up quite well:

> "In the top level management of the firm, there is often a conflict between optimisation of return on capital and the increasing demand that waste of human, natural, and financial resources cause. Risk managers can help in the resolution of the conflict through their activities in risk and cost control.".

subjective dislike for risk amongst stakeholders and in particular a firm's senior executives or managers may actually prove to be desirable.

In order to see the value of risk aversion imagine a two-by-two risk management co-ordination game in which C>R>B>A[68]. In such a game the strategy (Certainty, Certainty) is clearly Pareto superior, however, it is by no means assured that the two firms will be able to achieve such a desirable equilibrium. The basic problem is trust. Although the potential payoff from Certainty is highest if both firms choose it (C), this will need to be traded off against the risk of receiving the lowest possible payoff (A) if a firm's rival does not. Thus a firm may well prefer to select Risk unless it can be sure (or at least almost sure) that its rival will definitely choose Certainty.

By establishing a convention which guarantees that firms will choose Certainty the problem of trust in a co-ordination game such as C>R>B>A should be eliminated. One such convention is that of risk aversion. In effect what strategically interdependent firms could do is establish a Casson type leader to ensure a (Certainty, Certainty) equilibrium. This leader could be simply made up of key individuals responsible for each firm's individual risk management function[69], however, in order to establish a strong and unambiguous convention (see section 3.3.1 above) it is likely that firms would use in conjunction with this a common trade association, mutual broker or consultant, or even a professional risk management association such as the Institute or Risk Management in the UK. The purpose of this leader would be to ensure that the key stakeholders of each firm (such as senior managers) maintain the industry norm level of risk management. Individuals/groups that deviated from this

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68 This is commonly known as the "stag hunt" game - for more information on this game and its applications see O'Neill (1994) and Crawford (1995).

69 For example these key individuals might include a formal risk manager, company secretary or finance officer (see Chapter 3, section 3.2).

norm might then be punished either tangibly (via pay awards, or pecuniary benefits etc.) or even intangibly through the instigation of group feelings of guilt or remorse.

Thus, although in many contexts risk aversion is not likely to influence corporate risk management decisions, its significance to some strategically motivated firms should not be underestimated. Indeed in co-ordination games where (Certainty, Certainty) is the Pareto dominant equilibrium stakeholder risk aversion may be both a cause and effect of investment in corporate risk management. However, it is important to remember that in no way are such feelings of risk aversion either irrational or unprofitable, instead they are part of a fully considered attempt to maximise joint profits.

3.3.2.2 The relationship between risk perception heuristics and risk management co-ordination games.

An increasing amount of contemporary research into risk management is exploring the idea that individuals and firms may sometimes behave as seemingly irrational entities that use heuristics, or less technically "rules of thumb", to make their decisions (see Chapter 4, section 3.1). In the course of this research the influence of many different heuristics have been explored, however, what remains to be explained is their root cause (Pidgeon et al 1992). Admittedly some attempts are now being made to try to explain heuristics using what is commonly termed "cultural theory" (e.g. Douglas & Wildavsky 1982, Dake & Wildavsky 1990, Yardley et al 1997), yet, despite some work in the corporate context (such as Perrow 1984, Pidgeon 1991, Turner 1978, 1994, Clarke 1992) little has been done to relate the development of heuristics to the strategic behaviour of firms. The purpose of this section is, therefore, to provide some possible explanations for the exploitation of heuristics by a strategically motivated profit maximising firm.

To many the idea that a "rational" profit maximising firm could attempt to exploit certain heuristics might seem rather paradoxical. Cultural theory, the currently predominant explanation for the presence of heuristics, is based on the tenets of sociology and anthropology (Pidgeon et al 1992). As such its proponents argue that it is the subjective and often irrational beliefs of social groups that will most influence the heuristics used in both individual and corporate decisions. However, as has already been demonstrated in this Chapter, apparently subjective attitudes and beliefs and the rational desire for profit can exist in tandem. In this thesis, therefore, it is argued that in the case of closed loop co-ordination games rational, profit maximising firms might, through their risk management functions or some joint leader (such as a joint captive or trade association etc., see section 3.3.2.1 above), deliberately encourage the use of decision heuristics by their employees - providing these heuristics help to ensure Pareto efficient equilibria[70].

Imagine, for example, a simple two-by two co-ordination game in which C>B and R>A but C=R and B=A (see section 2.5). In this game there are two equally profitable strategies (Certainty, Certainty) and (Risk, Risk), however, the problem is that each time the game is played a firm will be unable to predict whether its rival will choose either Risk or Certainty. What each firm needs, therefore, is to establish some mechanism that can help it to predict its rival's actions and achieve co-ordination. The exploitation of a commonly known and accepted heuristic such as the phenomenon of "Anchoring" (Tversky & Kahneman 1974, Shiller 1997) could provide just such a solution[71]. Anchoring denotes the tendency for decision makers to use past actions or

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70 It is also interesting to note that in a recent empirical study of the relevance of cultural theory in explaining the use of heuristics an explicit causal link could not be found (Sjonberg 1997).

71 For example, the "sticky prices" phenomena talked about in the industrial- and macro-economics literature's (e.g. Means 1935, Weiss 1977, Schramm & Sherman 1977, Rotemberg

information as a suggestion for future outcomes. Consequently what firms (or rather their risk management leader) could do is use the Anchoring Heuristic to establish a convention amongst their key stakeholders that once a given action yields either of the two Pareto efficient equilibria - (Certainty, Certainty) or (Risk, Risk) - it should be consistently repeated[72]. Obviously such a convention does not guarantee co-ordination the very first time a game is played, however, if the game is repeated co-ordination should (since firms have a 50% chance of achieving co-ordination in each game) in all probability be ensured for each subsequent repetition (Crawford & Haller 1990)[73].

Other heuristics could also be used to help provide Pareto efficient solutions to certain co-ordination games. Take the phenomena observed in some markets known as the "Disjunction Effect" (see Tversky & Shafir 1992, Shiller 1997). This effect denotes the tendency of decision makers to wait to make decisions until further information is revealed, even though this information may not be technically relevant to the decision in question and even if they might have made the same decision without it. Although it may seem quite irrational to wait for seemingly unnecessary information, in the strategic context the benefits of doing so have already been explored (e.g. Cass & Shell 1983, Maskin & Tirole 1987). In the current context, for example, irrelevant information might be of value where it is assigned a common meaning since it could then be used as kind of random signalling device to indicate the exact risk control

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& Saloner 1986 see also Martin 1993, Ch. 15 for a good review) might well be the result of a rational co-ordination strategy adopted by strategically interdependent firms.

72 See Crawford & Haller (1990) for a variant of this game.

73 A similar concept is the phenomenon of "magical thinking" (Skinner 1948). This concept denotes the tendency of decision makers to repeat past actions where they are believed (rightly or wrongly) to lead to beneficial outcomes.

action that a firm should take (Sugden 1986, 1989). Imagine a game of "chicken" (where A>B>C≥R). Here the emergence of say a sun spot on one particular day (i.e. a Tuesday) might be taken the mean that firm 1 should defer and choose Risk, while firm 2 chooses Certainty. Moreover, note that although firm 2 has no way to punish deviant behaviour this arrangement should be self enforcing. The argument goes that since firm 1 will realise that when sun spots appear on a Tuesday its rival will automatically choose Certainty it knows that its best possible response will be to always choose Risk (Schelling 1960, Sugden 1986, 1989).

Finally the need to achieve co-ordination could explain the presence of fads and trends in corporate risk management decisions. Fads and trends are typically assumed to arise because decision makers lack the time and or ability to make fully informed decisions (see, for example, Shiller 1997). The idea is where decision makers cannot make fully informed decisions they will typically try to find meaningful ways in which they can restrict the data set that they actually use[74]. Fads and Trends provide just such a mechanism, since by being both familiar and popular they help to bring certain issues or outcomes to the fore-front of a decision maker's mind[75].

Usually fads and trends are seen as being quite irrational (e.g. Shiller 1987), however, it may be that where decision makers face co-ordination equilibria they could be used as the basis for profitable conventions. Take, for example, the current wave of interest in captive insurance companies. In recent years the number of captive insurance

74 Note that in the psychological literature this phenomenon is typically known as "selective attention" (James 1950), however, in the economics literature it is more commonly called "bounded rationality" (Simon 1957, Williamson 1975).

75 For empirical evidence of this phenomenon see Shiller (1984, 1987), see also the seminal work of Tversky & Kahneman (1973) into their so called "Availability Heuristic".

companies has been on the increase[76], despite the fact that many of the traditional benefits associated with captive use (tax breaks, reduced risk financing costs, etc.) are in decline. Indeed one well renowned captive insurance consultant Paul Bawcutt has recently indicated that in his opinion many of these newly formed captives should actually be shut down (Unsworth 1996, Howard 1996). However, it may be that this seemingly irrational fad for captives is in part a reflection of certain firms' attempts to solve risk management co-ordination games. A firm which sets up a captive is effectively deciding to increase its exposure to risk (unless it then decides to reinsure this risk)[77]. Thus, where a firm expects its rival to set up a captive and (Risk, Risk) is a Nash equilibrium rationally it should do the same.

4. Conclusions

Current research into risk and risk management is incomplete in that it does not effectively consider the strategic implications of a firm's decisions. This is unfortunate since the behaviour of duopolists and oligopolists under risk is likely to be considerably different to that of perfectly competitive firms (which seem to be the focus of much current risk management research) or even monopolists. Hopefully this chapter has to begun to redress this imbalance.

One important difference about duopolists and oligopolists is that their risk management decisions are not made in a vacuum but are instead often influenced by the actions of their rivals. This strategic interdependence can then yield some rather surprising results. It is possible, for example, that self interested firms will engage in

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76 In a recent survey Alexander & Alexander (1995) report that over 40% of the firms in their sample had formed a captive since 1990.

77 For more on the function of a captive see Appendix 4.

"*Risk Wars*" where they each choose to adopt a high risk strategy even though a low risk one would yield a Pareto improvement in terms of higher joint payoffs. On the other hand "*Certainty Wars*" are also a possibility, in which expected profit maximising firms spend too much on risk management in a vain attempt to gain a competitive advantage over their rival(s).

Secondly it would appear that in more dynamic closed-loop games firms may not only use risk management to reduce their joint exposure to risk but also to increase it. In particular it was argued that by exploiting the moral hazard incentives created by tools such as insurance or risk sharing arrangements risk management may have a role to play in helping to facilitate the prevention of "*Certainty Wars*". Similarly in co-ordination games it is even possible that firms will use insurance brokers or risk management consultants to help them mutually increase (rather than just reduce) their exposure to risk.

Yet, despite the fact that some of these propositions are rather unorthodox it is worth noting that a firm's use of risk management has not really changed in any great way. The modern finance approach is largely based on the assumption that the role of risk management is to help overcome market imperfections and align the often conflicting objectives of a firm's stakeholders. In this respect the role of risk management in the strategic context is not much different, however, rather than focus on all the conventional issues this chapter has introduced a new stakeholder group - the firm's competitors.

Chapter 7:
Conclusion

1. A New Paradigm for Risk Management?

Perhaps the most interesting thing about academic research into risk management is the comparative immaturity of the discipline. Unlike areas such as economics or modern finance theory risk management has few seminal and widely accepted ideas to draw upon[1], in fact risk management research could almost be said to be in a state of flux with more ideas than authors[2]. In part, this multitude of theories mirrors the complexity and diversity of real world decisions under risk, however, this rather ad hoc approach to research has done little to constructively further our understanding of the area. What risk management academics need to do now is find order in the chaos and provide a strong foundation on which future research can grow.

Admittedly some degree of cohesion has already been achieved by using the ideas of more established disciplines to provide a framework from which to understand the risk management decisions of firms (for example, modern finance theory, psychology, sociology and organisational behaviour). Indeed concepts such as the currently predominant modern finance approach reviewed in Chapter 2 have provided a useful guide, helping to direct risk management research into a number of interesting areas. However, these frameworks can prove to be rather restrictive, diverting attention from other valuable and equally plausible lines of thought. Moreover, at least in the case of the modern finance approach, the current lack of conclusive empirical proof for its associated hypotheses would also seem to suggest that it does not represent a panacea

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1 For example, much modern economic research is still based on the ideas of pioneers such as Adam Smith (1937) and Cournot (1838).

2 Hood et al (1992) call this the "Risk Archipelago" (see also Hood & Jones 1996, p3-6).

(see Chapter 3)[3]. The primary purpose of this thesis has, therefore, been to try and develop a new broader framework for risk management that cannot only embrace the widest possible assortment of views but also provide some definite predictions. The basis for this framework: neo-classical economics.

The role of economic theory in risk management research has had a rather chequered past. Many of the past and indeed current economic models of risk management decision making that have been proposed rely extensively on the predictions of expected utility theory. However, as shown in Chapter 4 (sections 2 and 3.1) the relevance of expected utility theory to corporate decision making has been widely criticised on both theoretical and empirical grounds. As such any attempt to explain corporate risk management that depends on the predictions of expected utility theory must at best be considered rather suspect and at worst futile.

Yet, despite the problems with expected utility theory there are other rather more plausible economic based explanations for corporate risk management. In particular this thesis has focused on two groups of economic consequences that can arise in a world of risk, those of "pure penalties" and "technological non-linearities". As has been demonstrated risk management research based around these twin concepts should benefit from a number of advantages. For example, not only are the definitions of a "pure penalty" or "technological non-linearity" sufficiently broad to encompass many of the ideas generated by the modern finance approach (such as bankruptcy costs and convex tax functions - see Chapter 4 sections 3.2 and 3.3), they can also be used to produce numerous additional scenarios in which a firm may wish to control its exposure to risk (such as in monopolistic and oligopolistic markets - see Chapter 5,

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3 Note that recent research into "cultural theory" has also been criticised on the grounds that it may be unrealistic (Johnson 1991, Sjonberg 1997).

sections 4.2 and 4.3). In addition, by using these concepts it was shown in Chapter 5 that risk management can bring tangible and immediate benefits to the firm - in terms of increases in both its optimum output level and short run profits.

Another important advantage with using economics as a basis for risk management research is that it enables a strategic dimension to be added to a firm's risk management decisions. Indeed as demonstrated in Chapter 6 risk management is likely to be of considerable importance to strategically motivated firms. This importance does not, however, always stem from the simple desire of a firm to reduce its exposure to risk. It is possible, for example, that duopolists or oligoplists will use certain risk management tools to help prevent "*Risk Wars*" and "*Certainty Wars*" - where self interested firms jointly expose themselves to too much or too little risk respectively. Similarly when faced with multiple Nash equilibria it is possible that firms will use their risk management functions to help profitably co-ordinate their risk control decisions.

How then can the contribution of economic theory to risk management research be summed up? Perhaps the most important insight is the idea that a firm's risk management decisions can make a direct contribution to its short run profits. The returns from risk management have typically been seen as being both hard to measure[4] and taking a long time to materialise (see Chapter 2). In an economic context, however, the benefits of risk management are often not only immediate but highly tangible as well. In view of this one of the central ideas of the modern finance approach to risk management (see Chapter 2, section 3.1) - that there will be a conflict of interests regarding risk exposure between shareholders and the firm's other stakeholders - may need to be rethought. If risk can have an immediate and tangible

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4 It would be difficult for a firm to estimate how many third party liability suits might be avoided through investment in environmental risk management, for example.

effect on the profits of a firm then it stands to reason that its shareholders will want managers to invest in cost effective risk management. In short it may well be that shareholders are not as "averse" to expenditure on risk management as has previously been thought.

A second related contribution of economic theory is that it places much more emphasis on the mean returns (i.e. profits) of a risky decision than its variance. Perhaps as a consequence of expected utility theory[5] much of the research into the modern finance approach to risk management still focuses on how seemingly risk averse stakeholders will react to increases in the variance of their returns (see Chapter 2)[6]. The trouble with this, however, is that a decision maker's attitude towards the variance of his or her returns is an inherently personal one, as such it is very difficult to achieve a reliable prediction on how different decision makers will respond to the same level or type of risk. The advantage of focusing on the mean returns of a risky decision is that this problem can be largely eliminated. In general it is reasonable to assume that all decision makers will prefer more returns to less - thus where risk can be shown to have a direct impact on the mean returns of a decision maker it becomes much easier to make general predictions.

Finally economic theory can be used to provide a definite link between a firm's core business and risk management decisions. Certain authors in the modern finance approach to risk management (e.g. Froot et al 1993, Stulz 1996) have already recognised that a firm's risk management function can be used to support both its long

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5 It is hard to deny that expected utility theory has not had a major influence on much of the recent modern finance and organisation behaviour based research into firm (or indeed individual) behaviour in a world of risk.

6 However, it should be noted that the modern finance based research into convex tax functions and bankruptcy costs does not share this problem - see Chapters 2 and 4.

term investment and short term operational decisions, however, what this research has failed to do is provide explicit proof of this link. By using economic theory this thesis has been able to provide some supportive evidence. In particular it has demonstrated that investment in risk management can enable a firm to profitably increase or (in the case of strategically motivated firms) even decrease its output. Moreover, it should not be too difficult to show in subsequent research that risk management can be used to enhance a variety of other decisions, such as pricing, long term investments, advertising or research and development.

Thus it would appear that the ideas which underpin economic theory have much to contribute to our understanding of corporate risk management. Hopefully future research in the field of risk management will begin to adopt a more formal economic view, investigating perhaps some of the extensions to the current work suggested in section 3 below. This is not to say, however, that other perspectives are invalid. Economic based risk management research undoubtedly has its limitations (see section 2 below), moreover, our finite understanding of the behaviour of real world firms would appear to suggest that they may have more complex concerns than simple profit maximisation (Schoemaker 1993). Yet, in order to maintain a balanced view of corporate risk management decisions, the predictions of economics based risk management models should not be ignored.

2. Limitations of Current Research

Many of the limitations of the analysis in this thesis have been identified in the relevant Chapters and sections above. What follows, therefore, is a brief summary of some of the more important issues.

2.1 *Use of ordered attitudinal data to test the modern finance approach in Chapter 3*

The purpose of Chapter 3 was to attempt to identify whether the various predictions of the modern finance approach actually explained why large UK companies spend money on risk management. In general the results of this analysis were quite negative with there being little evidence that anything, other than the personal attitudes of managers, actually influenced a firm's risk management programme.

It is quite likely that the lack of support found for the modern finance approach in Chapter 3 reflects the real world insignificance of its hypotheses[7]. However, it is also possible that the use of ordered attitudinal data to measure the various dependent variables lead to a degree of bias in the analysis. Although respondents were asked to answer all questions on the basis of what was important to their *company*, rather than themselves, it is impossible to be sure that their personal opinions did not influence their responses. Thus it may be that the questionnaire data collected reflected what respondents felt should be the motivations for their company's risk management programme rather than what their company's motivations actually were.

Yet, despite the limitations of attitudinal based data it is unclear as to how general surveys on the modern finance approach to corporate risk management can proceed without making extensive use of such information. Reliable, objective information about risk management is scarce at best - a situation that does not appear likely to

7 Indeed other empirical studies of the modern finance approach have not found overly strong support for it either - see Chapter 3, section 2.

change (see section 2.2 for more information on this). Thus it may be some time (if ever) before a conclusive test of the modern finance approach can be undertaken.

2.2 *The need for further empirical research on the significance of "pure penalties" and "technological non-linearities" in motivating corporate risk management*

An important limitation of this thesis is the lack of any empirical research regarding the economic impact that "pure penalties" and "technological non-linearities" may have on the risk management decisions of firms. Future research will definitely have to address this issue, however, at the current time it is unclear as to how many of the hypotheses contained in Chapters 4, 5 and 6 could be tested. One problem is that the behaviour of real world firms is likely to be very sensitive to the internal and external environments that they face (in terms of the type of risk, number of inputs used, the nature of competition, etc. - see Chapter 5, section 3) - as such it may be quite difficult to find industries which meet the various assumptions that have been made. To make matters worse, there is also a lack of publicly available information about the nature of a firm's exposures to risk and its reactions to it (see Chapter 3). Most firms are not prepared to reveal information about their risk management programmes. Moreover, although government reports such as the Cadbury Committee on corporate governance (Cadbury 1992) have recommended that this situation should change, it does not seem that anything will be done about this in the near future.

2.3 *Simplicity of the models used in Chapters 5 and 6*

Many of the assumptions made about the economic models examined in Chapters 5 and 6 are quite simplistic. Simplified models have the advantage of keeping the analysis fairly tractable, allowing this thesis to focus on some of the key features of economic risk management models. However, it would be fair to say that some of the assumptions made in especially Chapter 5 (such as the use of a linear demand function or the fact that a firm is restricted to using only one productive input) are not wholly realistic. It would, therefore, be advisable for future research to address this issue (see sections 3.1 and 3.2 below) and attempt to relax some of the more restrictive assumptions made here.

2.4 *Focus on profit maximisation*

To proponents of the modern finance approach to risk management and "cultural theory" the focus on profit maximisation in Chapters 4, 5 and 6 might seem to represent something of a limitation. Modern finance theorists have effectively adopted a political view of the firm, arguing that the concerns of non-shareholder stakeholders will often conflict with objectives such as short run profit maximisation. Moreover, cultural theorists have even gone a step further embracing the contextual view of the firm in which organisations are assumed to be so complex that the formation of definite, objective goals such as profit maximisation are said to be virtually impossible[8].

However, despite the current unfashionability of profit maximisation in risk management research it is hoped that this thesis has demonstrated that the concept is far from redundant. As Schoemaker (1993) points out rational economic models have an important role to play in our understanding of a wide range of corporate behaviour. In particular, rational models keep the analysis tractable, enabling the consideration of complex issues such as the strategic interdependence of firms (see Chapter 6). Moreover, although it is undoubtedly true that real world firms are concerned about goals other than profit maximisation, it is also fair to say that most are still in the business of making a profit (see, for example, Hay & Morris 1991, p292-296).

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8 For more on the political and contextual views of the firm see Schoemaker (1993).

3. Possibilities for Future Research

3.1 *Changing the assumptions*

As illustrated in Chapters 5 and 6 one of the biggest problems with economic based risk management models is that their resultant predictions are highly sensitive to the assumptions made about firms and the types of risk that they face. For example in Chapter 5 the behaviour of a perfectly competitive firm was significantly affected by whether it faced firm specific or industry wide technological risk. Moreover, it would not be too difficult to show that other changes to the model (such as exposing the firm to multiple unreliable inputs, price fluctuations or a non-linear industry demand function) might also affect a firm's behaviour. Chapter 6 was kept deliberately general to incorporate the widest possible variety of effects on a strategically motivated firm, however, even here the associated technical analysis (such as in Appendix 3 or the discussion of risk wars in section 2.3) was largely limited to quantity setting duopolistic firms facing technological risk.

Future economics based research could, however, address this issue. In fact, albeit without much explicit attention to risk management many different sets of assumptions about the economic behaviour of firms in a world of risk have already been investigated[9]. What is needed, therefore, is to adapt these ideas into formal models of corporate risk management. Then when this is done academic research should benefit from a much more comprehensive and clearer idea about the risk management motivations of firms.

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9 For more on this area see Chapter 5, especially section 2.

3.2 *Increasing the diversity of strategic equilibria in risk management games*

Perhaps the most novel feature of economics based risk management research is that it allows a strategic dimension to be incorporated into the decisions of firms. Chapter 6 dealt with this area, demonstrating that a wide range of different and sometimes surprising outcomes may arise when strategically motivated firms are able to manipulate their exposure to risk. In particular five specific groups of symmetric Nash equilibria were focused upon: "*Certainty*" equilibria, "*Risk*" equilibria, "*Risk Wars*", "*Certainty Wars*" and finally co-ordination equilibria.

These five groups of equilibria illustrate many of the interesting features that are likely to characterise strategic risk management games, however, it is hard to deny that in other situations the behaviour of strategically motivated firms might well change. One obvious extension is to investigate the behaviour of firms in asymmetric games. Indeed, as already stated in Chapter 5 (section 4.2) the cost and efficiency of risk management is likely to be highly important to an imperfectly competitive firm. This importance could then be reflected in the types of equilibria faced by firms. For example, a firm with a relatively low unit cost of risk management or more efficient risk management programme might well be able to dominate its industry - because it will possess a comparative advantage in terms of reduced production costs in a world of risk. This should then provide all firms in the industry with a strong incentive to improve the cost effectiveness of their risk management programmes, leading perhaps to "*Efficiency Wars*". Moreover, following on from the work of Salop & Scheffman (1983) a firm might even attempt to worsen the cost effectiveness of its rivals' risk management programmes in order to improve or achieve a dominant position in the market[10].

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[10] For example, by encouraging safety legislation that has a disproportionate effect on the cost and or efficiency of rival risk management programmes.

3.3 *The role of communication*

Within the organisational behaviour based "cultural theory" literature the advantages of risk management communication have been well-researched (e.g. Shrivastava et al 1988, Quarantelli 1988, Pidgeon et al 1992, Turner 1994, Weir 1996). The basic thrust of this work is that both intra- and inter-firm communication can have an invaluable role to play in helping to prevent and mitigate disasters. However, in the strategic context the benefits of communication are less clear cut (see Fudenberg & Tirole, 1984, 1986, Vives 1984, Gal-Or, 1985, 1986, Shapiro, 1986, Roberts 1987, Cason 1994, Farmer 1994). Consider, for example, the case of a "*Risk War*" or "*Certainty War*". In these situations a firm might well try to keep its rivals in the dark about the extent of its expenditure on risk management, preferring them to believe that it is exposed to more or less risk than it actually is. The idea behind this strategy would be to achieve an inexpensive competitive advantage - since a firm will generally find it cheaper to *pretend* to be exposed to more or less risk than actually modify its exposure. Yet, ultimately this pretence would probably just increase the chance of a "*Risk War*" or "*Certainty War*" (since the costs associated with self interested behaviour should be reduced). Moreover, the presence of asymmetric information may even make "*Risk Wars*" or "*Certainty Wars*" more difficult to prevent, since a firm will find it very difficult to properly monitor rival behaviour.

3.4 *The role of "pure penalties" and "technological non-linearities" in describing the behaviour of individuals*

This thesis has focused primarily on the risk management decisions of widely held (i.e. quoted) firms, as such it is not immediately obvious whether its predictions could be used to explain the behaviour of individuals, especially in a non business environment. However, despite this focus on corporations it may well be possible that individual behaviour is also affected by certain "pure penalties" and "technological non-linearities".

In recent years the ability of expected utility theory to explain the decisions of individuals has been under perhaps even more attack than its use in the corporate context. In particular, numerous authors have argued that rather than following the rather precise axioms of utility theory most individuals instead use heuristics (such as Kahneman & Tversky 1973, Slovic et al 1980, Fischhoff et al 1981, see also Chapter 4, section 3.1). This has lead to extensive criticism of expected utility theory and although some have attempted to revise its assumptions (e.g. Machina 1987) for many it has largely been discredited (see Pidgeon et al 1992).

Given the quite large number of empirical studies into the role of heuristics it is hard to deny that they will not colour the real world decision making processes of individuals However, what is still rather unclear is the source of these heuristics. As stated in Chapter 6 (section 3.3.2.2) the current view is that heuristics are predominantly socially/culturally determined. Yet as Sjonberg (1997) points out empirical studies in this area have not provided conclusive proof of this claim. Admittedly the lack of statistical significance in these empirical studies could be due to the difficulties that can be associated with measuring subjective concepts such as culture, however, it is perhaps more likely to be caused by the fact that individual heuristic biases are the result of other factors (Johnson 1991).

If individual heuristic biases are not always the result of culture it would seem worthwhile to explore other avenues of research. As such the concepts of "pure penalties" and "technological non-linearities" may provide useful explanations for observed individual behaviour. Take, for example, Tversky & Kahnemans' (1981) observation that individuals are often more averse to risks that are framed as losses rather than gains. Although seemingly irrational when looked at through the lens of expected utility theory (through violation of the context independence axiom - see Gravelle & Rees 1992, p554-556), this behaviour can easily be explained within a "pure penalty" framework. Risks that only offer negative returns are effectively pure risks that can only reduce the wealth of an individual. As such it is perhaps unsurprising that individual decision makers will prefer to avoid such risks since doing so will help to protect them from suffering their inevitable associated losses[11].

Similarly, heuristics such as "loss aversion", one of the core ideas of "Prospect Theory" (Kahneman & Tversky 1979) could be explained by the presence of technological non-linearities. Loss aversion refers to the tendency for individuals to be more sensitive to reductions in their wealth than to increases. Although usually seen as irrational[12] this phenomenon may arise because the monetary payoff function of a particular risk is kinked so that the adverse financial impact of "bad" states of nature considerably outweigh the benefits of "good" ones. Risks which offer the prospect of bankruptcy provide a good example of this. Just as in the case of a firm, bankruptcy can represent a considerable cost to an individual - due to the future denial of credit, unavailability of bank accounts or the forced liquidation of capital at below market value. Thus where an individual is faced with a decision that could result in bankruptcy it would seem quite logical for them to be unwilling to take it.

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11 It is also interesting to note that many of the risks that were "over estimated" or strongly disliked in other empirical studies of heuristics use by individuals have also been framed as pure risks (e.g. see Slovic et al 1980, Fischhoff et al 1981).

12 See, for example, Samuelson (1963).

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Appendix 1:

Risk Management Questionnaire.

This questionnaire is targeted at risk/insurance managers and finance managers who are employed by companies operating within the UK.

The following questions seek to investigate the reasons why these managers believe risk management to be an important investment for their companies.

Companies spend money on risk management in an attempt to deal with the adverse impact that fortuitous risk may have upon their operating cash flows, arising from: asset damage (machine breakdown, property loss through fires etc.), business interruption, employee injury and damage liability costs (pollution, product malfunction, etc.).

Please answer these questions as truthfully as possible, there are no trick questions!.

If you would like to receive a synopsis of the survey results, please tick the box at the end of the questionnaire.

When completed please return questionnaire to:

Mr Simon Ashby
University of Nottingham Insurance Centre
School of Management & Finance
Social Sciences Building
University of Nottingham
NOTTINGHAM NG7 2RD
Fax: (0602) 515262

In case of any queries please contact:

Mr Simon Ashby
Phone (0602) 515495

Section A. The Scope of Risk Management.

1. Several companies may be exposed simultaneously to the risk of large scale disasters whose impacts are difficult to diversify away (e.g. storms, floods, earthquakes, economic recession). How important is **your company's** risk management programme in reducing the adverse impact such events may have on your share price?

	Unimportant				Important
Don't know ☐	1	2	3	4	5

(Please either tick the box or circle a number)

2. Considering the impact of the risk of physical injury on employees, how important is **your company's** risk management programme in contributing to the following corporate objectives?

(a) A more productive work force.

	Unimportant				Important
Don't know ☐	1	2	3	4	5

(b) Reducing labour turnover.

	Unimportant				Important
Don't know ☐	1	2	3	4	5

(c) Reducing your company's wage costs.

	Unimportant				Important
Don't know ☐	1	2	3	4	5

(d) Reducing the legal liability costs of your company.

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(e) Conforming to government safety regulations.

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(In each question please either tick the box or circle a number)

3. The risk of corporate insolvency exposes employees to the possibility of redundancy. In this respect: how important is **your company's** risk management programme in contributing to the following corporate objectives?

(a) A more productive work force.

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(b) Reducing labour turnover.

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(c) Reducing your company's wage costs.

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(In each question please either tick the box or circle a number)

4. Considering your consumers safety, how important is **your company's** risk management programme in contributing to the following corporate objectives?

(a) Providing basic product safety, by complying to the relevant statutory safety regulations.

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(b) Reducing the legal liability costs of your company.

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(c) Reducing the losses associated with the decline of sales and consumer confidence.

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(In each question please either tick the box or circle a number)

5. Considering the effect of the production process on the external environment (e.g. pollution), how important is **your company's** risk management programme in contributing to the following corporate objectives?

(a) Ensuring that regulatory and legal costs are reduced. (e.g. in helping to avoid fines and liability suits)

	Unimportant			Important	
Don't know ☐	1	2	3	4	5

(b) Ensuring a good public image.

		Unimportant				Important
Don't know ☐		1	2	3	4	5

(c) Ensuring an ethical approach to your business.

		Unimportant				Important
Don't know ☐		1	2	3	4	5

(In each question please either tick the box or circle a number)

6. How important is **your company's** risk management programme in reducing the rate of interest charged by the following types of creditors, thus reducing your cost of capital?

(a) Trade creditors.

		Unimportant				Important
Don't Know ☐		1	2	3	4	5

(b) Short term bank creditors. (overdrafts)

		Unimportant				Important
Don't Know ☐		1	2	3	4	5

(c) Bondholders. (Long term loans)

		Unimportant				Important
Don't Know ☐		1	2	3	4	5

(In each question please either tick the box or circle a number)

7. Considering your shareholders, how important is **your company's** risk management programme in contributing towards the following corporate objectives?

(a) Maintaining existing dividends, thus protecting the value of your company's shares.

	Unimportant				Important
Don't know ☐	1	2	3	4	5

(b) Increasing dividends, thus raising the value of your company's shares.

	Unimportant				Important
Don't know ☐	1	2	3	4	5

(c) Reducing your company's tax liabilities.

	Unimportant				Important
Don't know ☐	1	2	3	4	5

(d) Avoiding the costly effects of financial distress and/or bankruptcy.

	Unimportant				Important
Don't know ☐	1	2	3	4	5

(In each question please either tick the box or circle a number)

8. When your company has expanded its range of activities, (e.g. new acquisitions, product range expansion) was any risk management advice sought?

		Never				Always
We have never sought to expand	☐	1	2	3	4	5
Don't Know	☐					

(Please either tick a box or circle a number)

9. For many industries, expansion into new risky areas is seen to be an unprofitable and thus undesirable move. Is risk an important barrier to expansion for your company?

	Unimportant				Important
Don't know. ☐	1	2	3	4	5

(Please either tick the box or circle a number)

10. When your company has considered divesting itself of any of its activities, does the level of long term risk (e.g. pollution, latent injuries) encourage or discourage divestment?

		Discourage				Encourage
We have never sought to divest	☐	1	2	3	4	5
Don't know	☐					

(Please either tick a box or circle a number)

11. Do you contract out risky activities to small, independent, specialist companies?

	Never				Always
Don't know ☐	1	2	3	4	5

(Please either tick the box or circle a number)

Section B. BASIC INFORMATION QUESTIONS.

ABOUT YOU IN 1991/2.

12. What, in your opinion, is the most suitable level of insurance cover for your own personal possessions?

	Wholly insured				Wholly uninsured
Don't Know ☐	1	2	3	4	5

(Please either tick the box or circle a number)

13. What, in your opinion, is the most suitable level of property insurance cover for the assets of your company?

	Wholly insured				Wholly uninsured
Don't Know ☐	1	2	3	4	5

(Please either tick the box or circle a number)

14. In comparison with your company's senior management, are you more or less of a risk taker?

Less		Same		More
1	2	3	4	5

(Please circle a number)

15. In comparison with your company's senior management, are you more or less likely to consider the longer term impact of your company's investment decisions?

	Less		Same		More
	1	2	3	4	5

(Please circle a number)

16. Who is your direct superior?

Chief Executive ☐

Board level Executive ☐

Non board Manager ☐

(please tick a box)

17. What is your specific job title/description?

18. Do you, or anyone else within your department, sit on your company's Health and Safety Committee?

Yes ☐

No ☐

(please tick a box)

19. How many years have you worked in the field of Risk Management/Finance?

(Delete as Appropriate)

20. In what area/s are your professional qualifications?

Risk Management related

(e.g. IRM) ☐

Insurance ☐

Legal ☐

Accounting ☐

Engineering ☐

Company secretary ☐

Other ☐

(please specify below)

(please tick one or more boxes)

21. Do you receive any of the following incentive schemes?

Profit related pay ☐

Share option schemes ☐

Personal performance based schemes ☐

None of the above ☐

(please tick one or more boxes)

If you would like a synopsis of the results, please tick this box: ☐

Name

Address

Appendix 2:

Correlation Coefficients of Independent Variables

	CAPLAB	COMINS	DIVERSE	DUMCAP	GEARING	JOBRM
CAPLAB	1	-0.0771	-0.1683	0.1378	0.0479	0.0442
COMINS	-0.0771	1	0.1699	0.069	-0.0453	0.2529
DIVERSE	-0.1683	0.1699	1	0.1278	-0.0088	-0.0408
DUMCAP	0.1378	0.069	0.1278	1	0.1486	0.0424
GEARING	0.0479	-0.0453	-0.0088	0.1486	1	0.0517
JOBRM	0.0442	0.2529	-0.0408	0.0424	0.0517	1
LTRISK	-0.1215	-0.0274	0.0915	0.035	0.0309	-0.1618
PAY	-0.0579	0.1223	0.0312	-0.1264	-0.0292	0.1142
PAYINC	0.0374	0.0295	0.2438	-0.1229	-0.1557	-0.145
PERINS	0.0309	0.5658	-0.0679	0.0796	-0.1325	0.0908
PRORAT	0.0991	0.0357	-0.143	-0.2703	-0.178	0.0701
RISK	0.1315	-0.0913	0.0344	0.3532	0.277	-0.1027
SALES	0.0625	0.2714	0.0613	0.087	0.1563	0.1932
XSALCAP	0.1372	0.2422	0.0092	0.3948	0.2041	0.1282

	LTRISK	PAY	PAYINC	PERINS	PRORAT	RISK
CAPLAB	-0.1215	-0.0579	0.0374	0.0309	0.0991	0.1315
COMINS	-0.0274	0.1223	0.0295	0.5658	0.0357	-0.0913
DIVERSE	0.0915	0.0312	0.2438	-0.0679	-0.143	0.0344
DUMCAP	0.035	-0.1264	-0.1229	0.0796	-0.2703	0.3532
GEARING	0.0309	-0.0292	-0.1557	-0.1325	-0.178	0.277
JOBRM	-0.1618	0.1142	-0.145	0.0908	0.0701	-0.1027
LTRISK	1	0.1977	0.262	0.1516	-0.0924	0.0475
PAY	0.1977	1	0.3175	0.0536	0.085	-0.0023
PAYINC	0.262	0.3175	1	0.1091	0.0943	-0.053
PERINS	0.1516	0.0536	0.1091	1	0.0789	-0.0345
PRORAT	-0.0924	0.085	0.0943	0.0789	1	-0.4061
RISK	0.0475	-0.0023	-0.053	-0.0345	-0.4061	1
SALES	0.0022	0.1417	0.0526	0.2741	-0.103	-0.1368
XSALCAP	0.0219	0.0993	-0.0237	0.154	-0.1647	-0.0193

	SALES	XSALCAP
CAPLAB	0.0625	0.1372
COMINS	0.2714	0.2422
DIVERSE	0.0613	0.0092
DUMCAP	0.087	0.3948
GEARING	0.1563	0.2041
JOBRM	0.1932	0.1282
LTRISK	0.0022	0.0219
PAY	0.1417	0.0993
PAYINC	0.0526	-0.0237
PERINS	0.2741	0.154
PRORAT	-0.103	-0.1647
RISK	-0.1368	-0.0193
SALES	1	0.7796
XSALCAP	0.7796	1

Appendix 3:
An Example of a Cournot-Nash Risk Management Game

From Chapter 5, section 4.3 consider a pair of expected profit maximising duopolists labelled i = 1,2 with perfectly substitutable outputs q_1 and q_2 and a linear inverse demand function $p=a-b(q_1+q_2)$, where $a,b > 0$. Both firms have production functions which display constant returns to a single input z_i, but are faced with multiplicative technological risk so that $q_i=z_i\varepsilon_i$, where $\varepsilon_i > 0$ is a random variable with mean standardised to 1, variance $\sigma_i > 0$ and covariance σ_{12}. The unit cost of z is c for both firms. Thus each duopolist's expected profits are therefore:

$$E[\pi_i(z_1 z_2)] = (a-c)z_i - b(\sigma^2(m_i)+1)z_i^{\,2} - b\{\rho\sigma_1(m_1)\sigma_2(m_2)+1\}z_i z_j - rm_i, \text{ for } i,j=1,2; i \neq j$$

where ρ is the correlation coefficient that denotes the sign and strength of the covariance between σ_1 and σ_2. Following on from the analysis in Chapter 5 (section 4.3) the first order Cournot-Nash equilibrium condition for the optimal value of z_i* is then[1]:

$$z_i^* = \frac{\frac{(a-c)}{b}.\left[2(\sigma_i^2+1)-(\rho\sigma_1\sigma_2+1)\right]}{4(\sigma_1^2+1)(\sigma_2^2+1)-(\rho\sigma_1\sigma_2+1)^2} \quad \text{for } i \neq j.$$

Now assume that each firm can eliminate its exposure to technological risk by investing in costly risk management. A firm is, therefore, able to control the variance of σ_i, choosing to expose itself to either the prevailing level of risk (which in this case is assumed to be σ_i = 1) or certainty (σ_i = 0) so that $q_i=z_i$. The terms R_{CC} and R_{CR} represent the cost of risk management denoting the lump sums payable in the

---

1 For the derivation of this equation and its associated second order conditions see Chapter 5, section 4.3.

(Certainty, Certainty) and (Certainty, Risk) or (Risk, Certainty) cases respectively. The payoffs in this game are then obtained by substituting the optimal values for z_i* (for $\sigma_i = 1$ and $\sigma_i = 0$ respectively) into the expected profit maximising condition. Given that the variables *a*, *b* and *c* are constant all payoffs are expressed in units of $(a-c)^2/b$.

		Firm 2	
		Certainty, $\sigma_i = 0$	*Risk,* $\sigma_i = 1$
Firm 1	*Certainty,* $\sigma_i = 0$	$(1/9-R_{CC}, 1/9-R_{CC})$	$(9/49-R_{CR}, 2/49)$
	Risk, $\sigma_i = 1$	$(2/49, 9/49-R_{CR})$	$(2/(\rho+5)^2, 2/(\rho+5)^2)$

Payoffs to: (Firm 1, Firm 2)

Table 1 : A 2x2 Risk Management Game with Technological Risk and Linear Demand

From table 1 it should become clear that in the current simplified model the Nash equilibrium[2] that will eventually arise will depend on the prevailing values of ρ (the correlation coefficient) as well as R_{CC} and R_{CR} (the potential costs associated with investment in risk management). Note, therefore, that since the value of ρ can never be greater than one[3] a "Risk War" is not a possibility as 2/49 cannot exceed $2/(\rho+5)^2$. This is a consequence of the rather restrictive assumptions of the current model. If, for example, firms were exposed to a non-linear demand curve or a different type of risk (demand or cost say) a risk war might become possible[4]. There are, however, (from Chapter 6, section 2) four other main possibilities.

2 A Nash equilibrium can be defined as an equilibrium from which no firm would unilaterally wish to deviate (for example see Rasmusen 1994, Ch. 1).

3 For a good discussion of this issue see Greene (1997).

4 See Chapter 6, section 2.3 for more information on the possible causes of risk wars.

(1) A "Certainty" equilibrium will arise if $1/9\text{-}R_{CC} > 2/49$ and $9/49\text{-}R_{CR} > 2/(\rho+5)^2$.

As might be expected a "Certainty" equilibrium is most likely when the costs associated with investing in risk management (R_{CC} and R_{CR}) are not too high. For example, in the case where $\rho=0$ investment in risk management will be Pareto optimal when $R_{CC} < 0.03111$ and $R_{CR} < 0.10367$[5]. Note also that for negative values of ρ the maximum values of R_{CC} and R_{CR} necessary for a "Certainty" equilibrium will decrease, while for positive values of ρ they will increase. When $\rho < 0$ the natural hedge that is caused by firms' negatively correlated output fluctuations reduces their exposure to costly price fluctuations and thus the need for risk management. On the other hand when $\rho > 0$ each firm's exposure to output induced price fluctuations will rise causing the cost of risk and thus the value of risk management to increase[6].

(2) A "Risk" equilibrium, where neither firm invests in risk management, will occur if $1/9\text{-}R_{CC} < 2/49$ and $9/49\text{-}R_{CR} < 2/(\rho+5)^2$.

A "Risk" equilibrium is in effect the corollary of a "Certainty" equilibrium. Thus the chance of a "Risk" equilibrium will generally increase as the lump sum costs of risk management rise and or the value of the correlation coefficient (ρ) decreases[7].

(3) A "Certainty War", where $9/49\text{-}R_{CR} > 2/(\rho+5)^2 > 1/9\text{-}R_{CC} > 2/49$.

Thus the values of R_{CC} and R_{CR} that will yield a "Certainty War" will be heavily influenced by the value of ρ. For example when $\rho=0$ a "Certainty War" will arise if

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5 For $\rho = 0$ the maximum value for R_{CR} is simply calculated by subtracting $2/(5)^2$ from 9/49. Similarly, the maximum value for R_{CC} is calculated by subtracting $2/(5)^2$ from 1/9. Note that although (Certainty, Certainty) will also be a Nash equilibrium when R_{CC} is sufficiently small to ensure that $1/9\text{-}R_{CC} < 2/49$ (i.e. if $R_{CC} < 0.07029$), where $0.03111 < R_{CC} < 0.07029$ this will actually generate a "Certainty War" (since $2/(5)^2 > 1/9\text{-}R_{CC}$).

6 For example when $\rho= 1$, a "Certainty" equilibrium will occur when $R_{CC} < 0.05555$, $R_{CR} < 0.12812$. While for $\rho= -1$ it will occur when $R_{CC} < 0.01388$, $R_{CR} < 0.05867$.

7 For example assuming that $\rho= 0$ a "Risk" equilibrium will arise if $R_{CC} > 0.07029$ and $R_{CR} > 0.10367$.

$0.03111 < R_{CC} < 0.07029$ and $R_{CR} < 0.10367$. However, when $\rho=-1$ a "Certainty War" will arise if $0.01388 < R_{CC} < 0.07029$ and $R_{CR} < 0.05867$[8].

(4) Finally a pair of co-ordination equilibria (Certainty, Certainty) and (Risk, Risk) can occur if $1/9-R_{CC} > 2/49$ and $9/49-R_{CR} < 2/(\rho+5)^2$.

Thus the likelihood of a pair of co-ordination equilibria arising will increase as: (i) the more the cost of unilateral investment in risk management (R_{CR}) exceeds the cost of joint investment (R_{CC}); (ii) when $\rho < 0$. For example, when $\rho=0$ both (Certainty, Certainty) and (Risk, Risk) will be Nash equilibria if $R_{CC} < 0.07029$ and $R_{CR} > 0.10367$. However when $\rho=-1$ the chances of a pair of co-ordination equilibria will increase substantially requiring only $R_{CC} < 0.07029$ and $R_{CR} > 0.05867$ [9].

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8 To obtain the critical value for R_{CR} subtract $2/(\rho+5)^2$ from 9/49. To obtain the critical range of R_{CC} subtract $2/(\rho+5)^2$ from 1/9 to get the minimum value and then 2/49 from 1/9 to get the maximum. Ignore any minus signs.

9 To get the critical values of R_{CC} and R_{CR} necessary for this pair of co-ordination equilibria simply subtract 1/9 from 2/49 and 9/49 from $2/(\rho+5)^2$. Again ignore any minus signs.

Appendix 4:
A Glossary of Risk Management Terms

Hedging (see also Natural Hedge)

As a generic term hedging describes any action that balances a possible gain against a possible loss. The hedging of an existing risk, therefore, effectively involves exposure to another risk the outcomes of which (for a given state of nature) are opposite in sign to those of the existing risk (i.e. the two risks must be negatively correlated).

In business formal hedging tools are generally known as derivatives. Derivatives include financial instruments such as futures contracts, currency swaps and options (e.g. see Brealey & Myers 1991, Ch. 25). Note that derivatives may also be used speculatively to increase a firm's exposure to risk.

Insurance

Insurance is a form of risk financing, however, an important difference between insurance contracts and other risk financing tools is that with insurance a firm legally transfers the financial impact of a particular loss onto the insurer. Assuming full insurance the act of transferral effectively eliminates all the adverse financial consequences of a loss thus providing a firm with a very stable income stream. Given the stability that insurance can provide it might seem to be a very desirable risk financing tool, however, it is important to note that insurance can be very expensive and for certain risks may also be unavailable (see Williams et al 1995 for a good discussion of this topic).

Insurance Broker

Traditionally corporate insurance brokers were simply financial intermediaries that helped to select and arrange suitable insurance cover for their clients and administer claims. More recently brokers have taken on many other roles including acting as risk management consultants and loss adjusters (an agent which helps to determine the monetary value and insurability of losses).

Insurance Premium

The price paid by an insured for an insurance contract.

Insured

The purchaser of an insurance contract.

Joint Captive

A joint captive is an insurance company that is owned by a group of firms whose risks it primarily insures. Usually this ownership takes the form of holding the captive insurer's common stock.

In many respects a joint captive performs the same function as a risk financing pool - to help its owners share their losses between themselves. However, joint captive arrangements are rather more formal than risk financing pools. The main difference is that joint captives are legally classified as a normal insurance company - a situation which provides them with greater legal powers to ensure that premiums are paid and warranties (such as contractual requirements to install certain risk control devices, for example) are adhered to (see Chapter 6, section 3.2.1).

Risk Financing Pools

The basic idea behind a risk financing pool is that its members agree to share the financial impact of each other's losses. For example, a group of oil companies might agree to share liability exposures arising from oil spills through such an agreement. Under this agreement the financial impact of each firm's liability exposures then becomes more predictable.

Note that risk financing pools are not the same as insurance. The crucial difference is that in a risk financing pool a firm does not transfer the financial impact of a particular loss but merely shares it. However despite this technical difference insurance and risk financing pools effectively perform the same function - to reduce the variability of cash flows.

Single Parent Captive

A single parent captive is an insurance company that is owned by the firm whose risks it primarily insures. Usually this ownership takes the form of holding the captive insurer's common stock.

Note that although legally an insurance company the role of a single parent captive is quite different to that of a traditional (external) insurer. The most important difference is that a firm which sets up a captive insurer is not trying to transfer the financial impact of its losses (unless the captive is used to gain access to the wholesale "re-insurance" market). Instead single parent captives are typically viewed as a more efficient form of retention fund.

Loss Prevention Tools

Loss prevention tools are risk control activities intended to reduce or eliminate the chance that a firm (or individual) may experience a loss. Loss prevention activities include hazard warning lights (as fitted in planes), the salting of roads and safety training or monitoring programmes, for example.

Loss Reduction Tools

Loss reduction tools are risk control activities that reduce the impact of losses that do occur. Examples of loss reduction tools include catastrophe plans, sprinklers and protective clothing.

Natural Hedge

A natural hedge is a hedge that exists without any deliberate action on the part of a firm (or indeed individual). Natural hedges may be caused by many things, however in the current context the assumed negative correlation between output and price fluctuations is an important example (see Chapter 6).

Retention Fund

A retention fund is simply a formal financial arrangement (usually a dedicated bank account) in which funds are deposited to help pay for future losses.

Although retention funds are often used in place of risk sharing or insurance arrangements (especially where these are either impractical or too expensive) the way that a retention fund works is quite different. A firm that uses a retention fund is neither transferring or sharing the financial impact of its losses, instead all a retention fund offers is a way of smoothing the impact of financial losses over time.

Risk Control Tools

Risk control tools are those that focus upon directly avoiding, preventing, reducing or otherwise controlling risk. Risk control tools can take simple forms such as making sure that a factory has functioning fire extinguishers. They can also be more complex, such as the development of a catastrophe plan to use in the event of a major emergency.

Risk Financing Tools

The primary aim of any risk financing tool is to provide funds to help pay for losses that may occur as a result of a firm's exposure to risk. Risk financing tools include measures such as the purchase of insurance coverage, the establishment of a captive insurer, letters of credit or derivatives trading. Note that traditionally risk financing tools were only thought to have a role to play in financing losses, however, more recently authors such as Mayers & Smith (1982), Skogh (1989, 1991), and Grillet (1992) have recognised that these tools can also facilitate the direct control of risk.