Corporate Underinvestment in the Presence of Symmetric and Asymmetric Information

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Introduction

1 Overview and structure

You cannot avoid the inevitable: there is absolutely no chance that one is going to write a dissertation on corporate investment and financing decisions without mentioning the famous Franco Modigliani and Merton Miller, or "MM", as they have come to be known. The two authors have shown in their seminal 1958 paper that corporate financing decisions do not matter, in that corporate value is unaffected by them when capital markets are perfect. Regardless of whether a firm completely relies on equity or is financed by 99.9% debt in its capital structure (or any proportion in between), firm value is always the same for a given corporate investment scheme. This does not only apply to common equity and straight debt, but to every mix of securities conceivable. Financing simply does not matter. "The economic intuition is simple, equivalent to asserting that in a perfect-market supermarket, the value of a pizza does not depend on how it is sliced" (Myers, 2001, p. 85). The reason is quite simple: in perfect markets, changes in the corporate capital structure can simply be undone on the investors' individual level by adjusting their personal portfolios.[1] The irrelevance theorem was later on shown to be quite robust in that it holds in more general settings, too. For example, Stiglitz (1974) discards the corporate risk classes (that firms belong to) used in the original model and accommodates dividend payout ratios, differing bond maturity structures and leverage ratios. The author shows that irrelevance is upheld under a set of certain "weak" assumptions.

Nowadays, there is broad agreement that the MM theorem holds only in the perfect, highly stylized model world envisaged by the authors at the time they were formulating the irrelevance propositions. It does not, however, hold in the real world, where numerous frictions are most certainly present. But that is not the point. What is most important to understand when considering the irrelevance theorem is that its significance is not so much due to the

[1] In the unlikely event that some readers are unfamiliar with MM, we recommend to skip the original paper from 1958. Rather, some few years later, Modigliani and Miller (1969) provide a much shorter, much clearer, more intuitive and more general version of their irrelevance theorem.

actual result or the ingenuity required to produce such a theory. Rather, it has proven to be of such enormous value over the years because it sparked the tremendous lot of subsequent research produced by scholars to this date. It serves as the basic research for past and future developments in corporate financing, so to speak. More precisely, it does so by telling researchers *where* to look for determinants of corporate financing policy. In the words of Miller (1988, p. 100): "showing what *doesn't* matter can also show, by implication, what *does*" [emphasis in the original]. An obvious way to "overcome" MM is to deviate from the assumptions of perfect capital markets. "We believe capital markets are generally well-functioning, but they are not 100 per cent perfect 100 per cent of the time. Therefore, MM must be wrong some times in some places" (Brealey et al., 2003, p. 504). In reality, a great variety of market frictions exist that justify relaxing the assumptions of MM. A classification of different frictions is provided by DeGennaro and Robotti (2007). For example, different securities come with different transaction costs. Managers take them into consideration when deciding on raising new funds via the issue of new securities. Cost considerations may motivate them to prefer one type of security over the other, so that financing matters. Taxes are another frequently mentioned friction. Debt financing can increase firm value because interest payments are tax deductible from corporate taxable income by law and, thus, create valuable interest tax shields. At the same time, debt creates the risk of default. When costs of financial distress are introduced (yet another deviation from perfect markets), financing matters in that the value of a levered firm is depressed by the (expected) value of these costs. Thus, managers must carefully trade off the advantages and disadvantages of leverage in deciding on corporate capital structure because this choice affects the firm's value. There are many more imperfections that make financing matter. One that we will be concerned with in the first part of this dissertation is asymmetric information. Akerlof (1970) and Stiglitz and Weiss (1981) have prominently shown that capital markets can break down and can be characterized by credit rationing, respectively, in the presence of asymmetric information. But there are various other distortions that matter in this regard. We examine how asymmetric information between different market participants influences financing decisions and, thus, firm value. Specifically, if outsiders cannot verify the value of the firm, the choice of a certain type of security to be issued sends a signal to the market that it uses to update its estimate of the firm's value. Management, aware of these valuation effects, may thus be biased towards a certain type of security.

In the second and third part of this dissertation, we elaborate on the possibility of financing *relevance* even when financial markets are assumed perfect. "In an ideal world with no taxes,

transaction costs or other market imperfections, only investment decisions would affect firm value" (Brealey et al., 2003, p. 592). Thus, if financing decisions alter a firm's investment decisions, then the capital structure matters and MM does not hold (yet again). Specifically, we will consider a model setup (Myers, 1977) where shareholders (as the owners of the firm) refuse to invest in a profitable project that would increase the firm's value, but not the value of their own claims. Hence, they will rationally decide to pass up an investment opportunity that would be undertaken if the firm had only equity in its capital structure. In other words, the firm's investment decision is influenced by corporate debt.
All the above examples of imperfections that prevail in the real world point out that financing matters. To put it in the words of Myers (2001, p. 85): "[A]fter all, the values of pizzas *do* depend on how they are sliced" [emphasis in the original].

The dissertation is structured as follows. In the first part, we consider the consequences of a deviation from the notion of perfect markets à la MM induced by the presence of asymmetric information between market participants. Specifically, we present in detail the much-quoted model of Myers and Majluf (1984) that assumes that corporate managers are better informed about the value of the company than outside investors. The latter consider purchasing fresh equity to be issued by the company for reasons of financing an investment that is *known* to have a non-negative net present value [NPV]. As we will see, managers, who are assumed to act exclusively in the interest of the original shareholders, pass up a profitable investment opportunity in some circumstances, for it would harm the original owners otherwise. This is because the market may misprice a particular issue due to the informational asymmetry such that the old stockholders would be forced to give up too big of a part of the firm by issuing shares so as to still make the investment project a profitable venture for them. Not undertaking a worthwhile investment opportunity is what we will be referring to as "underinvestment" throughout this dissertation. Once alternative modes of financing (e.g., debt) are introduced, we will come to know that capital structure *does* matter in the model of Myers and Majluf (1984). Different securities have different value implications in that the announcement of their issue causes share price reactions of varying degree, thus either exacerbating or alleviating the mispricing. Furthermore, we will consider the influence of negative-NPV investments on the conclusions of the model. As we will see, managers may rationally decide to undertake a (seemingly) bad project.
The theory leads to several testable hypotheses. We provide an extensive literature overview that presents the major empirical results. While the model does exceptionally well at explaining share price movements upon the announcement of a new security issue (depending

on the kind of security), its performance is unsatisfactory when it comes to explaining why corporations choose the securities they issue. The section concludes by reconsidering whether the irrelevance of financing can be restored.

In the second part, we reveal that corporate underinvestment is not confined to the presence of asymmetric information. To the contrary, it can also arise when all market participants are equally well informed. The seminal paper in this regard comes from Myers (1977). He shows that all that is necessary for underinvestment to occur is the assumption that the management of a firm levered with risky debt acts exclusively in the interest of its shareholders. By the use of a numerical example, we will show that the intuition of the model is straightforward. Imagine a firm that has the chance to undertake a profitable new investment opportunity that is risk-free, i.e., a sure increment in firm value. If, however, a state materializes in which the company's value is well below the face value of the outstanding debt, managers will rationally decide to pass up the opportunity because it would harm shareholders, who have to provide the funds. If the investment's NPV is not enough to raise the firm's value above the face value of debt, then it entirely goes to enhance the debtholders' claims. In such a scenario, shareholders have no interest in investing, and a good opportunity vanishes. Thus, preexisting debt causes a financial distortion to corporate investment. This represents (once again) a clear deviation from MM's irrelevance proposition: the market value of the firm *is* dependent on its capital structure. Here, excessive leverage alters the firm's investment scheme to the worse. If the firm were financed completely with equity, it would always invest, for the NPV would entirely go to shareholders. A broad overview of the existing literature will show that this type of underinvestment is in fact a real-world concern. For example, economists regularly invoke its detrimental effect on investment as a justification for providing debt relief (to corporations, financial institutions, households as well as entire countries).

In the third and main part, we will apply Myers' (1977) underinvestment problem in the reconstitution of damaged assets, as first considered by Mayers and Smith (1987). The worthwhile investment opportunity the firm faces in this scenario is accounted for by the fact that the firm is assumed to be able to rebuild its assets for an investment cost that is lower than the actual damage. That is, rebuilding has a positive NPV. Yet management will in some states of the world refrain from investing if the firm is levered with risky debt. Unless it purchases casualty insurance. As we will see, an appropriately structured insurance contract completely removes the underinvestment problem and, thus, restores the first-best

firm value, irrespective of the amount of risky debt the firm has in its capital structure. However, this result prevails only as long as the insurance company does not include a safety loading in the insurance premium. For Schnabel and Roumi (1989) show that, in this case, the conclusions of the original model do not hold any longer in that the firm abstains from acquiring insurance coverage for some levels of risky debt. This is where the contribution of this dissertation comes into play. It holds true that a safety loading *may* alter the conclusions of the original model. However, we provide proof that, if it does, the correct outcome from Schnabel and Roumi's (1989) model is exactly the other way round. The results we present have economic meaning. Specifically, given a sufficiently high safety loading, we show that there is a critical level of debt above which the firm stops to take out casualty insurance. Shareholders of a highly levered firm have little stake in the company. If, in addition to that, the insurance company charges a high safety loading, which represents a deadweight loss to shareholders, then they have no interest in saving a company from default that basically does not belong to them. They rather take their chances, and make use of their option to default if a bankruptcy state materializes. By contrast, shareholders generally acquire insurance coverage for low levels of risky debt. We establish the proof for two settings. One is general, while the other is for a special case that considers uniform state prices. We do so because the latter both offers better intuition and provides neat graphical representations.
We further contribute to the existing literature by incorporating bankruptcy costs into the underinvestment model in the presence of a safety loading. As we will see, such costs have an influence on the firm's decision to insure. We close another research gap by explicitly considering the effects of a safety loading in the "financing condition" interpretation of the model that was first provided by Garven and MacMinn (1993) in a follow-up paper to Mayers and Smith (1987). This setup allows the face value of debt to change with the insurance/no-insurance decision. We show that our main result also holds under this alternative financing assumption.

Throughout this text, it will become clear that underinvestment remains an active and wide area of research. It is applied in many different areas of economics, ranging from financial to development economics. By providing the new insights concerning corporate underinvestment and casualty insurance, a small contribution to current research is made by this dissertation.

Part II

Corporate Underinvestment and Asymmetric Information

2 The Myers and Majluf (1984) model

"Asymmetric information" is merely a fancy phrase to express that one party has more information than another. "I know more than you do". In a perfect capital market, there is, inter alia, no such thing as asymmetric information. Every single piece of information is readily and costlessly available to everybody.[2] If this were indeed the case in reality, it would imply that, for instance, high ranking managers of a firm, who deal with internal corporate matters on a daily basis, have exactly the same level of knowledge about the value of their own company as random outside investors, say, investment bankers. In reality, however, the latter, being institutional investors, spend a considerable amount of resources – this cuts out the "costlessly"-part – and time – this cuts out the "readily"-part – on trying to lay their hands on the very information in possession of the firm's management. Still, even when ignoring the costs and the delay in time, is it reasonable to assume that investors can really succeed in gathering all of it? Common sense tells us that, generally, the answer must be: no. For example, why else would there be laws against insider trading in real life? What is more, for a great number of companies, maintaining an informational advantage and keeping this firm-specific information from the market and, by implication, their competitors is the source of economic success.[3] Therefore, it sounds like a good idea to ease this strict assumption of perfect information — exactly what Stewart Myers and Nicholas Majluf set out to do in their 1984 paper. They examine how the presence of asymmetric information, in that managers have knowledge about their firm's payoffs ahead of the market, alters the firm's decision to invest, given the investment needs to be financed by issuing new shares.[4]

[2] The characteristics of perfect capital markets are explicitly laid out in Miller and Modigliani (1961, p. 412), along with an explanation of "rational behavior".

[3] For a deeper insight into the importance of information and its interrelation with corporate success, which constitutes a research area in the field of business administration, see, e.g., Porter (1985).

[4] As mentioned by Myers and Majluf (1984, p. 196) themselves, their paper, like so many others, traces back to Akerlof's (1970) pioneering work on asymmetric information in the market for used cars — the famous

Model setup and assumptions are laid out in the next section. Intuitively, however, a major result of this equilibrium model is easy to grasp right away: once potential new investors cannot be certain about a firm's value anymore, they become suspicious whenever management announces that it wants to raise funds by issuing new shares. "Suspicious" in that they will presume the new shares are overvalued and that management wants to take advantage of their relative ignorance. As a consequence, the market revises downwards the price it is willing to pay for the new stocks. If the accompanying decline in firm value is too large, the firm will refrain from offering new shares in the first place. In consideration of these adverse effects of fresh equity, an opportunity for new debt as a substitute means of financing could open up in the quest for securities less prone to asymmetric information. Let us have a look.

2.1 Model setup

In our model world, there are three dates: $t = -1$, $t = 0$ and $t = +1$. There are three types of risk-neutral actors: a firm's managers, its shareholders and outside investors ("the market"). While the information about the firm's value is the same for all parties at $t = -1$, the informational asymmetry is incorporated at $t = 0$, when management receives new information that the market does not learn until $t = +1$. That is, at $t = 0$, and at that date only, management is better informed. Informed about what exactly? The true value of the firm. Consider a company that is made up of an asset in place [AIP] and an investment opportunity. The potential values of the former at $t = 0$, labeled a, are represented by the distribution of the random variable $\widetilde{A}$. The realization a is yet unknown to both management and outside investors at $t = -1$. With each party being aware of the distribution of $\widetilde{A}$, everyone rationally agrees that the value of the AIP at $t = -1$ is the (unconditional) expected value $\overline{A} = E(\widetilde{A})$.[5] The realization a becomes known to management at $t = 0$, whereas it takes the market until $t = +1$ to find out about it. The same logic holds true for the NPV of the investment opportunity, the second (potential) contributor to firm value. Possible NPVs at $t = 0$ are described by the distribution of the random variable $\widetilde{B}$, which again is known to both management and outside investors from the beginning, so that the market value at

lemons problem. For a discussion of the overall significance of the economics of information for modern-day economics, see Stiglitz (2000). Of course, asymmetric information is just one way of introducing a market imperfection among many others. See, e.g., Calcagnini and Saltari (2009) for a compilation of different market imperfections and their influence on economic decision-making.

[5] As most of the times in economics, we, too, impose that individuals act rationally. They behave like the notorious *homo oeconomicus*. If you are not a friend of the concept of rational behavior as it may not always represent actual human characteristics, it might provide at least a little bit of relief to know that the concepts presented here (and elsewhere in economics) would totally work on the planet Vulcan from the fictional Star Trek Universe. Think of the famous Mr. Spock. The planet's inhabitants, Vulcans, are guided by pure logic and rationality. This is also the reason why they completely suppress their feelings.

$t = -1$ is $\overline{B} = E\left(\widetilde{B}\right)$. The actual project NPV, b, is known to managers from $t = 0$. The market needs an extra period to find out about this information.

We assume the firm does not have enough internal funds to finance the growth opportunity entirely by itself. Rather, these internal funds, C, are used to draw down the (residual) amount to be raised through a public stock issue (debt will be considered later on). In other words, the firm needs to conduct a seasoned equity offering, more commonly known as SEO. As mentioned by Myers and Majluf (1984, p. 190), internal funds – the authors call them *financial slack* – are composed of cash at hand, marketable securities and the amount of risk-free debt the firm can issue (more on the latter later). The amount raised in equity is denoted by E. Referring to the investment necessary to finance the growth opportunity as I, it follows that $E = I - C$, where $C < I$. The project is non-divisible, investing in part of it is not possible. Given this information, we make a distinction between old shareholders, i.e., the ones holding stocks at $t = -1$, and new shareholders, those buying the new stocks in case of an issue. Initially, there is no risky debt in the firm's capital structure. Managers decide on whether to pursue the investment opportunity at $t = 0$, *after* they have come to know a and b. If they wish, they have the option to let the opportunity pass, without it ever coming back (the reasons to be explained in a moment). The investment is "now or never". Thus, if decided against, there will be no issue of new shares and no NPV b accruing to the firm.[6]

Additionally, the realized values of the AIP and NPV are assumed to be non-negative, i.e., $a \geq 0$ and $b \geq 0$. In other words, the distributions of $\widetilde{A}$ and $\widetilde{B}$ each are truncated at zero. This is not surprising, once considering that managers decide on the investment project *after* learning its true NPV. For if it were negative, they would simply choose not to take on the project. Limited liability guarantees that the lowest value the AIP can take on is $a = 0$. The non-negativity assumption is a major point of importance to the model. Later on, we will explore the consequences of relaxing it.

In traditional finance theory, the NPV of an investment is the crucial decision criterion. One is to invest in every project that has a positive NPV. When NPV is zero, there is indifference between investing and not investing. In that case, we assume that the firm will still go on with the project[7]. Since $b \geq 0$, one is tempted to think that the firm should always invest.

[6] Morellec and Schürhoff (2011) present an adaption of Myers and Majluf's (1984) model where this assumption is dropped. Instead, they offer a real options framework that allows for flexible timing of the investment project. In this scenario, the timing becomes vital as it acts as a signal of firm quality to the market. Specifically, good firms may separate from bad ones by (costly) speeding up investment, thus impeding mimicking behavior on behalf of firms of worse type.

[7] See Berkovitch and Israel (2004) for a model suggesting that NPV may turn out to be an ineffective tool in a firm's capital allocation process in the presence of agency problems between different levels of management.

As we will see, however, this is not the case here — classical finance theory does not apply. We will refer to firm value when always investing as "status quo". If management decides against the positive-NPV project in only one situation, this poses a deviation and, thus, a loss in firm value relative to status quo.

One crucial assumption is that management works exclusively in the interest of old shareholders — "old shareholder value maximization", so to speak. In other words, objectives of management and old shareholders are perfectly aligned such that conflicts of interest between them, as initially and best described by Jensen and Meckling (1976), are irrelevant.[8] The market is aware of this fact. Managers themselves do not own any stocks, neither do they participate in a potential issue of fresh equity.[9] If management were allowed to trade, this would further complicate matters because the amount of new securities bought would act as a signal to the market.

As indicated above, management may not always decide to invest. Therefore, we need a differentiation of share value conditional on the outcome of the firm's issue-invest decision. We refer to the market value of old shares at $t = 0$ as P' in case of an SEO. If the firm decides not to invest, the market value at $t = 0$ of the old (and only) shares is denoted by the letter P. Management's objective of exclusively maximizing old shareholder value gives rise to a conflict of interest between the two shareholder groups (if there are two). Herein also lies the explanation for why the firm, i.e., its managers, may not always reach for status quo. Correct, if the aim were to maximize *firm* value, then, since $b \geq 0$, management would always have to invest as it faces a net contribution to firm value. Maximizing company value is not their objective, however. They would only do so if it were equivalent to maximizing the old shareholders' *true* value, i.e., the value that becomes known to the market at $t = 1$. This is generally not the case in the model: when managers learn a and b at $t = 0$, they must make the issue-invest decision. The problem they are facing is that (generally) the *market* value of

According to the authors, other common capital budgeting measures, such as the internal rate of return, do a better job in maximizing firm value.

[8] This is a strong assumption indeed. Noe and Rebello (1996), for example, abandon it and allow for agency problems caused by the incompatibility of interests. In pure agency theories, for instance Jensen (1986), managers usually posses a unique skill set and, therefore, seek to secure rents for themselves as they want to increase their personal wealth, giving rise to agency costs. The novelty introduced by Noe and Rebello (1996) is that they combine these agency considerations with the adverse Myers-Majluf-style effects that result from information asymmetries between inside and outside investors regarding a profitable investment opportunity. Whether debt or equity is used to signal firm quality critically depends on who is in charge of financial policy, i.e., whether share- or bondholders control corporate investments. The two groups face tradeoffs between different costs in coming to a decision.

[9] In a related model setup, Bradford (1987) examines what happens when managers are owners themselves and also get to trade in the company's shares during a stock issue used to finance a worthwhile investment opportunity. There, too, the investment is not always undertaken. Share price may rise, fall or stay unchanged. See Fields and Mais (1994) and Bigelli et al. (1999) for empirical examinations of managerial ownership and trading behavior during SEOs.

the old shares and their *true* value will not be one and the same at that time. Only managers know the intrinsic value[10] of old shares at $t = 0$, which they aim to maximize. It holds true that the market will come up with exactly the same price tomorrow – but not today ($t = 0$). Therefore, acting rationally and knowing the joint distribution of $\widetilde{A}$ and $\widetilde{B}$, outside investors have to resort to expected values at $t = 0$ in assessing the price (estimate). This generally causes a discrepancy between true and market value, resulting in over- or undervaluation of the shares. And this is where it gets interesting. Managers may be put in a situation where the firm at $t = 0$ is (rationally) undervalued such that, if it went ahead and issued shares, it would have to sell them for a bargain.[11] Once the market, given a share issue, learns the true value of the firm at $t = 1$, the formerly underpriced new shares rise in value.[12] Since intrinsic firm value, i.e., $E + C + a + b$, is fixed, this gain must come from the old shareholders. "The 'wrong' price for a security issue does not affect firm value. It just transfers value from some securityholders to others" (Myers and Majluf, 1984, p. 213). That is, there is a transfer of value from old to new shareholders (the opposite holds true in the case of formerly overpriced new shares) and, thus, a dilution of the wealth of old claimholders. Clearly, this cannot be in the interest of original shareholders, since the transfer constitutes a cost to them. At the same time, they do want the NPV from the investment project. This is the tradeoff faced by management. If the (dilution) cost of issuing undervalued shares, i.e., the transfer of value, is greater than the gain to old shareholders, i.e., the investment opportunity's NPV, then managers will decide not to undertake the project. They will, in equilibrium, let a worthwhile opportunity pass by. Project NPV acts as a cushion to investing, which is why management, ceteris paribus, prefers highly profitable investment opportunities.

Furthermore, potential new shareholders, knowing that management acts in old shareholders' interest, correctly infer from an announcement of an SEO that it must be beneficial to old shareholders. This causes them to update (downwards) the price they are willing to pay for the new shares, which in turn may effect management's decision to issue and invest in the first place, as we will see.

[10] In the words of Myers and Majluf (1984, p. 191): "Here 'true' or 'intrinsic' value means what the shares would sell for, conditional on the firm's issue-invest decision, if investors knew everything that managers know". Put more simply, given a decision on the investment, the true value is the value that managers know today, and the market will learn tomorrow.

[11] One might wonder how this is possible, since the amount E to be raised in the issue is fixed: correct, E is exogenous, but the number of shares necessary to raise that amount is not. Thus, given undervaluation, the firm needs to issue a greater amount of shares in order to raise E. Accordingly, the proportion of the firm's shares held by old shareholders is lower in case of underpricing (cf. Myers, 1984, p. 583-84).

[12] This is one of the differences to Akerlof's (1970) setup where a single good (car), whose quality is not verifiable by the buyer, is sold. Here, two goods are sold not in full, but partially, namely claims to the AIP and to the investment project. Informational asymmetry regarding true value prevails for both of them (cf. Myers, 1984, fn. 12, p. 583).

Financial markets are assumed perfect, except for the informational asymmetry. Notably, this implies that there are no taxes. Accordingly, debt cannot create valuable tax savings (interest tax shields) due to the fact that interest deductions diminish taxable corporate income. Nor are there costs of financial distress or transaction costs associated with issuing shares. "We assume capital markets are perfect and efficient with respect to publicly available information" (Myers and Majluf, 1984, p. 190).

The only source of risk (to undertaking a worthwhile investment opportunity) considered in the model stems from the informational asymmetry between insiders and outsiders. Hence, there is no need to be concerned about adjusting for risk when discounting future cash flows. In fact, there is no discounting at all: "The future values could be discounted for the time value of money without changing anything essential" (Myers and Majluf, 1984, p. 190).

One final assumption is that old shareholders do not buy (part of) the new issue, i.e., they are passive. Neither do they sell some (or all) of their shares. Original shareholders hold on to their claims until the end of the last period, when the company is liquidated. Hence, it is guaranteed that the groups of old and new shareholders are not one and the same, which allows us to focus explicitly on the conflict of interest between the two.[13]

Finally, note that we speak of *the firm*, i.e., we use singular. There is no multiplicity of different firm types such that there exist good, mediocre and bad firms, depending on their cash flow distribution. This point has been subject to criticism, see, e.g., Nachman and Noe (1994, p. 3), who state that, typically, in the presence of asymmetric information "...the market's beliefs regarding the productivity of the issuing firm are part of the equilibrium outcome and cannot be fixed exogenously". Therefore, Nachman and Noe (1994), among others, develop a model which incorporates firm types of varying productivity. Most prominently, Greenwald et al. (1984), around the same time as Myers and Majluf (1984), present a (complex) model that considers equity markets as a source of financing to complement Stiglitz and Weiss' (1981) well-known result of credit rationing in debt markets. Their conclusions are similar in that financing via equity is perceived as bad news by investors in the presence of asymmetric information. In their model, only bad firms seek equity financing. Good firms use the debt market, even though they have to accept bankruptcy costs. Necessarily, such an advancement increases model complexity. The beauty of Myers and Majluf's (1984) model is its simplicity.

In the following, we will formally derive the three fundamental results of the model: firstly, we will show that asymmetric information may prompt the firm to pass up the opportunity. Since firm value is reduced relative to status quo, this is what we refer to as underinvestment.

[13] Note that this assumption is crucial to the model outcome. For a comprehensive discussion of passive versus active shareholders, we refer to section 4 in Myers and Majluf (1984, pp. 210-14).

Secondly, we will explain why stock prices fall upon an issue announcement. And lastly, the advantages of debt financing and its implications for corporate capital structure will be presented.

2.2 Underinvestment — the model

As already noted, an issue of new shares is necessary because we assume that $C < I$. Internal funds ("cash") must be non-negative, such that we have $0 \leq C < I$. The more internal funds there are, the less new equity, $E = I - C$, is necessary. We stated that managers maximize old shares' true value, which they come to know at $t = 0$ when learning the realizations of $\widetilde{A}$ and $\widetilde{B}$, i.e., a and b. But how exactly do we determine the true value? Keeping in mind that we may or may not have an issue of new shares, it must hold true that, since managers may let some opportunities pass by, we need two "true" values conditional on the firm's issue-invest decision. If the firm chooses not to issue, it keeps its internal funds in the cash box, issues no equity and obtains no NPV. Along with the asset already in place, this yields a true value of

$$V^{old}_{no\ issue} = C + a. \tag{2.1}$$

Due to that fact that no new shares are issued, this is also the intrinsic *firm* value. In case the company decides to invest, it issues equity worth E. On top of that, it receives the NPV b. Thus, the intrinsic value of the firm is $V^* = E + C + a + b$ in the event of an issue. Since $E = I - C$, rewriting yields $V^* = I + a + b$, where $I + b$ constitutes the *gross* present value from investing. Firm value is thus comprised of the AIP plus the entire cash flows from the investment project. Obviously, this cannot belong to old shareholders alone. Now, they have to share with the new stockholders. Therefore, we have

$$V^* = V^{old}_{issue} + V^{new}.$$

Conditional on an issue, the intrinsic value of the firm (which managers know at $t = 0$ and the market learns at $t = 1$) is the sum of the true values of the old and the new shares, to be specified subsequently. It is clear that the two shareholder groups each hold a proportion of V^*. The weights must be the fractions of all shares held by the respective group. Thus, the post-issue weighting for old shareholders is $\frac{P'}{P'+E}$. Accordingly, their intrinsic value is given by

$$V^{old}_{issue} = \frac{P'}{P'+E}\left(E+C+a+b\right). \tag{2.2}$$

Following the same logic, the fraction held by new shareholders $\frac{E}{P'+E}$.[14] It follows that the true value of the new shares is

$$V^{new} = \frac{E}{P'+E}\left(E+C+a+b\right). \tag{2.3}$$

Again, both theses values are already known to management at $t=0$. Generally, they will not equal their respective market counterparts at that time. For outsiders to find out about (and agree with) V^{old}_{issue} and V^{new}, it takes another period.

Management, when learning a and b at $t=0$, must decide on whether to issue or not. They will do whatever yields the higher intrinsic value to old shareholders. Therefore, it follows that the issue will only be executed in case it holds true that $V^{old}_{no\ issue} \leq V^{old}_{issue}$, i.e.,

$$C+a \leq \frac{P'}{P'+E}\left(E+C+a+b\right).$$

Combining the two $(C+a)$-terms allows us to express this inequality equivalently as

$$\frac{E}{P'+E}\left(C+a\right) \leq \frac{P'}{P'+E}\left(E+b\right) \tag{2.4}$$

Presented in this manner, there is a nice interpretation: $C+a$ on the left-hand side is the true value of the firm already in place, i.e., excluding the investment project, cf. equation (2.1). If undertaken, investment causes firm value to increase by $E+b$, as seen on the right-hand side. Combined with the respective weightings, as found in (2.2) and (2.3), the inequality tells us that the firm will issue and invest if the share of the increase in firm value received by old stockholders is greater than the share of "old" firm value going to new stockholders via the transfer of value (that is, old shareholders lose part $1-\frac{P'}{P'+E}$ of the pre-issue firm to the new co-owners). In short, old shareholders need to gain more than they lose in order for the SEO to be conducted. Rewriting the condition yet another time yields $\frac{E}{P'}\left(C+a\right) \leq \left(E+b\right)$

[14] At first, it seems strange that the fractions are not expressed in terms of number of shares such that, say, the fraction held by new shareholders is the number of new shares divided by the overall number of shares after the issue. Myers and Majluf (1984) do not provide an explicit explanation. Let o denote the number of old and n the number of new shares. It follows that the fraction of shares held by new shareholders is $\frac{n}{o+n}$. The market value of old shares at $t=0$ is P' conditional on an issue, while the corresponding value is E for new shares. Obviously, stocks must trade at the same price once issued (for reasons of arbitrage). Therefore, price per share is $\frac{P'}{o}=\frac{E}{n}$. Staying with the new stockholders, rewriting their fractional ownership yields $\frac{n\frac{E}{n}}{(o+n)\frac{E}{n}}$ and, hence, $\frac{E}{o\frac{E}{n}+E}$. Since $\frac{P'}{o}=\frac{E}{n}$, we ultimately have $\frac{E}{P'+E}$, as presented in equation (2.3) Accordingly, the fraction is $\frac{P'}{P'+E}$ for old shareholders, cf. (2.2). There is no need to introduce the number of shares.

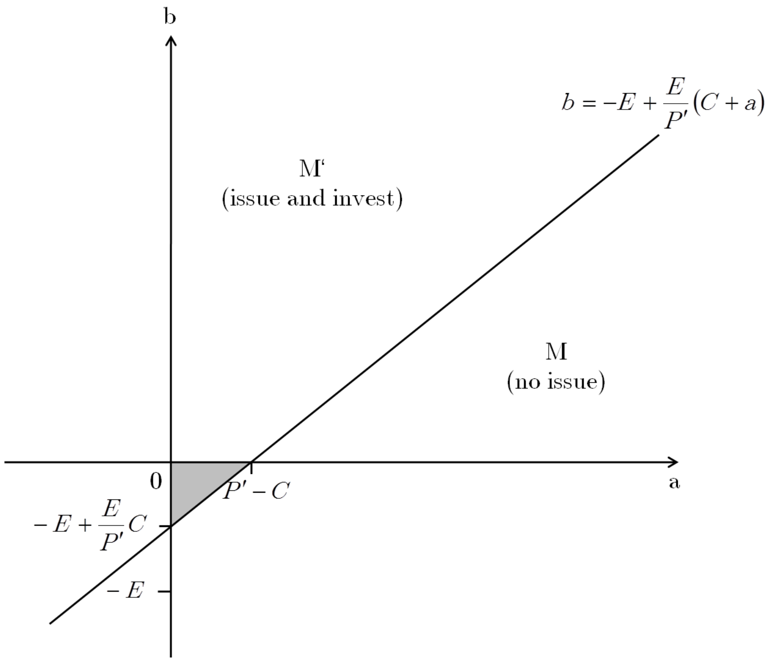

Figure 2.1: The Issue-Invest Decision Faced by Managers at $t = 0$.

and, thus,

$$\frac{E}{P'}C - E + \frac{E}{P'}a \leq b.$$

As long as the project's NPV is large enough, the firm will issue shares and invest. Given this inequality, the issue-invest decision is nicely depicted in an (a, b)-diagram. See Figure 2.1, which follows Myers and Majluf (1984). Graphically, the line

$$b = -E + \frac{E}{P'}(C + a) \tag{2.5}$$

represents those (a, b)-combinations for which the firm is just indifferent between investing and not investing (and will, per assumption, settle for an issue). It represents the investment-indifference line.

From the last inequality, the firm issues for all (a, b)-combinations falling into the region on and above the indifference line , denoted by M', in Figure 2.1. Recall that we restricted a and b to non-negative values. Therefore, all realized combinations of the random variables $\widetilde{A}$ and $\widetilde{B}$ must not lie outside the first quadrant in the figure. As a result, the shaded, triangle-shaped area below the a-axis and (on and) above line $b = -E + \frac{E}{P'}(C + a)$ is not part of region M'.

If, on the other hand, (a, b) falls into region M, managers will forgo the valuable investment opportunity as doing so would only harm old stockholders because the firm would issue shares that are undervalued too heavily.[15] This is also the reason why, as can be seen in Figure 2.1, the firm will only issue shares when b is high enough (for a given a) in that (a, b) is located on or above the investment-indifference line: the gain from investing is large enough to outweigh the loss caused by the transfer of value to new shareholders. Generally, combinations of high NPVs and low values of the AIP make an issue of new shares most likely. When a is low, there is not much value to be transferred to new shareholders in absolute terms, while a high b leaves a lot to gain for old shareholders, cf. (2.4). Note that underinvestment occurs whenever an (a, b)-realization is located in region M — firm value is reduced relative to status quo; the classical paradigm to invest in every non-negative-NPV project is violated.

Figure 2.1 is also useful in understanding the composition of both P', the market value of old shares at $t = 0$ when issuing, and P, the market value when not investing. Even though already used in the (in-)equations above, we have not determined these two values so far. First of all, outside investors are not stupid. To put it simply, Figure 2.1 is not exclusively known to management, but also to the market. Remember that outsiders are aware of the joint distribution of $\widetilde{A}$ and $\widetilde{B}$. They can thus tell which of them fall into region M and M', respectively. Therefore, once management has decided on an action, there is no need to incorporate all possible realizations of $\widetilde{A}$ and $\widetilde{B}$ into the market's price estimate when establishing the expected values of AIP and NPV. A public announcement at $t = 0$ to issue stocks acts as a signal to the market. Outside investors learn from this decision that the realized combination of a and b must obviously lie (on or) above the indifference line, i.e., in region M'. This leads them to update their estimate of existing shares' intrinsic value (the market value). Given an issue announcement, investors rationally establish the expected values of both the AIP and the NPV solely over those realizations that fall into region M'. Define the expected values conditional on an issue announcement by $\overline{A}\,(M') \equiv E(\widetilde{A} \mid E = I - C)$ and $\overline{B}\,(M') \equiv E(\widetilde{B} \mid E = I - C)$, where $E = I - C > 0$. It follows that the market value of old shares when investing at $t = 0$ is given by the equilibrium value

$$P' = C + \overline{A}\left(M'\right) + \overline{B}\left(M'\right). \tag{2.6}$$

Generally, the true value, which the market does not learn until $t = 1$, will not coincide with this market value. P' is correct on average, however. It is the rationally formed expectation

[15] An overvaluation obviously is in the interest of managers. New shares are sold for more than they are actually worth. Once the overvaluation becomes known at $t = 1$, new shareholders suffer a capital loss because the share price shifts to its intrinsic value as all the informational insecurity is resolved. In that case, there is a transfer of value, but "the other way round", i.e., from new to old shareholders.

over all possible intrinsic values in subregion M'.[16] Note that the same holds true for new shares' market value E: although a certain SEO will be mispriced, there is no systematic capital gain to be made. In an equilibrium with a stock issue, outside investors do not expect a change in the value of new equity from $t = 0$ to $t = 1$. Managers know the actual change from $t = 0$ on.

The reasoning just applied also holds true for the market price of the old shares in case the firm decides not to issue. In determining the market value of the AIP, only those realizations lying below the indifference line in Figure 2.1 are taken into account (there is no need to compute the expected value of the NPV over all realizations lying below that line, since there will be no investment and, thus, no NPV when there is no issue). The absence of an announcement to issue acts as a signal, too. In this case, it tells outside investors that the realized values of a and b do not satisfy the requirement for an issue, as given by inequality (2.4). We define the expected value of the AIP conditional on no issue of new shares as $\overline{A}\,(M) \equiv E(\widetilde{A} \mid E = 0)$. Note that the conditional expected values, i.e., $\overline{A}\,(M')$, $\overline{B}\,(M')$ and $\overline{A}\,(M)$, contain all the information at hand to *outside* investors at $t = 0$, namely the joint distribution of AIP and NPV as well as either the announcement to issue and invest or the decision not to issue. It follows that the old (and only) shares at $t = 0$ are worth

$$P = C + \overline{A}\,(M) \tag{2.7}$$

when the firm does not invest. That is, the conditional expected value of the AIP plus the cash at hand. Since there is no stock issue, this value furthermore equals the overall market value of the firm at $t = 0$. The firm itself may still be under- or overvalued, but it has no consequences for the owners because there exist no new shares to/from which wealth could be transferred.

The values of both P and P' are governed by the (a, b)-combinations and their respective probabilities of falling into regions M and M'. In other words, they depend on the joint probability density function of $\left(\widetilde{A}, \widetilde{B}\right)$. Likewise, the boundary of both regions itself depends on P', cf. equation (2.5). As mentioned by Myers and Majluf (1984, p. 201), this implies that the equity values P and P' and the regions M and M' are determined simultaneously.[17] Once

[16] Only if the firm were to always invest, i.e., not let a single project pass, then the (status quo) value of old shares would equal $P' = C + \overline{A} + \overline{B}$. The issue announcement would be fully anticipated, and no signal sent to the market. Hence, we implicitly assume that region M carries positive probability mass, so that underinvestment may actually occur.

[17] Consider this small thought experiment to clarify the point: based on Figure 2.1, assume that the line parting the two subregions had the same intercept, but was modified to be just a little flatter. Now, more (a, b)-realizations would fall into region M', altering P' (and thus P) because the conditional expected values $\overline{A}\,(M')$ and $\overline{B}\,(M')$ would be calculated over more (a, b)-combinations than before. From (2.5), this would

again, keep in mind that P and P' reflect *all* information possessed by outside investors. Myers and Majluf (1984, p. 203) themselves say it best: "They are rationally-formed, unbiased estimates of the firm's decision *rule* as well as its decision" [emphasis in the original].

Before we go on to examine the share price reaction to an issue announcement, let us briefly refer to an interesting statement made by Myers and Majluf (1984, p. 203) about the impact of informational asymmetry in the model: "One insight of the model is that you need asymmetric information about *both* assets in place and investment opportunities to get interesting solutions" [emphasis in the original]. The best way to grasp this point is by using the following example: suppose there is no asymmetric information regarding the true value of the AIP. Everybody learns a at $t = 0$. The market is merely confronted with not knowing b before $t = 1$. Equation (2.6) becomes $P' = C + a + \overline{B}\,(M')$, where a has replaced $\overline{A}\,(M')$. Rewrite (2.4), the condition for an issue, as $E\left(\frac{C+a}{P'}\right) \leq E + b$. We know that $\overline{B}\,(M') \geq 0$ in the P'-equation because $b \geq 0$ per assumption. It follows that $P' \geq C+a$ and, thus, $\frac{C+a}{P'} \leq 1$. In that case, the issue-invest inequality is always satisfied as $\left(\frac{C+a}{P'}\right) E \leq E$ and $b \geq 0$. In other words, when there is no informational asymmetry concerning the value of the AIP, the firm will always decide to issue and invest. Status quo prevails because there is no underinvestment and, consequently, no problem (despite the informational asymmetry regarding the project's NPV). Worthwhile investments are always carried out. Consequently, the value of the old shares is given by $P' = C+a+\overline{B}$. Since the firm *always* invests, the expected value is computed over all realizations b, and conditional and unconditional expected values coincide. Note, however, that an issue can still be under- or overvalued in such a situation. This may occur via $b > \overline{B}$ or $b < \overline{B}$, respectively. The point is that now there is always some (net) value to gain for old shareholders (and none to lose from the AIP). Therefore, asymmetric information about a *and* b at $t = 0$ is imperative for underinvestment.

2.3 Why an issue announcement is perceived as bad news

The heading forecloses the result: share price will always drop upon management's announcement to issue and invest. Mathematically, we have to show that $P' < P$ to prove this assertion.[18] The proof is easy. Check Figure 2.1 again. The indifference line crosses the abscissa

alter both the intercept and slope of the indifference line, which again would modify the values P' and P, and so forth. Therefore, the values are determined simultaneously.

[18] The number of old shares is fixed. Therefore, when the value of old shares given investment, P', is less than that when not investing, P, the same holds true for the price of a single share. Note that these two share prices would coincide if region M indeed carried no probability mass because then the market would know for sure that the firm will invest such that there is no information to be inferred from an issue announcement to update the price estimate.

at $a = P' - C$. This follows from setting $b = 0$ in equation (2.5) and solving for a. Graphically, if the (a, b)-combination falls into the no-issue region M, the firm does not take any action. Most importantly, the figure tells us that region M only "commences" to the right of $a = P' - C$. Consequently, every single a-value to be found in M must exceed $P' - C$. $\overline{A}\,(M)$ is the expected value of all these realizations in M. Hence, it must be greater than $P' - C$, too. Additionally, we know from equation (2.7) that this conditional expected value is given by $\overline{A}\,(M) = P - C$. Taken together, it follows that $\left(\overline{A}\,(M) =\right) P - C > P' - C$ and, hence, $P > P'$. This completes the proof.

Let us focus a little more on the intuition behind this important result. Why should the stock price fall when management announces that it will pursue an investment project that the market *knows* has positive NPV? For a start, Myers and Majluf (1984, p. 203) offer the following statement: "P exceeds P' because investors rationally interpret the decision not to issue as good news about the true value of the firm". By implication, a decision to raise new capital must convey (relatively) bad news. We have already mentioned why this is the case: a decision to issue, i.e., (a, b) falling into M', will be interpreted as an attempt by management, which works for old stockholders, to rip off the market by issuing overpriced shares, leading to a loss for the new owners at $t = 1$, when the true value is revealed. A decision not to issue sends a signal of good news regarding the firm's true value to the market, which is why P exceeds P': the (preannouncement) firm must be worth more than what the market thinks, since only this situation will lead management, whose decision-making rule (2.4) is well known, to decide against the worthwhile investment. The transfer of value from old to new shareholders would be too large in that it would outweigh the gain from investing. The consequence is that management refrains from issuing shares.

One other point helps to clarify. Recall that $b \geq 0$. Now, what if $b = 0$ in some circumstances?[19] The investment project is neither bad nor good. It simply is a zero-NPV project, not adding to (nor reducing) overall firm value. From Figure 2.1, an issue given $b = 0$ may well happen. This is because the segment on the a-axis from zero up to $a = P' - C$ is part of region M'. It follows that an issue does not necessarily signal that the firm is going after a positive-NPV project (this statement holds the more true, the higher the probability that $b = 0$ on the mentioned part of the segment). Instead, it may well be that a is low enough ($a \leq P' - C$) such that the firm even finds zero-NPV opportunities attractive. Therefore, "...the decision to issue does not signal 'positive-NPV investment' but only 'region M''" (Myers and Majluf, 1984, p. 205).

[19] For example, picture a situation in which the company cannot find profitable investment projects and, therefore, decides to deposit the money in the bank.

In case one is still wondering: note that the quote above does not imply that a firm may never pursue a "really good" investment opportunity, i.e., one with a high value of b. Such a situation may well occur. It can cause confusion, however, to understand that going after a highly profitable opportunity is not considered good news. It is good news indeed — but not at $t = 0$. The distribution of $\widetilde{B}$ (and $\widetilde{A}$) is known from $t = -1$. At that time, the market (and management) rationally determines the value of the NPV to be its unconditional expected value $\overline{B}$. Hence, all the good news of potentially very lucrative projects is incorporated into the preannouncement value already. Subsequently, the market value changes *relative* to that, depending on the issue-invest decision made at $t = 0$. "Truncating the distribution of $\widetilde{B}$ at zero means that the market anticipates a profitable new project. This positive information is reflected in the preannouncement price. Thus, when the firm announces an equity issue, the negative information concerning the overvaluation of assets-in-place overwhelms any additional positive information about the project" (Cooney and Kalay, 1993, p. 156).

2.3.1 SEO announcement returns — evidence from the real world

Stock returns following the announcements of public SEOs in the U.S. have been subject to vast empirical research. We will now give an overview of the main results. Generally, (average) negative stock price reactions to a public seasoned equity issue have received broad empirical support, as predicted by Myers and Majluf (1984). The first studies on U.S. corporations from the 1980s and 1990s are nicely surveyed by Smith (1986) and Eckbo and Masulis (1995).[20] Both report average two-day abnormal common stock returns of the order of -3% for industrial firms. When taking into account utility companies, whose price reaction averages about -1%, the overall average amounts to -2% (where average is calculated using the individual sample sizes as weights). Consistent with these findings, Mikkelson and Partch (1988) observe that cancellations of previously announced SEOs are followed (on average) by a significantly positive valuation effect.

While -3% may seem like a small reduction at first sight, it really is not. It is important to remember that this decline applies to the *entire* (pre-issue) equity market value. Asquith and Mullins (1986) relate this reduction in dollar value on the announcement day to the proceeds obtained in the subsequent SEO. They conclude from their sample ($N = 121$) that, on average, an amount corresponding to 31% of the funds raised in the SEO is lost. Eckbo et

[20] Asquith and Mullins (1986), Masulis and Korwar (1986) and Mikkelson and Partch (1986) are frequently quoted among the first to empirically investigate the stock price reaction to an SEO. Abnormal returns are calculated using event study methodology. Two-day abnormal returns usually relate to the day of the public announcement and the day before.

al. (2007) report a lower, but still impressive 15%. Since the loss occurs *at* the announcement, it obviously comes out of existing shareholders' pockets. That is, it represents a real-world measure of the dilution sustained by original owners when issuing fresh equity. Interestingly enough, in Asquith and Mullins' (1986) sample 6% of the issues involve dilution of more than 100%: the firm's market capitalization after the issue is actually *lower* than before.

More recent results – some of them surveyed by Eckbo et al. (2007) – confirm that the negative price reaction shown by common equity upon announcement is robust over time. For example, Heron and Lie (2004), Bethel and Krigman (2008), Lee and Masulis (2009) and Henry and Koski (2010) all report statistically significant negative average price reactions in the range of −2% to −3% for U.S. firms. Heron and Lie (2004, p. 630) conclude: "Overall, the evidence is consistent with the notion that managers make decisions related to equity offerings that maximize the value for existing shareholders".

Note that the smaller market reaction associated with utility offerings mentioned above is not evidence against, but rather in favor of the underinvestment theory. As explained by Eckbo and Masulis (1995, pp. 1049-50), "[T]he investment and financing decisions of utilities are highly regulated, and public knowledge of regulatory policy lowers the probability that a utility announcing a stock offer is attempting to take advantage of an informational asymmetry in the stock market". Consistent with this, Polonchek et al. (1989) report that U.S. commercial banks' stock prices are significantly depressed upon SEO announcements, but to a lesser extent than shares of industrial firms. Such weaker reactions are attributed to the fact that the commercial banking sector is subject to tight regulations (regulatory capital, leverage ratios, etc.). More evidence along these lines comes from an interesting study by Cornett and Tehranian (1994), who also examine public common stock issues of commercial banks. The advantage their sample offers is that roughly half of the 491 issues are executed involuntarily because regulation authorities mandated them in order to make sure that certain capital standards would be met. Since management is hardly likely to pursue existing shareholders' interests with such offerings, they should not convey as much information according to our theory. This is how results turn out indeed. While voluntary issues show a significantly negative two-day announcement return (−1.56%) for common stock issues, mandated offerings show a significant, but less negative average wealth effect (−0.64%), where the difference between the two is statistically significant.[21] Unfortunately, this evidence is not indisputable. As part of their paper on commercial bank SEOs, Krishnan et al. (2010) redo

[21] Other types of securities are issued, too. They generally show no significant two-day abnormal return, neither in the voluntary nor in the involuntary sub-samples. The fact that we still observe a negative return of −0.64% should not be too surprising, considering that a mandated issue due to failure to meet capital standards is probably in itself not the best of signals.

Cornett and Tehranian's (1994) procedure using a sample that is smaller, but encompasses a longer time span. *Both* groups are subject to statistically significant negative announcement returns, but the difference between the two is not significant.

Krasker (1986) generalizes Myers and Majluf's (1984) model by endogenizing management's choice of the equity offer size. The author finds that larger issues are associated with greater price declines. This is consistent with empirical findings summarized by Eckbo and Masulis (1995) and Ritter (2003).
Interestingly, the announcement effect becomes significantly positive when funds are raised by public firms in a non-public offering (private placements). This is first reported by Wruck (1989) and later on confirmed in many studies, as reported by Eckbo et al. (2007).
The picture changes considerably when looking at the rest of the world (where, unlike in the U.S., rights issues are usually the predominant form of executing an SEO). For example, Cooney et al. (2003) find that announcements of public SEOs are accompanied by a significant positive stock price reaction in Japan, while Gajewski and Ginglinger (2002) find a slightly negative, but insignificant price impact following announcements by French firms. We refer the interested reader to Eckbo et al. (2007), who survey a great amount of international studies.

Choe et al. (1993) explicitly consider certain macroeconomic variables and document that the business cycle has an influence on the average SEO announcement return in that it turns out significantly less negative in economic boom phases. Presumably, there is less uncertainty associated with issuing equity because investment projects are generally of higher profitability in such periods, prompting investment even by firms of otherwise worse quality. Increased equity offering behavior is indeed reported during periods of economic upturn.
Supposedly, one possibility to decrease the informational uncertainty/asymmetry associated with an SEO is to have the issuing firm covered by financial analysts. Since their job is to produce information about the company for outside investors, this should hold the more true the greater the number of analysts in place, provided their information is not contradicting. Consistent with these predictions, D'Mello and Ferris (2000) find that the average (three-day) abnormal return surrounding SEO announcements is significantly more negative for those companies covered by a smaller number (below sample median) of analysts. It also holds true that information of lower quality, as indicated by a higher standard deviation of analysts' predicted earnings, leads to a significant valuation effect that is more negative than that of high-consensus offerings. Best et al. (2003) confirm these results. Using a sample of

717 SEOs, they determine that a sub-sample comprised of companies followed by analysts ($N = 560$) experiences a significantly less negative announcement return than its non-covered counterpart. Korajczyk et al. (1991) provide evidence that firms actively seek to minimize the degree of informational uncertainty when conducting SEOs. Supposedly, information asymmetry in the market is low (at least concerning AIPs) after the release of meaningful corporate information, such as annual reports. The authors rely on quarterly earnings disclosure statements as a proxy and find that SEOs indeed tend to cluster subsequent to these notifications. Consistent with theoretical predictions, price drops are lower the sooner after the information release the announcement is made.[22] Dierkens (1991) also finds evidence of SEO announcement clustering following earnings releases. Interestingly, firms' information policy may even assume a proactive role: Lang and Lundholm (2000) compare a small sample of 41 SEO firms and 41 non-SEO firms. They report that, starting six months prior to the issue announcement, offering companies significantly increase their information disclosure (to the extent it is legal) relative to the control sample. With these deliberate actions, firms presumably aim to bring down the level of asymmetric information by the time the offering is announced.

Henry and Koski (2010) present evidence on increased (and manipulative) short selling activity surrounding the actual issue date, while no abnormally high shorting behavior is reported at the time of the announcement. This implies that market participants generally are not privately pre-informed about an impending issue notification — a situation that would permit to earn a profit on average by taking advantage of the imminent price decline. Also, Loughran and Ritter (1995) conclude from an enormous sample of some 3,700 seasoned equity issues that a commensurate control sample of non-issuing firms considerably outperforms SEO firms in the five-year time window subsequent to the announcement. One interpretation is that the market lags behind in that it does not fully react to information at the time the offering is declared. This suggests that announcement returns would actually be a lot more negative than reported if they capitalized all information at once. However, this "new issues puzzle" is "solved" by Eckbo et al. (2000), who show that the underperformance assertion cannot be upheld once correctly adjusting the differences in risk between SEO and non-SEO firms in the econometric process leading to Loughran and Ritter's (1995) results. We advise the interested reader that there exist alternative theories that also provide solutions to the puzzle. In addition to advancing their own proposal, an overview is provided by Lyandres et

[22] The same authors one year later formalize these results in a dynamic model of time-varying asymmetric information. Even though deferring is costly, good firms will find it optimal to postpone SEOs until after the next information event, when the asymmetry about AIPs has dissolved. See Korajczyk et al. (1992).

al. (2005).

As noted by Myers and Majluf (1984, p. 195, fn. 5), a rights issue, an alternative mode of issuing fresh equity, has the potential to completely solve the underinvestment problem. When every existing stockholder makes use of his (temporarily) certified right to acquire a pro rata share of the new issue, and holds it subsequently, there effectively will be no new shareholders to whom value could be transferred. Accordingly, asymmetric information would not pose a threat to reaching status quo in the model.[23] Of course, this is likely to be impractical in real life. Some owners may not have the financial means or may follow a portfolio strategy that does not support the purchase. Nevertheless, Eckbo et al. (2007) report that various studies indicate that, in the rare event of an announcement of an uninsured rights issue in the U.S., the price reaction is neutral, while shares on average display a slightly negative performance (significant abnormal return of around -1%) when the market placement is guaranteed ("insured") by an underwriter. Gebhardt et al. (2001) report an average two-day announcement effect for German rights issues that is not significantly different from zero. On the other hand, Eckbo and Masulis (1995) state that stock prices outside the U.S. usually react positively to rights issues.

Finally, note that the finding of negative announcement effects of SEOs in the U.S. is not a trivial result, for there are theories that would justify positive valuation effects (wait for the next section). One example is the frequently quoted "static tradeoff" theory, cf. Scott (1976) or Myers (1984): management sets the level of corporate debt to strike the optimal balance between its benefits (tax shields) and costs (of financial distress/bankruptcy). By implication, there is a non-excessive target debt ratio in place. Such ratios have indeed been found for some firms in surveys conducted by Graham and Harvey (2001), albeit with differing degrees of strictness. Thus, in a situation where a firm's leverage ratio is "too high", an equity issue should be received as "good news". It should be met with a positive price reaction as it moves the firm closer to its value-maximizing target debt ratio, cf. Myers (1993). We now return to the model.

[23] Wu and Wang (2007) reintroduce this threat by considering asymmetric information surrounding private benefits of control in a setting where a rights issue is the selected mode of financing. The paper also sheds some light on the low popularity of rights issues in the U.S., unlike in European markets. See also Eckbo and Masulis (1992) for a model on the choice of the equity flotation method in the presence of asymmetric information, where old shareholders' participation rate in a rights issue has informational content.

2.4 One small change in the assumptions, one big change in the outcome

To be fair, the negative share price reaction in the model critically depends on the assumption that negative values of b are ruled out. Overstating it a little, $b \geq 0$ is similar to assuming that management is flawless, perfectly able to filter out any bad investment opportunity and, thus, capable of presenting only worthwhile investment projects to shareholders. It is easy to argue that the assumption is unrealistic. Obviously, even highly qualified corporate managers make bad decisions in real life, resulting in the execution of a project that turns out to be bad, i.e., has negative NPV. Why else would there be bankruptcy codes all over the developed world? Therefore, it is fair to ask how the share price behaves when there are not only good investment projects, but bad ones, too.

This is exactly the question posed by Cooney and Kalay (1993) in a direct extension of the underinvestment model.[24] Assumptions are exactly the same as above, short of one exclusion: in addition to zero and positive NPVs, we also allow for negative NPVs. Given this modification, we basically redo section 1.2 in the following and ask once again how the stock price will change in reaction to an announcement of an equity issue. Note that the equations we have established in prior sections remain unchanged in appearance. For example, the issue-invest decision is still represented by inequality (2.4). Market and intrinsic values, too, present themselves in the same manner as before. The only distinction is that $\widetilde{B}$ may take on negative values in all these equations, and then ask ourselves: what are the consequences for the outcome of the model? Graphically, the difference to Myers and Majluf (1984) is that regions M' and M become bigger in size. Now, they also expand into the second quadrant. Figure 2.2 follows Cooney and Kalay (1993) and displays the new scenario accordingly.

Since negative NPVs are present, the shaded, triangle-shaped area in Figure 2.1, which is denoted by M'_S in Figure 2.2, is not excluded from M' anymore such that we have $M'_S \subset M'$. It has become part of the (new) issue-and-invest-region M', represented by the lightly shaded area in Figure 2.2. Evidently, in addition to underinvesting (region M), managers may be put in a situation where they decide to issue new shares despite knowing that the project has negative NPV. This happens when the value of the AIP is relatively low ($0 \leq a < P' - C$) and NPV is slightly negative, causing the (a, b)-combination to fall into subregion M'_S. Notably, this means that management deliberately goes after an investment project that it knows has negative NPV, reducing overall firm value. Given we defined not taking on a worthwhile

[24] Myers and Majluf (1984, fn. 12, p. 203-04) briefly touch on this issue themselves, but in a slightly different manner: they raise the possibility of incurring issue costs when selling the new equity. If these costs exceed the project's non-negative NPV, then effectively it becomes negative. The authors acknowledge that $P' < P$ cannot be guaranteed in that case, but do not pursue this issue any further. Instead, they assume that the mentioned costs are of second order.

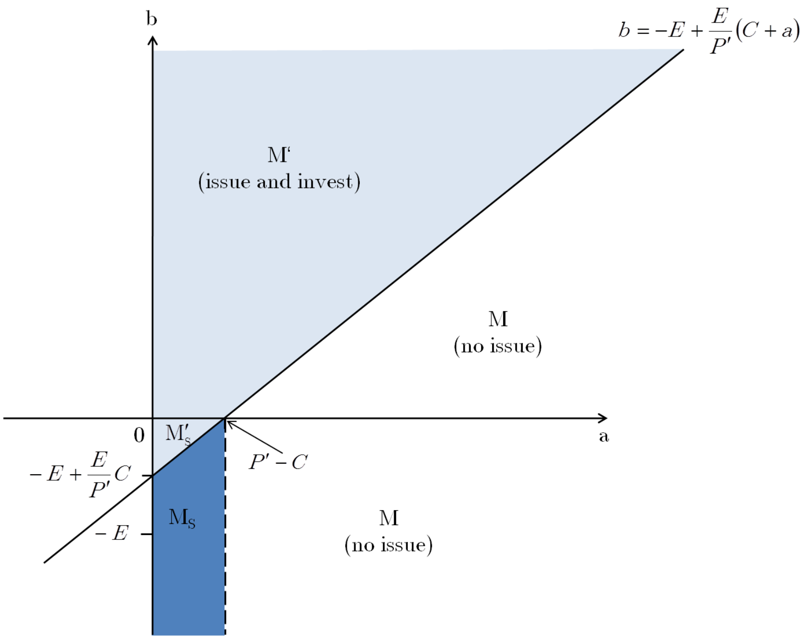

Figure 2.2: The Issue-Invest Decision at $t = 0$ When Allowing for Negative NPVs

investment opportunity as underinvestment, this means that *over*investment may occur in the presence of negative NPVs.[25]

Before we continue to investigate the circumstances under which overinvestment will arise, let us provide some intuition right way: at first, it may sound uncommon to learn that management will deliberately invest in a value-destroying project — just as it sounds uncommon *not* to invest in a value-creating project. The bottom line is, once again, that management is solely concerned with the maximization of the old owners' wealth. Its actions are (still) guided by the decision rule in (2.4), i.e., $\frac{E}{P'+E}(C+a) \leq \frac{P'}{P'+E}(E+b)$. Thus, when management opts for overinvestment, this is because it is beneficial to old shareholders.[26] From the inequality, the condition for the firm to issue and invest can be satisfied for negative values of b: a needs to be relatively small in that the (a, b)-combination falls into subregion M'_S. There, managers will take advantage of the low true value of the AIP and sell part of the old firm for more than it is really worth. The simultaneous loss from investing in a project with

[25] See De Meza and Webb (1987) for another model dealing with overinvestment in the presence of asymmetric information, where different projects have different expected returns.

[26] Stulz (1990) presents a model of asymmetric information where the assumption of compliant management is dropped, and costly overinvestment happens out of self-interest of managers who derive utility from *any* kind of investment (while not owning any stocks themselves). Constantly claiming to be in need of external funds to finance new investments, management is condemned as untrustworthy by shareholders, leading to underinvestment because good opportunities find no financing when internal funds are indeed too low. Debt financing is beneficial for battling overinvestment because it generally makes less funds available to management as it requires payouts (coupon payments); this is the same argument as in Jensen's (1986) famous free cash flow theory. At the same time, it exacerbates underinvestment. The converse logic holds true for equity. The authors then derive the firm-value-maximizing financing policy. See McConnell and Servaes (1995) for some empirical insights in this regard, such as the twofold effect of leverage.

negative NPV is justified by selling shares that certify ownership to an AIP that should be worth less. Note that this rationale will only work as long as NPV is not getting too negative (for a given a in M'_S). For if it were, we would move out of the issue-region M' in the figure (into region M_S), since the loss from investing would dominate. In that circumstance, the interpretation is simple and straightforward: the firm does not want to undertake a project whose NPV is strongly negative.

Likewise, region M, where the firm decides not to issue and invest, expands to the entire area below the a-axis, with the exception of subregion M'_S (which includes the indifference line). The crucial point is that (a, b)-combinations may appear anywhere in the second quadrant now. Note that this includes the heavily shaded area labeled M_S ($M_S \subseteq M$). The consequence is that, unlike in the previous section, $\overline{A}\,(M)$ is not necessarily greater than $P' - C$ (the intersection of the indifference line and the a-axis).[27] For it to be smaller, the heavily shaded subregion M_S comes into play. If the joint probability density function of $\left(\widetilde{A}, \widetilde{B}\right)$ is constructed such that there is enough probability mass on realizations in M_S, an area where the AIP takes on quite low values and NPVs are even more negative than in M'_S, then it will follow that $\overline{A}\,(M) \leq P' - C$ holds true for the expected value of AIPs in the no-issue region M. As $M_S \subseteq M$, this statement signifies that there must be a substantial probability that the firm will decide not to issue. If, on the other hand, there is sufficient probability mass on realizations in the remainder of region M, then $\overline{A}\,(M) > P' - C$ prevails. As shown in section 1.3, it results from equation (2.7) that $P' < P$ is implied by $P' - C < \overline{A}\,(M)$. Accordingly, $P' > P$, i.e., a positive stock price reaction, follows from $P' - C > \overline{A}\,(M)$ (and $P' = P$ for $P' - C = \overline{A}\,(M)$).[28] As we just mentioned that we cannot exclude the latter case any more (depending on the joint distribution function), we cannot exclude $P' > P$ at $t = 0$ any more either. An announcement to issue new equity may increase share price. This is the novelty introduced by Cooney and Kalay (1993).[29]

[27] In the words used in the last section: region M does not "commence" to the right of $a = P' - C$ any longer, but also includes lower values of a (those of the (a, b)-combinations in M_S).

[28] In addition to the joint probability density function of $\left(\widetilde{A}, \widetilde{B}\right)$, whether $P' - C < \overline{A}\,(M)$ or $P' - C > \overline{A}\,(M)$ applies also depends on the cash C and the size of the equity issue E. The former is obvious from the two inequations above. The latter is true because E (besides C) helps to establish the indifference line, which is responsible for the partition of space into the areas M' and M, cf. equation (2.5).

[29] We have made it clear that the stock price at $t = 0$ may be greater with an issue than without, i.e., $P' > P$, when the distribution of $\widetilde{B}$ is not truncated at zero. Cooney and Kalay (1993) go one step further and explicitly model the price change from period $t = -1$ to $t = 0$ conditional on the issue-invest decision. Denote the market value of old shares at $t = -1$ by P_b and the (known) probabilities of (a, b) falling into M' and M by π_{is} and π_{no}, respectively. As there are no other regions, we have $\pi_{is} + \pi_{no} = 1$. Accordingly, market value at $t = -1$ is given by $P_b = \pi_{is} P' + \pi_{no} P$ (remember that the interest rate is zero and agents are assumed risk-neutral). Since P_b is merely the weighted average of the (positive) potential market values at $t = 0$, it follows that $P' > P_b$ if, and only if, $P' > P$, which we have just shown to be feasible in the current setup. In other words, in case the share price at $t = 0$ is greater with an issue announcement ($P' > P$), then the share price is also greater after the announcement than before it ($P' > P_b$). For the model as considered

Intuitively, when the probability of (a, b) in M_S is high, the market will perceive the decision *not* to issue as bad news, reasoning that the AIP will (likely) have little value and NPV will (probably) be highly negative — a rather bad combination of a and b. Therefore, if the firm should indeed decide to issue new shares in this situation, the announcement will be received as good news because it tells investors that the NPV will be positive or at least not as negative as originally imagined, causing stock price to rise. Thus, the announcement of an equity issue need not necessarily be bad news any more.

Depending on the joint probability of $(\widetilde{A}, \widetilde{B})$, it may be the case that the firm now chooses not to issue precisely because it faces a bad combination of a and b. In other words, it might simply decide not to pursue a bad investment project (which it signals to the market via the decision to go without an issue). This most straightforward interpretation of not investing becomes possible because region M contains negative realizations of $\widetilde{B}$ in this model setup. From Figure 4.2, with the exception of subregion M'_S, where overinvestment occurs, managers will never pursue the investment project when its NPV is negative.

We have explored the circumstances under which an issue announcement will boost the stock's value. Conversely, share price when issuing will still be lower than its counterpart, i.e., $P' < P$, when $P' - C < \overline{A}(M)$. This happens either when NPV is non-negative, as in Myers and Majluf (1984), or, in the presence of value-destroying projects, when there is not enough probability mass in subregion M_S. Overall, the value of old equity may fall, rise or stay unchanged ($P' = P$) following an announcement to issue new stock if bad investment opportunities are present.

In yet another direct extension of Myers and Majluf's (1984) framework, Wu and Wang (2005) not only build on Cooney and Kalay's (1993) model by dropping the convention of solely having non-negative NPVs, but furthermore allow managers to be self-interested. That is, another assumption essential to the results of the original underinvestment model is discarded, namely the perfect alignment between original shareholders' and management's interests. This is accomplished by adopting managerial stockholdings ("insider ownership") and introducing private benefits of control, which accrue to management *whenever* it (issues and) invests in a new project. As opposed to maximizing old shareholders' value, the objective function now envisages the maximization of management's own wealth, composed of both the value of their stockholdings and the private benefits of control.[30] The equivalent of the

by Myers and Majluf (1984), this implies that share price also decreases relative to its pre-announcement value in response to a statement to issue and invest. Note that this pre-announcement value P_b will generally not coincide with the one calculated under Myers and Majluf's (1984) framework because here we allow for $b < 0$.

[30] Dyck and Zingales (2004) present an international comparison of private benefits of control in 39 countries.

issue-condition (2.4), which now states that (managers' personal) wealth must not decrease if an issue is to take place, is given by $w\,(C+a) \leq w\frac{P'}{P'+E}\,(E+C+a+b-c)+c$. Here, w represents insider ownership, i.e., the percentage of old shares held by management, while c stands for the dollar amount of the control benefits. The benefits accrue in full to management, but at the same time lower their (and everybody else's) share value as a consequence of the socially irresponsible handling of corporate resources. Consistent with Cooney and Kalay (1993), both over- and underinvestment may occur in this setup. Notably, overinvestment will not be excessive: yes, investment in a negative-NPV project is favorable for management through private benefits, but at the same time it may decrease their claimholdings' worth. Generally, insider ownership and benefits of control each have a conflicting impact in the model: when managers own a larger percentage of shares (ceteris paribus), their wealth is more sensitive to adverse stock price movements. This reduces overinvestment while exacerbating underinvestment.[31] When private benefits are larger in turn, management's incentives to invest are increased, prompting more overinvestment, but less underinvestment.

An interesting alternative explanation of overinvestment comes from the field of behavioral finance. Malmendier and Tate's (2005) model attributes such behavior to CEOs who overassess their own capabilities. As a consequence of their overconfidence, CEOs ascribe higher returns to investment projects than the market. On the one hand, this leads them to overinvest when sufficient internal funds are readily available. On the other, they refrain from raising capital externally because they think its offer price is too low. The authors find empirical support for their model, where overconfidence is measured in relation to the duration of managerial stock (option) holdings.

This concludes the excursion to the field of negative NPVs and overinvestment in the context of Myers and Majluf's (1984) model. Let us now return to the original theory, i.e., back to $b \geq 0$, and explore alternative modes of financing.

Generally, the better a country's (legal) institutions, the lower the level of private benefits. Such benefits accrue to management when it exploits its control over corporate resources such that it (exclusively) enjoys advantages. One type, which may take on many different forms, is "self-dealing", cf. Djankov et al. (2008); a classic example is management awarding a possibly overpriced contract to a firm it (partly) owns. "Tunneling" is a closely related pattern, occurring when corporate resources are expropriated from the firm and transferred to managers/controlling shareholders. It ranges from outright theft to selling corporate assets or products to management at below-market prices, cf. Johnson et al. (2000). Zingales (1994) presents an empirical study on corporations in Italy. There, private benefits of control are tremendous, translating into a huge trading premium (82% on average) enjoyed by voting shares.

[31] See, e.g., Morck et al. (1988) and McConnell et al. (2008) for empirical examinations of the relationship between insider ownership and corporate value. These studies find that such stockholdings can be value-increasing up to a point, beyond which firm value diminishes with increasing insider ownership.

2.5 Debt financing

So far, we have exclusively considered issuing new shares as a means of externally financing the investment opportunity. We have neglected the possibility of financing through a debt issue. This changes now. As we will see, model results will not remain unaffected. Denote the debt counterpart of E by $D\,(= I - C)$. To illustrate the advantages of debt, let us first compare the two modes of financing separately. Suppose that the firm publicly decides on one of the two sourcing policies in the first period, and sticks to it subsequently.

Starting with equity, let us slightly rewrite the true value of the old shares when issuing at $t = 0$, cf. (2.2). Myers and Majluf (1984, p. 207) state it as: $V^{old}_{issue} = E + C + a + b - E_1$, with E_1 (known to management at $t = 0$) denoting the market value of the new shares at $t = 1$, i.e., after the transfer of value has occurred. Remember that there is no informational asymmetry at the final date: outside investors have learned a and b, which is why the market value of the new shares equals their true value at $t = 1$. The new equation merely presents the true value of old shares in a slightly different manner. While the initial equation (2.2) states that old shareholders own part $(\frac{P'}{P'+E})$ of the entire firm's true value $(E + C + a + b)$, the new equation states that old shareholders own the entire firm's true worth minus the value of new equity, which, by assumption, is not theirs.

There is, however, a minor redundancy in writing out the new equation in the way done by the authors: introducing the term E_1 is unnecessary, given that Myers and Majluf (1984, p. 192) define the true value of new shares by V^{new}, cf. equation (2.3), in their paper. The two notations in fact are one and the same. To prove this, we simply equate the expressions for the true value V^{old}_{issue} such that $E + C + a + b - E_1 = \frac{P'}{P'+E}\,(E + C + a + b)$, and solve for E_1. This yields $E_1 = \frac{E}{P'+E}\,(E + C + a + b)$. By (2.3), the right-hand side describes V^{new} and, thus, the true value of new shares. Therefore, $E_1 = V^{new}$.

Given an issue-announcement, define by $\Delta E \equiv V^{new} - E$ the actual change in the value of new equity from $t = 0$ to $t = 1$ (recall that there is no discounting). ΔE may be positive or negative, i.e., outside investors may realize a capital gain or loss at $t = 1$, depending on whether the shares are under- or overvalued, respectively, when issued at $t = 0$. Such misvaluations may take place in any particular issue. However, the market expects ΔE to be zero in equilibrium, so that the purchase of the new stock has an expected NPV of zero to new shareholders. Original owners' intrinsic value becomes $V^{old}_{issue} = C + a + b - \Delta E$, and the issue-no-issue decision, $V^{old}_{no\ issue} \leq V^{old}_{issue}$, is given by $C + a \leq C + a + b - \Delta E$. Accordingly, the firm will opt for investment if $b \geq \Delta E$. The NPV must not be smaller than the new shareholders' capital gain (or loss). In other words, the maximum amount of new shares' undervaluation that old stockholders are willing to tolerate in an offering is b. Intuitively, old shareholders, who are in charge, want a piece of the pie, too. Hence, project NPV must at least suffice to balance the new co-owners' realized capital gain such that some non-negative amount is left over for the original owners. Obviously, this is always the case when an SEO is overvalued: the ensuing capital loss to new shareholders, i.e., $\Delta E < 0$, causes $b \geq \Delta E$ to be satisfied as $b \geq 0$ per assumption. This is consistent with the statement that the firm always wants to issue overvalued shares and, thus, take advantage of the market. Recall that mispricing does not affect the intrinsic value of the firm, which increases by $E + b$ if the firm decides to issue, but instead causes a transfer of wealth from one group of shareholders to the other. In case of an overvaluation, it follows from $V_{issue}^{old} = C + a + b - \Delta E$ that old shareholders not only receive the project's NPV in full, but on top of that benefit from a transfer of value from new shareholders, cf. fn. 15. This implies that the portion of the rise in firm value going to old shareholders when investing amounts to an absolute value greater than b. Note that, since NPVs are non-negative per assumption, shares that are fairly priced ex-post ($\Delta E = 0$) prompt an issue, too. Buying shares in this case turns out to be a zero-NPV investment to outsiders: the entire NPV (but no more) goes to the holders of the old shares, whose value becomes $V_{issue}^{old} = C + a + b$. Given $\Delta E > 0$, the investment decision is, as already mentioned, dependent on whether the size of the NPV is big enough to outweigh the capital gain to new shareholders.[32]

Now, consider debt financing. Assume all other things equal, except that bonds must be issued instead of new shares to finance the investment project. Following the same reasoning as above, denote by D_1 the true/market value of debt at $t = 1$ (when the information asymmetry has dissolved). The capital gain or loss put into effect at $t = 1$ is labeled $\Delta D \equiv D_1 - D$ accordingly, where D is the amount raised in the debt issue. In order to compare the two financing policies, we merely substitute debt for equity in the equations such that the true value of the original equity is $V_{issue}^{old} = D + C + a + b - D_1$, i.e., the true firm value less the intrinsic value of debt. Hence, management will issue and invest in the project if the inequality $b \geq \Delta D$ is satisfied.

At this point, we have the means to come back to a statement made at the beginning. Risk-free debt should be included in the internal funds C along with cash. When debt is riskless, its price is not subject to fluctuations as it is not threatened by default. In other words,

[32] Cadsby et al. (1990) develop a modified, game theoretic version of Myers and Majluf (1984), where two types of firms exist and auctions decide over which investor gets to finance a project. The authors examine the model predictions by playing the sequential game in an experimental setting with various participants. One group of participants ("firms") first decides on investment, the other ("investors") then engages in the bidding process for the right to finance.

given no discounting for time value, ΔD is always zero when debt is risk-free. Since $b \geq 0$, $b \geq \Delta D$ holds true at all times, and the firm reaches status quo due to the fact that it always issues and invests with riskless securities. The value of risk-free debt is not affected by private information. This is the same result as obtained when financing entirely with cash. Provided that the firm has enough internal funds at hand, it does not need to issue any kind of risky security, but will rather take on every worthwhile project, for the entire NPV goes to the old (and only) shareholders. In this case, we are back to the classical paradigm of investing in every non-negative-NPV project. Cash and risk-free debt can be used interchangeably, and the capacity to issue riskless debt should count towards financial slack.

Therefore, we consider risky debt in what follows. In other words, the company is assumed to face the risk of not being able to pay back its debtholders. Like ΔE, the change in debt value may be negative, zero or positive, but is expected to be zero as it is the equilibrium value. Clearly, one is tempted to conclude that, since we merely alter denomination, the firm will take on or not take on the very same projects irrespective of equity or debt financing. This conclusion is wrong.

There is one major difference between equity and debt. It holds true that ΔD will always show the same mathematical sign as ΔE, but it will at all times be less in absolute values such that it holds true that $|\Delta E| > |\Delta D|$. This is a well-known result from option pricing theory. Myers and Majluf (1984) refer to Galai and Masulis (1976) for a rigorous explanation of the underlying options theory. For example, as pointed out by Myers (1984, p. 584), one requirement implicitly imposed hereby on the model is that changes in corporate value follow a lognormal distribution and that all actors agree on its variance. A quote by Frank and Goyal (2003, p. 220) should help to clarify: "[E]quity is subject to serious adverse selection problems while debt has only a minor adverse selection problem. From the point of view of an outside investor, equity is strictly riskier than debt. Both have an adverse selection risk premium, but that premium is large on equity. Therefore, an outside investor will demand a higher rate of return on equity than on debt". Corporate public debt will always be under- or overvalued when equity is under- or overvalued, respectively, but it will be less so because it is a safer security than equity; residual claims are exhausted first in case of an adverse shock to firm value because they are least senior and, thus, more prone to new information. Eckbo et al. (2007) add that, by virtue of being a fixed claim, cash flows of a straight debt security are more easily predictable (plus they usually recover some value in case of default). This is why debt with almost absolute certainty carries less potential for misvaluation and, thus, underinvestment.

It follows from the logic applied in the case of equity that the firm will always invest when debt is either overvalued or correctly priced ($\Delta D \leq 0$) because $b \geq 0$ per assumption. It gets interesting when comparing capital gains of newly issued equity and debt securities. Given the firm issues equity in such a situation, it follows from $b \geq \Delta E$ that $b > \Delta D$ (as $\Delta E > \Delta D$). Whenever equity leads to investment, debt does so, too. What if $b \geq \Delta D$? Then, equity need not necessarily lead to an issue because $\Delta D \leq b < \Delta E$ is possible. Assuming at least one such b exists, we will have a situation in which debt is issued, but equity not. Public debt thus leads to a lower expected underinvestment loss in firm value relative to status quo. That is, debt always enjoys an advantage over equity as a source of financing. Generally, more projects are funded when debt is the security of choice.

Remember, however, that up to now we have assumed that the firm publicly pre-commits at $t = -1$ to one of the two modes of financing. What if it does not, but instead only decides at $t = 0$ which type of security to offer? Here is the (seemingly) perfect solution for management: in case a new issue has to be sold for less than it is worth, the firm should always use debt. Its lower undervaluation leads to less dilution of existing shareholders' claims and, accordingly, to a lower capital gain for the new claimholders. Management will never issue equity voluntarily when its value is too low. On the other hand, since equity is always more overpriced, managers should issue shares in case of overvaluation, for they can snatch more wealth from the new shareholders. Unfortunately, this only sounds like a perfect plan if one were to think that the market is stupid. Given that outsiders are rational, they will foresee management's reasoning.[33] Hence, every time an SEO is announced, the market will instantly know that management is trying to take advantage. As a consequence, outsiders are unwilling to invest in the company, forcing managers to issue debt instead.

Thus, regardless of whether the firm precommits or not, the (somewhat extreme) result of the model is that if investment takes place, it is *always* funded by debt. Equity is never raised again after the initial public offering [IPO]. These results, coupled with the insights of his 1984 paper, lead Stewart Myers to the formulation of a preference hierarchy of financial instruments to be used in funding investments, called the "pecking order" theory of corporate financing.

Before we set forth the pecking order in detail, however, let us first review the empirical evidence on the implication of Myers and Majluf's (1984) model that the announcement of a debt issue must lead to a less harsh stock price response compared to an SEO, since debt

[33] The market may not be as rational in identifying overpriced shares in reality. Baker and Wurgler (2002) derive a very simple and appealing theory of corporate capital structure based on their econometric findings about firms' financing behavior. They state that capital structure is no more than "...the cumulative outcome of past attempts to time the equity market" (Baker and Wurgler, 2002, p. 29).

carries less risk of being overvalued and, thus, leads to more efficient financing.

2.5.1 The impact of new debt on share prices

As the price decline upon the announcement of a seasoned offering is predicted to increase with the security's sensitivity to asymmetric information by the pecking order, we expect it to be less severe for straight debt issues than for SEOs. Consistent with the theory, such offerings are indeed greeted with a less painful reaction by capital markets on average. That is, if there is one at all. We begin with Eckbo et al. (2007), who provide an excellent summary of some of the existing evidence. Out of the nine studies reviewed, merely two, namely Dann and Mikkelson (1984) and Howton et al. (1998), show average abnormal returns that are significantly negative. This, however, is not to be interpreted as evidence against the lower informational content of straight debt: the values are a mere −0.37% and −0.50%, respectively. The remaining studies cannot verify that announcement returns are significantly different from zero. While most present low negative price reactions, Johnson (1995) even reports a slightly positive average effect (a sub-sample even shows a significant positive price reaction). The calculated sample-weighted average abnormal return over all nine studies is insignificant and comes to −0.22%. Smith (1986) arrives at qualitatively similar conclusions in his survey paper.[34]

A look at junk bonds should be interesting, too. Presumably, because lower rated bonds carry more risk, they should be more prone to mispricing and, thus, accompanied by a more negative announcement effect compared to their investment grade counterparts. Yet evidence is mixed. Shyam-Sunder (1991) finds no significant average stock price reaction for straight debt issues for her entire sample (−0.11%), and these results do *not* change significantly when focusing at the low-grade bond issues only. Eckbo (1986) reports similar findings for his sample. Consistent with this, Castillo (2001), who looks at junk bonds exclusively, finds no average two-day abnormal return significantly different from zero (−0.28%). By contrast, Pilotte (1992) reports a significant negative wealth effect for below-investment-grade debt, suggesting that the drop in share price indeed depends on the bond's risk. Yet the effect is still a lot smaller than for fresh equity. Thus, the result remains that debt leads to a lower fall in stock price.

What is more, Smith (1986), among others, addresses an important concern that could other-

[34] Results are not always consistent in international data, which naturally receive less attention. For example, Verona Martel and García Padrón (2006) report statistically significant positive announcement effects for the Spanish market, and name other studies that all come to similar conclusions. Christensen et al. (1996) find that there is no wealth effect for Japanese straight debt offerings.

wise be raised as a point of criticism against the quality of the valuation results just presented: debt issues are predictable to some degree. Just think of maturing bonds that need to be rolled over. More precisely, certain preannouncement firm characteristics, such as earnings and investment growth, give away an impending debt issue to some extent, cf. Chaplinsky and Hansen (1993). Marsh (1982) is one of the first to formally provide a theoretical basis for issue prediction by constructing a descriptive (logit) model of a firm's financing choice between new equity and debt from a sample of nearly 750 offerings of these two types of securities. Since the (two-day) abnormal announcement return captures only the unanticipated part of the *entire* price change caused by the issue, it is conceivable that announcemenmt effects only appear so small and/or insignificant for debt issues because the market has already capitalized the "remainder" prior to the issue notice as it has expected it. Put differently, the claim is that the announcement effect is inversely related to the degree of anticipation of the issue.[35]

For all we know, this does not seem to be the case. First, Bayless and Chaplinsky (1991) try to directly test for anticipation, building on Marsh's (1982) model. They assign each of the security-offering public firms in their sample (252 debt and 223 equity issues in the U.S.) with a probability of using debt or equity in the issue. Presumably, if investors really anticipate the security issue and the type of financing instrument used, we should observe announcement effects of equity and debt that are more negative than usually reported once controlling for investors' believes. One way of doing so is to focus on those issues which show a high probability of one type of security being issued, but where the other one is actually announced and chosen. For these "unanticipated offerings", the informational content should be fully reflected in the abnormal return. Unexpected SEOs indeed show a more negative two-day announcement return (−3.5% versus −2.9% for all equity issues in the sample), while expected SEOs experience a less negative effect. Looking at unexpected debt offerings,

[35] Bayless (1994) uses Marsh's (1982) model to control for anticipation and reassesses the announcement impact using a sample of 826 public debt and equity offerings. First, the model is used to provide each individual issue in the sample with a likelihood of using debt as the security of choice (the accuracy rate of the logit model is 70% for debt and 83% for equity). Second, the cumulative two-day abnormal return of SEOs in the sample is regressed on this probability along with two dummy variables, one denoting the use of debt and the other indicating whether a firm has ever issued new securities prior to the current offering. The intuition for the latter variable is that the market infers information from experiences with prior offerings such that for first-time issuers the informational insecurity should be the largest, leading to a more extreme valuation effect (Carter, 1992, provides evidence from underwritten IPOs that low-risk firms show an increased likelihood and predictability of future offerings). Controlling for the anticipation of the type of security issued, first-time-ever SEOs lead to an announcement effect that is 4.15 percentage points more negative than that of new debt. Importantly, the difference in valuation effects for equity and debt is 2.88 percentage points when looking at non-first-time issuers only, akin to those of Smith (1986) and Eckbo et al. (2007). The difference between these two sub-samples is statistically significant. Note that the valuation effect of debt is hardly affected by prior offerings, further supporting that debt issues have little information content. First-time SEOs are subject to a harsher announcement effect than subsequent ones.

however, matters become puzzling. When firms identified as having a high probability of offering equity issue debt instead, a significantly positive announcement return of 1% is observed (all debt issues together yield an insignificant 0.1%). Bayless and Chaplinsky (1991, p. 213) themselves note that this is "...difficult to explain unless debt issues convey good news relative to equity issues". While it holds true, according to Myers and Majluf (1984), that debt is *relatively* better than equity, we should still observe a (significantly) negative price reaction upon announcement because the debt carries risk of overpricing, albeit to a lower extent. More conclusive evidence comes from Eckbo (1986), who segments 552 straight debt issues into sub-samples according to the use their proceeds are put to (refinancing debt, investment or unspecified). Generally, a straight debt offering intended to raise funds for investment purposes is less predictable than a simple roll-over because the maturity structure of the bond already in place is public knowledge. Consequently, if anticipation really matters, we should observe a more negative two-day announcement return when investment is the stated purpose. Though, except for a small investment-sub-sample of offerings by public utilities, neither one of the three stated purposes is associated with a significant valuation effect for any of the sub-samples. The observed announcement returns of straight debt thus do not seem to be influenced by (the degree of) anticipation. Somewhat ambiguous evidence along these lines comes from Chaplinsky and Hansen (1993), who, akin to Eckbo (1986), group bonds into four sub-samples corresponding to their respective purpose of financing stated in the issue notice. Those bonds whose purpose is "not specified" (about a quarter of the entire sample) display a significant two-day abnormal return. The argument goes that these firms are most concerned about information leaking prior to the issue announcement, for otherwise they could have stated their intent right away. Consequently, a significant price decline is consistent as the market cannot have (easily) anticipated the offering. On the other hand, the size of the valuation effect still is only -0.6%, well below returns caused by SEOs. Besides, it seems fair to question why the return for the sub-sample "investment" is insignificant and positive (the other two categories are devoted to roll-overs): given a firm is dependent on external funding to finance a profitable investment, it is reasonable that, considering such opportunities usually are both short-lived and valuable in the hands of competitors, the firm is anxious for non-disclosure, too. If anticipation really mattered, we would thus expect a (significantly) negative valuation effect. Finally, Shyam-Sunder (1991) checks for effects of anticipation by looking at trading periods starting as early as 60 days prior to the issue notice, but does not find evidence of significant abnormal returns and, thus, premature disclosure of information during this time span.

Eckbo et al. (2007) arrive at the conclusion that the greater part of the evidence, though not fully unambiguous, suggests that partial anticipation does not significantly bias reported results on the announcement effect of fresh debt.

A word of caution is in order at this point: Myers and Majluf's (1984) theory extremely well explains observed stock price behavior upon equity and debt issue announcements. However, it is certainly not the only theory of debt versus equity in the presence of asymmetric information. In his famous paper, Ross (1977) presents a model in which good firms signal their quality by the use of debt, for they do not face a high probability of bankruptcy. Klein et al. (2002) provide an overview of different models and empirical results concerning the choice between debt and equity when insiders are better informed.[36] We now come to the formulation of the pecking order of corporate financing

2.6 Pecking order

In a strict interpretation, firms will first exhaust internal funds (cash built up by retaining earnings, followed by riskless debt) to finance an investment opportunity, since there is no potential for dilution of existing claims caused by asymmetric information. When these funds are exhausted, the company will start to make use of external financing with risky securities. In doing so, it will first issue risky debt claims, securities that are less sensitive to private information. Only when the corporate "debt capacity" is fully used up, the company will issue new equity, as a last resort so to speak.[37]

The mentioned capacity for debt was introduced by Myers (1984) to put into perspective the extreme result that a company will never again issue shares after going public initially. Think of elevated costs of financial distress that preclude yet another increase in liabilities, giving rise to equity.[38] As noted by Frank and Goyal (2008, p. 151), there is no clear-cut definition

[36] For example, Narayanan (1988) examines this choice in a setting with a continuum of firm types where external funds are needed to finance a possibly profitable investment. The informational asymmetry solely pertains to the investment project. While firm types differ in their investment's quality, outsiders cannot discriminate between them initially: "lemon" firm types are present, which makes the investment risky to outsiders. In conclusion, debt is always preferred to equity. The reason is that risky debt, being a fixed claim, is less preferable to bad firms due to the risk of bankruptcy. Hence, profitable firms signal their quality by the use of debt, which, to bad firms, acts as an entry barrier into the market. This in turn increases the average quality and, thus, value of the remaining corporations. This holds true despite the survival of a few lemons in equilibrium: some otherwise unprofitable firms may end up making expected profits due to overvaluation. Equity is never issued in the model.

[37] Donaldson (1961, 1984) early on presents evidence from extensive case studies on large corporations and finds corporate financing behavior akin to the pecking order. He does not provide a formalized theory.

[38] If you are thinking that the issue of new stock in such a situation, where the firm has no choice other than equity, should act as a positive (pricing) signal, think again! First and foremost, the fact that the company all of a sudden switches to equity tells the market that it is in bad shape because management apparently is seriously concerned about financial distress.

of the debt capacity in the literature, which makes it harder to validate the theory empirically. Myers (1984) also addresses the issue of cash dividends, which the underinvestment model does not consider at all (nor does it explain why a firm should pay them in the first place). Given the existence of dividends, one prediction that we can make is that their payout ratio should be inversely related to investment and positively so to profitability: dividends use up valuable internal funds that could otherwise be used for financing new projects without incurring problems of asymmetric information. Regarding profitability, successful companies should be able to pay more dividends simply because they have enough cash to do so. Indeed, Fama and French (2002) report supporting evidence for these two assertions in their regression analysis. However, as explained by the authors, these findings cannot unambiguously be attributed to the pecking order, for they are also consistent with the tradeoff theory of corporate financing. Nevertheless, Myers (1984) postulates that firms adapt their payout ratios to suit investments. Importantly, this is done "at a slow pace" such that dividends are sticky. Myers (1984) does not explain his reasoning though it is backed by empirical evidence, cf. Fama (1974) and Fama and French (2002). An implication is that dividends will not be adjusted at short notice to provide more or less cash for countering short-term variability in investment opportunities.

Another issue we have not spoken about is financial innovation. Fine, we have considered equity and debt, but what about a hybrid security such as convertible debt which features characteristics of both (putting it in between the two in terms of sensitivity to private information)? In simplified terms, a convertible bond consists of a regular bond and a warrant, i.e., a call option written by the company on new stock exercisable at any time prior to the maturity of the bond. Upon exercise, investors make use of their right and exchange debt for equity according to a predefined conversion ratio (which defines the conversion price, the equivalent to the strike price of an option). Typically, after an initial protection period, such bonds are callable by the firm, in which case investors are compelled to decide on conversion before the bond matures. Thus, given "favorable" conditions, the company may force early conversion, effectively stripping investors of the time value of their warrant/option. Accordingly, management may see convertible bonds as a means of getting equity into the capital structure "through the backdoor".[39] Brennan and Schwartz (1988, p. 56) underline "the relative insensitivity of their value to the risk of the issuing company", which reduces the

[39] The (complex) classic paper on convertible debt valuation comes from Ingersoll (1977a). Duffie and Singleton (2003, chapter 9) provide a textbook treatment, while Brennan and Schwartz (1988) present a nice non-technical introduction to convertibles. See also Asquith (1995) for interesting insights into corporate call policies, notably the rectification of a common misconception regarding late calling.

potential for mispricing. Indeed, Stein (1992), in his adaptation of Myers and Majluf's (1984) model, shows that there is demand for such a security when an investment project requires external funding. Each of three considered firm types runs a chance or receiving either a high or a low cash flow (generated by the AIP and the investment). Types merely differ in their respective odds of achieving these cash flows, where probabilities are private information. Without going into detail, the appealing fact about Stein's (1992) work is that, albeit the setting is somewhat different to our model, the interpretation of its separating equilibrium outcome is supportive of the pecking order.[40] Given costs of financial distress, good firms, not facing the risk of bankruptcy, have unused debt capacity and issue bonds, which allows them to avoid the dilutional cost of equity. Bad firms, however, cannot afford this luxury and must issue equity for fear of bankruptcy, accepting the negative consequences of this information-sensitive security. Medium firms are able to utilize convertible debt instead, a security whose sensitivity to private information lies between debt and equity due to its hybrid character. Thus, in financing an investment opportunity externally, use is made of securities in the order of their informational sensitivity, starting with the claim that is least sensitive to information.[41] This leads to a testable hypothesis, namely that (given similar issue sizes) the announcement return of a convertible debt issue will lie somewhere between those of equity and debt as the security's potential for mispricing is less than equity's, but more than that of straight debt due to its hybrid character. This prediction has received broad support. De Roon and Veld (1998) nicely summarize a great deal of empirical studies.[42] Literally every one of them reports a statistically significant negative (two-day) valuation effect surrounding announcements of convertible bond offerings in the U.S., amounting to an average abnormal return of roughly -1.5% (weighted by the sample sizes). While the papers on announcement effects surveyed by Eckbo et al. (2007) reveal a significant sample-weighted average abnormal return of -2.22% for SEOs and an insignificant -0.22% for straight debt, the corresponding valuation effect is a statistically significant -1.82% for convertible bonds.

[40] Schulz (2003) sets about formally combining Myers and Majluf's (1984) and Stein's (1992) model into one.

[41] Nyborg (1995) criticizes Stein's (1992) model for considering forced conversions by management only, disregarding the right of claimholders to convert voluntarily (insofar as the convertible has not been called yet). Additionally, the author formally accounts for the fact that the decision on the part of the firm to force conversion has informational content as well, which remains unconsidered in Stein (1992). The announcement of a call to convert usually leads to another negative stock price reaction on top of the issue announcement effect, cf. Mikkelson (1981) and Brick et al. (2007). Therefore, convertible bonds actually induce more severe share price declines when called in the model. Nyborg concludes that the qualitative result of Stein (1992), i.e., the beneficial function of convertible debt in achieving investment efficiency in the presence of asymmetric information, holds true only if the conversion is voluntary.

[42] Among the first authors to empirically investigate this issue are Dann and Mikkelson (1984), Mikkelson and Partch (1986) and Eckbo (1986). Recent evidence, such as Liu and Switzer (2010), is supportive of their findings.

Note that the picture changes, once again, when looking at other countries. For instance, Kang and Stulz (1996) report a significantly positive announcement effect (0.83% for the two-day abnormal return) for convertible issues in Japan, while De Roon and Veld (1998) find a slightly positive, but insignificant return for Dutch offerings.[43]
Summing up, at least in the U.S., real-world data show that the hybrid security indeed lies between equity and straight debt in respect of the severity of the offering announcement price decline. This explanatory power is *the* key benefit of Myers and Majluf's (1984) theoretical predictions.

This brings us to the formulation of a less strict form of the pecking order, as considered by Myers (1984, 2002): financial slack is the preferred source of financing. Since dividend policy is sticky, corporate cash flows, which are subject to variation, may or may not suffice to finance an investment opportunity; if so, remaining cash flows go to build up financial slack or pay back debt. If not, cash holdings are spent. Once external funding is unavoidable, the firm first issues debt. As more external funds are required for investment, the firm works down the pecking order, issuing securities in the order of increasing informational sensitivity, that is from (safe to risky) debt via hybrid securities down to equity in the end, when there is no more capacity for any other security.

We finish this section with the advice to exercise some caution: researchers *think* that information asymmetry is the driving force behind the pecking order. It is by far the most popular explanation in the literature. However, we cannot exclude that other determinants may have some (or even sole) explanatory power. Frank and Goyal (2008, p. 151) state: "[T]o the best of our knowledge, no one has tried to distinguish among the alternative possible sources of the pecking order behavior". Myers (2003) himself points out that incentive conflicts of the type considered by Jensen and Meckling (1976) may lead to a pecking order, too. Fresh equity carries large potential for agency costs because it passes on part of the costs of the private benefits enjoyed by corporate management to new shareholders. Consequently, debt is the first choice when internal funds are exhausted. Furthermore, Altınkılıç and Hansen (2000) examine underwriter fees in seasoned issues of equity and debt. While there are obviously no issuance costs associated with cash, the authors show that, depending on the size of the issue and the bond rating, the costs of common equity may outweigh those of straight debt, implying a pecking order based on the cost of external financing.

[43] In case one is wondering what could cause these country differences, Moerland (1995) provides an interesting attempt to explain based on historical and cultural diversity leading to corporate systems that differ in their economic characteristics, including their way of dealing with agency problems.

2.6.1 ...Does it work?

A large body of empirical research on the real-world effectivity of the pecking order exists (using mostly U.S. data). To cut a long story short: for all we know up to this point, it is not a theory that entirely explains corporate financing behavior (in fact, there is not one doctrine to this date that can). Results are rather mixed. Given that equity should only be used a last resort, the sheer mass of empirical studies on SEO announcement effects, many of them mentioned above, may in itself be indication of the failure of the pecking order. Let us start off with a look at some real-world data on security issues, provided by Eckbo et al. (2007). Out of $80,627$ public and private security issues in the U.S. in the years 1980-2003, we have $37,398$ public straight debt offerings, $11,151$ SEOs and $1,545$ – less than 2% – convertible debt offerings among them (where the bulk of the remainder is split up between IPOs and private security issues). While debt issues are in fact the most common form of financing (consistent with the pecking order), its ratio to equity is roughly three to one. SEOs seem to be too high in number, considering they should be used as a last resort. Further, if the pecking order were indeed correct, we would have to identify convertibles outnumbering SEOs, which we clearly do not.[44] To put it in the words of Frank and Goyal (2003, p. 218), "[E]quity finance is a significant component of external finance".

Early evidence comes from Korajczyk et al. (1990), who take a closer look at the mentioned debt capacity prior to an SEO. Their underlying logic is that if the pecking order is in fact correct, firms would first use up their debt capacity before issuing equity. Consequently, we would expect a rise in corporate debt ratios (as measured in book values) in the periods leading up to an SEO. Contrary to this reasoning, the authors find that ratios do not increase, but rather decline (both in market and book values) in a sample of nearly $1,500$ seasoned offerings. Such behavior is interpreted as being inconsistent with the pecking order because equity is issued without having exhausted the ability to issue debt. Next, Helwege and Liang (1996) examine the financing behavior of a sample of young high-growth firms whose earnings are relatively low, reasoning that such firms will have an increased demand for external capital to support their investment strategy. The good news is that the firms generally do not go to the capital market when internal funds are sufficient in a given year. The consistency with the theory vanishes, however, when it comes to external financing. First, the pecking order is discarded at one central point: a greater cash deficit does not imply a greater likelihood

[44] For the sake of completeness: the average public debt issue raises $230 million, and is around three times the size of an SEO and twice that of an average convertible debt issue. When looking at issuer classes, industrial firms account for the biggest part of the capital put up in SEOs, while banks/financial institutions take the lion's share in the market for public straight debt. Utilities rank last in both these categories. The entire sample amounts to more than $12 trillion raised.

of obtaining external financing. This result is not driven by outliers having trouble raising funds. Second, firms that do issue securities basically are equally likely to use debt or equity, although, under the pecking order, there is no necessity to use the latter. Neither do firms with higher (proxied) asymmetric information show a decreased probability of equity issuance, which clearly violates the pecking order. Jung et al. (1996) show that nearly a quarter of the equity-issuing companies in fact conform to the characteristics of the typical debt-offering firm in their sample. The authors argue that their behavior is justifiable by the financing hierarchy only if the information asymmetry surrounding these firms happens to be small, in which case the SEO announcement return would have to be less negative than usually reported. This is not the case.

A much noticed study comes from Shyam-Sunder and Myers (1999), who set out to test the pecking order against the static tradeoff theory, utilizing a small panel data set of 157 mature (i.e., non-growth) industrial firms during the years 1971-1989. The link to testing the pecking order is its implication that there is no target debt ratio (unlike in the static tradeoff theory): capital structure is solely driven by the firms' outside financing needs such that the observed debt ratio merely reflects the cumulative corporate demand for external funds up to the present time. Since equity is meant as a last resort, the basic financing hierarchy is tested by simply regressing the change in book debt value ("debt issues") over a period on the deficit in internal funds (basically capital expenditures less internal cash flows) in that period. If this procedure and the theory are correct, we will observe a slope coefficient of one and an intercept of zero for a strict interpretation of the financing hierarchy. In short, they find that the pecking order surpasses the tradeoff model in explanatory power. More importantly, it survives tests of statistical power which the tradeoff theory does not. This leads Shyam-Sunder and Myers (1999, p. 242) to conclude that "[T]he pecking order is an excellent first-order descriptor of corporate financing behavior...".

Finally some good and persuasive results confirming the pecking order, correct? Unfortunately, this need not be the case. While Shyam-Sunder and Myers' (1999) methodology for testing financing behavior is novel, Chirinko and Singha (2000) convincingly argue that it is seriously flawed, and raise doubts about its usefulness in testing either one of the two theories. The authors present three scenarios where the testing procedure falsely accepts (rejects) the financing hierarchy when in fact it is void (valid). Frank and Goyal (2003) also reassess Shyam-Sunder and Myers' (1999) approach — and also offer criticism. Making use of a considerably larger data set of U.S. firms, they conclude that generally the pecking order does not describe financing decisions for the broad sample. Merely a sub-sample of large corporations displays financing behavior reconcilable with the financing hierarchy. Smaller and more growth-oriented companies (which we would expect to be more plagued by asymmetric information) fail in this regard. Most surprisingly, it is found that net equity issues, and not net debt offerings, do the better job in tracking the financing deficit, which is highly inconsistent with the pecking-order-implied dominance of debt. Yearly equity issues usually surpass their debt counterparts in magnitude in the sample, too. Beyond that, adding additional regressors, such as asset tangibility and profitability, yields better results, suggesting that the deficit is not the sole driver of debt issues. This casts further doubt on the pecking order. Fama and French (2002) use dividend and debt regressions to also test the tradeoff theory against the (dynamic version of the) pecking order, but cannot offer a clear winner. This is partly due to the fact that some of the findings can be attributed to both theories. On the other hand, the clear-cut predictions of either theory do not always receive support. Conclusive inferences cannot be made from their results.

Perhaps the lack of an unambiguous testing methodology represents a constraint to deriving clear results about the pecking order. For this would explain contradicting findings from testing it. For instance, Fama and French (2005) report that the pecking order works best for a sub-sample of smaller firms; which is inconsistent with Frank and Goyal (2003). The authors apply a different methodology by examining in detail the corporate equity issue behavior of a sample of all industrial firms listed on the major American stock exchanges during the years 1973 to 2002. As an example, in the last of the three decades considered, the average number of companies climbs to 4,417. Importantly, Fama and French (2005) include not only SEOs in the net equity issues, but rather argue that all other ways and means of equity financing, such as private placements, rights issues, mergers financed with new stocks or offerings to employees, should be included as well. They claim that not all of these instruments, as we have seen above in the case of rights issues, are necessarily exposed to problems of asymmetric information to the same extent as SEOs. The authors emphasize that their conclusion that "...the pecking order does a poor job describing the equity decisions of individual firms" (Fama and French, 2005, p. 571) could well be due to the fact that firms circumvent these problems by increasingly relying on such information-insensitive stock issuing techniques, which casts doubt on equity's role as a last resort. The percentage of firms that issue stock *every year* rises steadily, reaching a stunning 86% average in the final decade. The respective number for equity issues net of repurchases is 72%. During the same period, only 49% of the overall sample finance in a manner consistent with the pecking order. That is to say, every second firm violates it. Equity offerings are generally substantial in size and frequently exceed debt issues.

Recently, Leary and Roberts (2010) also have a try at testing the pecking order. Applying a different testing methodology, the authors identify financing decisions (by defining debt and equity issues as the net between-period-changes in book values of debt and equity relative to book assets above a certain threshold) and check if they are consistent with predicted financing behavior generated from a pecking order model defining financing thresholds above which the firm switches from internal resources to debt and, respectively, from debt to equity. Here, too, results are sobering. While it may be taken as a success that three quarters of the firms behave as specified by a strict interpretation of the pecking order model regarding the use of internal versus external funds, corporate financing decisions fail with respect to selecting the "right" type of security when it comes to outside finance. A mere 17% of sample firms act "correctly" when choosing between debt and equity. Only when considering a highly relaxed variant of the financing hierarchy, which also incorporates features of the static tradeoff theory, the security decision is correctly classified for a large proportion of the sample. This plays into the hands of Myers (2003) and Fama and French (2005), who suggest that it may be better to look at both theories not as mutually exclusive, but rather as existing side by side, each contributing to the understanding of observed corporate financing behavior. Another troublesome discovery made by Leary and Roberts (2010) is that (proxies for) incentive conflicts à la Jensen and Meckling (1976) rather than (proxies for) informational asymmetry have the highest predictive precision for pecking order behavior. This suggests that asymmetric information is not the actual driving force behind the financing hierarchy. On the other hand, Lemmon and Zender (2010) use a variation of Shyam-Sunder and Myers' (1999) approach that controls for the fact that firms operate at different levels of their debt capacity and argue that a modified pecking order does a good job in describing firms' financing behavior. Finally, Bharath et al. (2009) also rely on the Shyam-Sunder-Myers-type regression. Their innovation is that they construct an index of asymmetric information, compiled from measures used in the field of market microstructure, and annually partition the companies in their sample (1973-2002) into deciles according to the severity of the firm's information asymmetry. Regressions reveal that the financing deficit coefficient is indeed increasing as we move up in deciles, meaning that companies plagued by more asymmetric information adhere to the pecking order more closely, for they obtain a higher proportion of their external financing in the form of debt. While this speaks for a role of information in determining financing decisions, other factors exert influence as well: further regressions and robustness checks, inter alia to account for the aforementioned methodological criticism by Chirinko and Singha (2000), show that the asymmetry index is just one (significant) determinant of leverage and, thus, capital structure among others. Therefore, the financing hierarchy is not the sole driver of financing decisions.

This look at the (older and more recent evidence) tells us either that there is not yet a convincing way to test the pecking order or that it not suited as a general theory to explain financing decisions made by firms. Until we are convinced of the contrary, we adhere to the latter.

2.7 Securities in the capital structure — security design

Like Stein (1992), Chakraborty and Yilmaz (2011) consider the role of convertible debt in resolving the underinvestment problem. The major novelty they introduce is that asymmetric information is only dissolved partially in their adaption of Myers and Majluf's (1984) framework. A convertible bond can be designed whose value is completely disentangled from any private information about the firm's type. No potential for mispricing remains and the firm always issues and invests. The underinvestment problem is completely solved, even though the firm faces a positive probability of bankruptcy.[45]

The usefulness of convertible debt has led to its inclusion in the pecking order, as we have seen. But this naturally brings forth the following question: why should it stop there? "The first problem is that only a limited menu of security designs have been considered, essentially debt and equity. With such narrow choice sets, claims of optimality are weak" (Nachman and Noe, 1994, p. 2). Especially in times of investment banking and financial engineering, there seems to be an almost indefinite number of issuable securities at the firm's disposal. Hence, the real question is this: when a firm is in need of external funds to finance a worthwhile investment project, "[W]hat securities should the firm sell to raise the required capital? This is the fundamental capital structure question reformulated (albeit loosely) as a security design problem" (Nachman and Noe, 1994, p. 2). The authors of the quote have first looked into this problem, and thereby initiated a new line of research in the context of the pecking order — security design. They use a two-date model in which a game of externally raising a fixed investment amount is played in the presence of asymmetric information. In contrast to Myers and Majluf (1984), both a broad set of securities and firm types are considered. Outside investors cannot observe the type, which is governed by the productivity of the investment project. Firms of high productivity face the risk of having to issue an undervalued security

[45]For further insights into the usefulness of convertible bonds in financing profitable new projects when the firm is better informed than the market, see Brennan and Kraus (1987) and Constantinides and Grundy (1989).

due to imitation of its design by bad companies — a classical lemons problem. Given this setup, the authors determine the characteristics a security needs to have in order to be optimal in raising external funds (in that it supports a pooling equilibrium outcome of the game; separating equilibria do not exist). The natural question to ask, given the multitude of securities, is whether straight debt, as suggested by the pecking order, actually turns out to be optimal in minimizing underinvestment (the "folklore proposition"). The authors determine that this is generally not the case. It holds true only if firm cash flows adhere to a strict ordering of stochastic dominance (conditional stochastic dominance). Therefore, support for the pecking order is limited. Note that Nachman and Noe (1994) consider security design in an ex-post setting. As in Myers and Majluf (1984), the issuing firm knows its own type and *then* decides on matters of design. Consequently, the choice conveys information to the market.

In contrast, DeMarzo and Duffie (1999) engage in optimal security design in an ex-ante setting in a model based on liquidity and asymmetric information. Issuers receive information on the payoff of the security not until they have finished designing it, but before offering it to the market. Hence, the issuing company cannot signal information by the choice of the design per se, but merely through the fraction of the issue sold to the uninformed market (and not retained). This, however, is where the problems of asymmetric information start to kick in. The firm credibly signals high quality (high cash flow) of its security only by keeping back a rather large fraction of the issue. But doing so is costly and decreases the amount raised through the flotation. In other words, when offering a large fraction to the public, outsiders will rationally interpret this as a sign of inferior quality. This leads to a depression of the security's market price through reduced demand, implying lower liquidity. This illiquidity problem, inter alia, depends on the sensitivity of the value of the selected design to the company's private information. Issuing firms establish the security that optimally solves the tradeoff between costs of illiquidity in the market and the retention costs due to asymmetric information. The model is related rather closely to Myers and Majluf (1984), but features some obvious distinctions. For example, the amount to be raised externally is not fixed. Furthermore, the offered security is completely backed by the firm's existing assets, and not the investment opportunity. Like Nachman and Noe (1994), the authors determine the conditions for a design to be optimal in general and address the situation in which risky debt fulfills these requirements in particular. Again, straight debt may be optimal, but only under certain restrictions imposed upon cash flow distribution — the same holds true for equity. Overall, the model provides mixed support for the pecking order, subject to the assumptions made.

Further studies exist that deal with the properties of security design under asymmetric information, though not as closely related to Myers and Majluf (1984) as the models just introduced. For example, Goswami et al. (1995) specifically focus on the design of an optimal debt contract. In their three-date model, a firm possesses superior information and seeks to raise funds through a debt issue to invest in a worthwhile project. The authors focus both on short-term and long-term debt securities. This distinction is relevant because the degree of asymmetric information surrounding short-term and long-term cash flows (of the project) may vary. Critically depending on the exact structure of asymmetric information in the different periods, the authors specify the optimal debt contract according to commonly used covenants, i.e., requirements imposed upon the borrower that are specified in the bond agreements ("indenture"), such as time to maturity, coupon payments and restrictions on dividends.[46] Next, Rahi (1996) considers the security choice of an owner-manager who possesses superior information regarding the investment's payoff. In equilibrium, the entrepreneur decides against issuing a security that would otherwise allow him to exploit his informational advantage. The cost associated with asymmetric information render this venture unprofitable. Therefore, all information is transferred to the market via price setting, leaving all actors equally well-informed. Since dilution is no longer a concern, the owner-manager opts for equity as the security of choice: a company financed by a single type of security distributes business risk efficiently across its holders. Heinkel and Zechner (1990) consider the optimal mixture of common stock, debt and preferred stock when externally financing a profitable project whose quality is private information to the firm. The latter two security types are beneficial because they curb underinvestment and because the model considers tax benefits. Finally, in the context of a signalling model, DeMarzo (2005) examines whether it is better to sell off assets separately or pooled, considering that financial intermediaries who buy and resell financial claims are better informed than the market. Both ex-ante and ex-post optimal designs are considered.

[46] Paglia (2007) provides a compact overview of covenants frequently used in large commercial bank loans. As an example, Smith and Warner (1979) look at a sample of 87 public debt issues and find that roughly 91% include covenants that restrict future issues of debt, while 23% have limitations on the distribution of dividends.

2.8 Cash holdings

We have seen that risky debt helps to alleviate the underinvestment problem. It does not solve it, however. Myers and Majluf (1984, pp. 216-17) provide an (seemingly) easy way to eliminate it entirely. The intuition is this: always make sure to have enough cash at hand when the project is due. If so, the problems caused by asymmetric information do not emerge as there are only insiders at work. This could be achieved by issuing fresh equity or debt in the first period of the model, when information is still symmetric, and storing the raised funds until they are needed in $t = 0$. This line of thought, in contrast to Jensen's (1986) agency theory, provides a strong rationale against paying out large amounts in dividends (even though not considered in the model) in order to conserve valuable financial slack. The bad news, however, is that this solution is not as easy as it seems: first of all, how much money is "enough"? If there is no upper bound on how much a new investment may cost, then one can never be sure to have raised enough cash to not be reliant on capital markets again during times of asymmetric information in the future. Moreover, even if the amount of investment I were known ahead of time, Myers and Majluf (1984) point out that the inefficiency result could be restored quite easily by assuming that the information disadvantage (in that the market learns news one period late) is permanent. If so, the problem of deciding on an issue is merely brought forward one period (assume managers know $\overline{A}$ and $\overline{B}$ at $t = -1$, whereas to the market these are just two random variables because the distributions of the AIP and the investment opportunity are yet unknown). Therefore, management may still decide not to issue (at $t = -1$) in some cases due to information problems. In this case, there is no easy way out of the underinvestment problem.

Nevertheless, it holds true that firms with considerable amounts of cash fare better in battling underinvestment than the ones without. Bates et al. (2009) report that the average cash ratio of U.S. firms has risen dramatically in the period 1980-2006. While the authors neither test for underinvestment nor exclude it specifically, they state that the likely cause for this build-up is that firm characteristics have changed in recent years. To give an example, cash flows have become increasingly volatile due to elevated firm-specific risk. Consequently, the rise in cash holdings is a precautionary measure against negative shocks to cash flows and, thus, default. Related to this development, Fama and French (2001) report that dividends increasingly "disappear".

Among others, Opler et al. (1999) and Dittmar et al. (2003) provide empirical studies attempting to explain the determinants of actual corporate cash holdings. Support for informational asymmetries and, thus, the pecking order as the main driver of corporate cash policy is limited — other theories of cash holdings trade off miscellaneous costs of holding cash against its benefits when determining the optimal cash balance. However, it is dangerous to call a single theory the winner, since, as noted by Opler et al. (1999, p. 14), there is a substantial overlap between them such that several of the empirical findings can be ascribed to more than one theory. Examining cash holdings across different countries, as done by Dittmar et al. (2003), more practical issues, such as corporate governance and legal aspects, tend to play a role, too.

2.9 Some final comments — restoring the irrelevance of financing

We are approaching the ending of the first main part. We have, quite extensively, considered inefficiencies in corporate investment decisions arising from the presence of asymmetric information, posing a departure from the stylized "perfect" market as considered by Modigliani and Miller (1958). One of the consequences, as seen in Myers and Majluf (1984), is that financing matters. In the models that we have considered in detail, asymmetric information favors debt financing over issuing equity, which has implications for corporate capital structure and, thus, contrasts with the famous MM irrelevance proposition.

As much support as there is for underinvestment and especially the ensuing announcement price declines, we would not be providing sincere scientific work if not pointing out that opposing views regarding information asymmetry and corporate financing exist, too. Dybvig and Zender (1991) provide a critique of Myers and Majluf's (1984) underinvestment result, and claim that optimal investment along with the irrelevance of capital structure (and dividend policy) may well prevail under asymmetric information. They present a model that very closely resembles that of Myers and Majluf (1984), with few exceptions: given an investment decision, the market does not learn a and b individually, but only $a + b$ in conjunction. In other words, it is assumed that the investment project is inseparably attached to the AIP and cannot be looked at as a stand-alone opportunity. Think of the costly upgrading of an existing production line, for example. The authors reason that, otherwise, the AIP could simply be spun off from the investment project (or sold) and be treated as a separate entity; this would solve the underinvestment problem because there is no more conflict between old and new claimholders. Be aware that this point does not go unnoticed by Myers and Majluf (1984, p. 202), who, however, treat it as a special case. Moreover, Dybvig and Zender (1991) allow for bad projects. Their main point of criticism aims at the assumption that managers act solely in the interest of old shareholders (cf. fn. 8) and do not follow their own objectives instead, so that agency conflicts between these two groups are prevented. Since such behavior leads management to execute the inefficient investment strategy in the first place, the authors endogenize the choice of management's incentive contract. To reach an optimal investment plan, i.e., investment in every worthwhile project, the authors argue that one has to set the incentive scheme for managers "optimally". Once compensation is chosen accordingly, it is shown that the firm reaches status quo irrespective of the mode of financing. Thus, an MM-type result holds despite the presence of asymmetric information. Furthermore, the authors claim that their paper may just as well explain observed issue announcement effects, suggesting that the great explanatory power of Myers and Majluf's (1984) theory is not exclusive in this regard.

Note that Myers and Majluf (1984, p. 210-12) themselves briefly point to another direction in reestablishing the irrelevance of financing: the assumption that old shareholders act passively has to be dropped, i.e., one has to allow them to trade in old and new claims such that they could, for instance, buy the entire new equity issue with their private cash. If so, basically the same argument as in Modigliani and Miller (1958, 1969) applies. That is, active original owners could always respond to changes in capital structure (induced by management's decision to invest) by rebalancing their own portfolios.[47]

Daniel and Titman (1995, p. 753-54) come back to a point made earlier in the context of rights issues. Underinvestment disappears if every original shareholder buys and holds a pro rata share of the new issue — regardless of whether debt or equity is chosen. The firm remains in the hands of old shareholders, for they are the sole investors. Hence, there is no conflict between original and new shareholders and, thus, no underinvestment. It follows that a management whose objective function is to maximize existing shareholders' wealth would invest in every non-negative-NPV project and, accordingly, reach status quo. Then again, this is easier said than done. For one, since shareholders are active, this may well conflict with their individual portfolio motives. Secondly, personal resources to provide funding for a new project may be constrained. That is to say, passive shareholding may not be such a bad assumption after all. Myers and Majluf (1984, p. 211, fn. 21) also recognize the ex-ante optimal character of having old shareholders completely fund a project (though not necessarily on a pro rata basis), but conclude that "...the problem is enforcing it". If shareholders are active, who is going to force them to buy new shares or stop them from selling old ones ex-post? Corporate claimholders are free to trade at will in real life. Fields and Mais

[47] Fulghieri and Lukin (2001) present a model that does not restore irrelevance, but where the pecking order may be "reversed". The novelty is that some investors may become informed by buying access to an information production technology. Depending on the degree of information asymmetry about the firm's quality and the cost and quality of the information, issuing equity (rather than straight debt) may prove beneficial to high-quality firms: as it is more information sensitive, it prompts more information production, which in turn increases overall demand and, ultimately, the offer price the market is willing to pay.

(1994) empirically investigate changes in ownership structure and find that managerial and institutional (banks, insurance and investment companies) ownership declines significantly in the wake of SEOs, suggesting passive behavior. By contrast, holders of large blocks of no less than five percent of the firm's equity trade actively: their fractional holdings do not change significantly. By implication, not all of the old claimholders share the desire to hold the corporation's new securities, promoting underinvestment.

In the end, asymmetric information most likely is *one* determinant of capital structure. Building an entire theory of a firm's mix of securities around it, however, does not get the job done properly. This holds true especially in case of the pecking order, for it does not imply a target debt ratio: the use of leverage merely reflects the cumulative demand for outside capital to finance investments when financial slack is insufficient. Capital structure remains an active and vast field of current research. Although there is not yet a unique and general theory, what we *can* say is that there are many more (potentially) determining factors of capital structure: taxes, bankruptcy, various agency costs, corporate control or market timing, to name just a few. We point to Harris and Raviv (1991) for an extensive introductory summary of different theories of corporate capital structure.

In the end, we take Myers and Majluf (1984) as a theory based on asymmetric information that exceptionally well explains the observed (negative) announcement effects of various types of securities — but not as a theory explaining why they are selected. As we will come to know in what follows, informational asymmetry is *one* cause of underinvestment, but not the only.

Part III

Corporate Underinvestment and Symmetric Information

3 Corporate underinvestment in the presence of symmetric information

Up to this point, we have come to know how informational asymmetry may lead to socially suboptimal investment behavior in that profitable investment opportunities are not pursued. Unfortunately, this need not only be the case in the presence of asymmetric information. That is, even if all parties share the same information (at the same point in time), underinvestment may still occur. Obviously, this must happen for reasons other than the ones just discussed. Therefore, the bigger part of the remainder of this work is dedicated to this topic. On our way to the model of underinvestment in the reconstitution of damaged assets, let us first have a glance at the model that laid the groundwork for all other work on corporate underinvestment in the presence of symmetric information to come.

3.1 The original underinvestment problem

The underinvestment problem in the presence of symmetric information – often also labeled the "debt overhang" problem – originates from a seminal paper by Stewart Myers published in 1977.[48] At the core of the problem lies the existence of risky debt in a firm's capital structure. *Risky* in the sense that a firm faces a positive probability of defaulting on its debt, i.e., with positive probability the value of the firm will not suffice to repay the face value to bondholders. Capital markets are assumed perfect and complete. Informational asymmetries and their associated consequences mentioned in the last part cannot cause any problems, either in Myers' (1977) model or the ones to be explained subsequently. Rather, the issue here is that the mere presence of risky debt will force a firm whose management

[48] According to the database IDEAS (http://ideas.repec.org/), Myers' (1977) paper has been cited 499 times and, thus, ranks among the top one percent of economic publications by number of citations (May 31, 2012).

acts in its shareholders' interest to pass up some positive-NPV investment opportunities, i.e., it *underinvests*. This suboptimal investment policy reduces the firm's market value relative to the case where it is financed with either risk-free debt or equity only. To grasp the idea, let us have a look at a simple example that neatly illustrates the entire concept of the model. Assume there are two dates. The firm's value as of the first date equals $V^* = 90$ (the AIP), and it has debt $F = 100$ outstanding, to be repaid at the second date. Suppose a risk-free investment opportunity arises that requires an initial outlay of 10 at the first date and promises a sure 15 at the second — clearly a positive-NPV project.[49] Investment requires fresh capital, however: the firm has no cash or other marketable securities at its disposal. If it decides to go ahead with the growth opportunity, it will have to issue new equity in order to raise the required capital.[50] For simplicity, we assume an interest rate of zero subsequently. What should the firm do? The first intuition is to give the go-ahead as any *Finance 101* class tells you to take every positive-NPV investment opportunity. Doing so, however, would make us really bad managers, provided our aim is to act in shareholders' best interest. The following table gives an overview of the firm's options.

value at second date	without project	with project
total firm	90	$90 + 15 = 105$
value of debt	90	100
value of equity	0	5

Obviously, debt is risky as not undertaking the project will not allow bondholders to receive their full promised repayment, i.e., the firm will default on its debt. The dilemma is this: yes, taking the positive-NPV investment will make the firm worth more. But only as a *whole*. Between the two groups of claimholders, there is a transfer of value from equity- to bondholders. Due to their higher seniority, debtholders are entitled to receive the incremental cash flows first, up to the point where they are fully paid off. Only then will shareholders, being residual claimants, also start to gain. They provide the whole 10 in funds, yet only receive 5. Thus, this project has a negative NPV to shareholders. This is a classical situation

[49] Thus, we implicitly assume that the risk–free interest rate is less than 50%. This is a reasonable assumption.

[50] Note that this assumption is not unrealistic. Campello et al. (2010) report from surveys conducted with CFOs that, in normal times, 46% of financially constrained firms (in that they have trouble getting funds from the credit market) are dependent on external financing (though not necessarily equity) as a means of raising funds for attractive investment projects.

of interest incompatibility between bondholders, who want to undertake the safe investment, and shareholders, who oppose. Put another way, the return threshold for which the project breaks even is higher for shareholders than for the firm as a whole due to the preexisting liabilities. Consequently, managers, acting on behalf of shareholders, will decide not to invest, leaving the firm worse off as a whole. This is the underinvestment problem.

Risky debt in the firm's capital structure discourages investment that would otherwise increase firm value. The reason for this is nicely expressed by Stein (2003, p. 116): "This is because if the existing debt is trading at less than face value, it acts as a tax on the proceeds of the new investment: part of any increase in value generated by the investment goes to make the existing lenders whole, and is therefore unavailable to repay those claimants who put up the new money". Another implication of the example above is that, everything else equal, the tax on the proceeds will be perceived as higher by shareholders if the face value of debt is even greater. In that case, NPV to shareholders will be even more negative. "Hence, the higher the probability of default, the lower the marginal return that the firm expects to receive from its investment, the smaller its incentive to invest" (Occhino and Pescatori, 2010, p. 1). Accordingly, theory predicts that the underinvestment problem is most severe when companies are highly levered and confronted with a high probability of default. Note that the transfer of value only harms *old* shareholders, i.e., the ones implicitly in control of the firm. Since markets are assumed perfect, the new shareholders will pay a fair price for the issue, making it a zero-NPV investment to them. This excludes transfers of wealth away from them.

Timing is crucial to the emergence of this underinvestment problem. The portrayed outcome is dependent on the assumption that "...the debt matures *after* the firm's investment option expires" (Myers, 1977, p. 153). For if it were the other way round, i.e., debt maturing prior to the investment decision, debtholders could simply take over the firm in the course of the firm's bankruptcy procedure, and then go ahead with the investment opportunity as the new owners. Timing issues aside, having creditors take over the firm after a default may prove rather problematic in reality: just think of the loss in reputation accompanied by a default. Additionally, corporate bankruptcy is not a process that is handled over night. By the time debtholders are in control, the business opportunity simply may have disappeared.

A short comment on the conflict of interest between bondholders and shareholders: this is not an unknown phenomenon. The reason for it to exist really is limited liability: you cannot lose more than the amount you have invested.[51] "By creating an asymmetry between the

[51] See Easterbrook and Fischel (1985) for an insightful discussion of limited liability.

costs and benefits of risky activities, limited liability causes bondholders and shareholders to have incompatible incentives whenever the corporation's debt is subject to the risk of bankruptcy" (Garven and MacMinn, 1993, p. 636). Generally, shareholders bear more risk than debtholders. This is because they are residual claimants after all. Their claims are wiped out first in case the firm value crashes. The upside is that they cannot be forced to contribute additional funds. Because of this limited liability, shareholders will not invest in a project which is known to have a negative NPV to them, even if it would benefit debtholders and, thus, the firm as a whole. Therefore, the firm underinvests.

Unfortunately, this need not necessarily be the end of the adverse effects of the debt overhang problem. Leaving the confines of Myers' (1977) model, there may follow up a second effect, making a bad thing worse. Hennessy (2004, p. 1737) finds that "...within a given firm, debt overhang distorts investment composition and not simply its level". In other words, in addition to investing less when highly levered, firms may change the scope of their investments, too. Note that this is not yet a negative statement per se, for the firm could take better investements. Sadly, this is generally not the case. Campbell (2010) also speaks on this issue and convincingly argues that shareholders, being in control of the firm, will further impair their company's prospects (but not their own) by taking on projects that are to a great extent riskier than would be optimal in case the firm's debt burden were significantly less. The reason is, once again, limited liability. Due to underinvestment, a safe project that yields a relatively low positive NPV is not desirable for shareholders as it has negative NPV to them. Consider another opportunity; this time with negative expected NPV, but extremely high cash flows in a few "good" states. The project as a whole is riskier to the entire firm, since it will destroy value on average. But to shareholders it is not. If the firm is in deep financial trouble already such that debt trades far below face value and equity is nearly worthless, shareholders have nothing to lose — but a lot to gain if they strike lucky. In the unlikely event that one of the high-cash-flow states materializes, shareholders will receive some of the NPV as well. They benefit from high payoffs, but do not bear the downside risk in such a situation.[52] Therefore, the firm is going to switch to a riskier investment plan that is harmful to the company on average. Parrino and Weisbach (1999), for example, provide results consistent with this view in their numerical simulations of the impact of leverage on a firm's investment decisions. Furthermore, they show that this risk-taking behavior intensifies when debt is increased.

[52] This is basically the risk-shifting argument, first made by Jensen and Meckling (1976). It is yet another agency cost of corporate debt and generally referred to as the "asset substitution" problem, since the firm substitutes investment in low-risk assets with investment in high-risk assets when being in financial trouble.

Debt overhang need not be a problem of (manufacturing) firms alone. It affects the entire financial sector as well. Allen et al. (2008) advance the view that the Myers-style underinvestment problem played a vital role in the 2007–2010 global financial crisis. They argue that the U.S. Treasury may have ordered the (quasi-) compulsory infusion of fresh (preferred) equity into the nine largest U.S. financial institutions (along with a government guarantee on freshly issued unsecured bank debt for the three years to come) for fear of underinvestment — apart from preventing the adverse effects of possible bank runs (Diamond and Dybvig, 1983) on the part of short-term creditors unwilling to execute debt roll-overs (cf. Veronesi and Zingales, 2010, p. 341).[53,54] Campbell (2010) reports that some U.S. investment banks had ratios as high as 30 dollars in debt for every dollar held in equity. In the light of Myers' (1977) model, by forcing a recapitalization, the government in effect hoped to stop existing debt from preventing financial institutions to carry out worthwhile investments, i.e., lending out money, by bringing down the leverage ratio. After all, one of the major concerns during the recent financial crisis was that corporations would not be supplied with enough loans by banks to keep their production processes and, thus, the economy running. The government hoped to counter this by its actions : "Purchasing equity would inject capital—the lifeblood of finance—directly into the undercapitalized banking system. That would reduce the risk of sudden failure and free up more money for banks to lend" (Bush, 2010, p. 464). Occhino (2010) adds that the granting of credit was especially lax in the pre-crisis years. Risks were perceived wrongly, excessive leverage was not taken as a potential threat and lending standards were loose. This led to risk premiums being lower than fundamentally justified (in hindsight, of course). As a consequence, assets were increasingly financed with debt. When asset values eventually plunged in the wake of the crisis, many firms were suddenly faced with

[53] Officially titled the *Troubled Asset Relief Program* [TARP], this was a $700 billion program under the *Emergency Economic Stabilization Act of 2008*, enacted by the Bush administration and intended to immediately counter the effects of the subprime mortgage crisis. This makes it the largest ever financial rescue package in the history of the U.S.. Here is what President Bush himself has to say about TARP in retrospect: "The strategy was a breathtaking intervention in the free market. It flew against all my instincts. But it was necessary to pull the country out of the panic. I decided that the only way to preserve the free market in the long run was to intervene in the short run" (Bush, 2010, p. 458-59). In any case, TARP did have major influence on the market: before finally passing in a second vote, the bailout-bill had initially failed on September 29, 2008. This caused the Dow Jones Industrial Average to plunge 777.68 points subsequently, the largest single-day loss in history to this day, cf. The Wall Street Journal (2008). See the U.S. Department of the Treasury (2011) for more information on TARP. Recently, Bayazitova and Shivdasani (2012) provide insightful background information, for example on the pivotal role of the restrictions on executive compensations, along with a critical assessment of TARP.

[54] According to Landler and Dash (2008), the banks' CEOs did not have the slightest clue of what was expecting them when being informed about the government's planned intervention by Treasury Secretary Hank Paulson in a private meeting. Apparently, Mr. Paulson's "plan" was presented more in the way of an ultimatum, leaving no room for debate. In the end, the executives came to realize that the bailout was a sweet deal: following its announcement by Secretary Paulson on October 13, 2008, the Dow Jones recorded one of its largest single day surges in history, gaining 936.42 points, cf. Stanton (2008).

an augmented debt burden, giving rise to underinvestment. The initial misjudgment certainly favored the emergence of debt overhang. Campello et al. (2010) survey a large number of CFOs of non-financial firms from 39 countries and state that financially constrained firms cut back on their investments more than less constrained corporations during the financial crisis. Veronesi and Zingales (2010, p. 364) attest to the capital infusion into the nine banks that it generally accomplished its purpose: "[F]rom a purely economic point of view, the plan could be considered a success because it created value". The authors calculate that the plan to purchase the \$125 billion in freshly issued equity on behalf of the U.S. Treasury immediately increased the value of the nine banks by a total of roughly \$130 billion following its announcement on October 13, 2008. The great deal of this identified rise is accounted for by debt, which gained \$119 billion in value. Existing preferred equity, which is junior to debt, but senior to other forms of equity, rose by \$6.7 billion. In contrast, common equity lost \$2.8 billion (in line with the underinvestment theory). Since the \$125 billion in preferred equity are estimated to be worth only between \$89 and \$112 billion, the bailout comes at a cost of between \$13 and \$36 billion to taxpayers, directly transferred to the banks (or, more specifically, mostly its creditors). Relating this to the gain of \$130 billion, it still represents an overall creation of value. Consistent with Myers (1977), the authors estimate the total transfer of value to debtholders upon the announcement of the capital injection to be \$38 billion, supporting the view that the great deal of the rebound in firm value is absorbed by debtholders. The data also suggest that the probability of a bank run decreased following the announcement of the equity infusion. Accordingly, the expected costs of bankruptcy were reduced and, thus, corporate values elevated. The financial institutions most threatened by a bank run recorded the highest gains in value. However, when considering (with the benefit of hindsight) alternative government interventions, the authors arrive at the conclusion that the outcome of the government intervention could have been reached on better terms, i.e., with less costs to taxpayers, for example trough a swap of debt for equity.

In his paper, Myers (1977) examines other possible solutions to the problem, such as rewriting and renegotiating the debt contract[55], shortening debt maturity[56] or restricting dividends in

[55] See Bhattacharya and Faure-Grimaud (2001) for more details on debt restructuring. Tirole (2006, p. 126) even suggests that it is not risky debt, but the lack of (partial) debt forgiveness that is at the core of the underinvestment problem: "Renegotiation breakdown creates debt overhang". Specifically, free-riding behavior among small public creditors poses a major threat. Individual investors have an incentive not to participate in the restructuring because their claims will rise in value if everyone else takes part (in an exchange offer, for example), cf. Gertner and Scharfstein (1991). Gilson et al. (1990) report from a sample of 169 public, financially distressed U.S. firms that in 53% of all cases private restructuring indeed failed, prompting bankruptcy and, thus, reorganization under Chapter 11. Furthermore, failure of private workout is more likely when ownership is less concentrated. Franks and Torous (1994) provide similar results.

[56] This point is frequently made in the literature. Assume debt is short-term in that it matures prior to the

order to maintain a certain level of cash to finance new investments.[57] However, he concludes that all these attempts are either impossible to enforce or costly to monitor. Moreover, in perfect capital markets potential lenders will foresee these costs. Upon issue, they will be reflected in the liabilities' market value, providing the firm with fewer funds. Thus, ultimately shareholders as the owners of the firm fully bear theses costs. At the same time, this provides them with a strong incentive to solve the problem. But this creates another dilemma: if the firm decides to take actions against the underinvestment problem by including appropriate covenants in the bond contract, the associated costs will also lower the firm's value relative to pure equity or risk-free debt financing. This comes down to trading off the two types of costs, as shown by Myers (1977). Occhino (2010) promotes the use of sinking funds. These are corporate accounts into which the firm makes predetermined payments which are then used to pay back parts of the loan early. The benefit hereof is that the level of corporate debt decreases with the (book) value of assets in place, which is depreciated over time. Provided that no new debt is taken on, this ensures that the likelihood of underinvestment is reduced. It is not abolished, however, since some liabilities remain (at least for some time to come) in the capital structure. The main point we want to emphasize is this: the only way to solve the problem without incurring *any* loss in value is the extreme result that risky debt should never be issued by firms. A firm financed with risk-free debt or no borrowed capital at all will feature a different investment behavior than one with risky debt in its capital structure, for the latter will let pass by worthwhile investment opportunities. "The suboptimal investment policy is an agency cost induced by risky debt" (Myers, 1977, p. 149).[58]

investment decision. If a state materializes in which shareholders would rather not invest, bondholders could simply take over the firm and invest in the profitable opportunity, cf. Myers (1977, p. 152). Therefore, debt overhang is usually considered to be more severe for long-term debt. Recently, Diamond and He (2011) refine this view. They point out that the maturity structure of short-term debt just considered is a special case. Rather, one should concentrate on debt of different terms to maturity *at the time* the investment decision is made. The authors consider a four-date model of a firm that has both long-term and short-term debt due in future periods, where the latter needs to be rolled over. They conclude that both types of debt may cause underinvestment. As a matter of fact, short-term liabilities may actually induce more severe debt overhang. The influence of maturity has also been subject to empirical testing, and results are mixed. Guedes and Opler (1996), who consider roughly 7,300 bond issues in the U.S., use the market-to-book ratio (book value of debt together with market value of equity over total assets) as a proxy for a firm's growth opportunities and find that firms with good prospects prefer debt with shorter maturities. Barclay and Smith (1995) also find that growth opportunities are negatively related to maturity. On the contrary, Johnson (2003) finds a positive relation between the two. Finally, Graham and Harvey (2001) survey nearly 400 CFOs and find that overhang generally plays no major role in determining corporate debt policy. Specifically, there is practically no support for the use of short-term debt as a means of mitigating underinvestment.

[57] See, e.g., Kalay (1982) for more information.

[58] Aivazian and Callen (1980) provide a theoretical counter-argument and claim that efficiency, i.e., the firm value maximizing investment strategy, is restored easily. Building on Myers' (1977) model, they argue that the adverse incentive effect of risky debt embodied in the transfer of wealth to bondholders is a negative externality (see Coase, 1960) to shareholding, which results in the value forgone by not investing. Given a perfect market where there are no transactions costs of bargaining, the authors state that, by the Coase Theorem, both shareholders and bondholders will want to internalize the externality and, thus, return to the optimal investment strategy (thereby sharing the resulting gains among them). Specifically, this is accomplished by

Obviously, confining oneself to issuing only safe debt may be impractical in real life. After all, highly levered firms do exist in the real world. Plus, there are other theories that may answer the question of why firms issue risky debt.[59] However, the model gives a strong rationale to limit debt in the capital structure.

3.2 Applications and quantifications

Before we focus our attention on debt overhang in the context of corporate casualty losses in the central part of this dissertation, take note that there exists a great number of other applications and extensions of the underinvestment problem. For example, Perotti and Spier (1993) present a model in which shareholders use potential underinvestment as a threat in a wage-bargaining game in order to achieve concessions from their employees. The firm faces a situation of low profits, which makes further worthwhile investments necessary to be able to fully pay out wages to the workforce, whose claim is considered senior to any other. Shareholders, knowing that workers are dependent on the investment decision, may issue junior debt and use the proceeds to buy back equity in the market in order to increase leverage in the firm's capital structure and, thus, convincingly threaten not to invest in profitable new projects. The concessions extracted in the renegotiation of the wage contract allow shareholders to reap a greater share of the investment's NPV.

Other extensions and applications of the underinvestment problem include Hart and Moore (1995) and Bhattacharya and Faure-Grimaud (2001). The former modify Myers' (1977) model structure to admit of debt of different maturities and seniorities available for financing investments as well as a self-serving manager, implying that both overinvestment ("empire building", perquisites, etc.) and underinvestment may impede socially optimal investment. Given these assumptions, the ideal mix of debt and equity with respect to maximizing the *entire* firm value is established in the absence of the possibility of renegotiation, with a

either debtholders or shareholders buying up all the claims from the respective counterparty (or an outside investor buying the entire firm). The price of the claims is a matter of negotiation – a cooperative game between shareholders and bondholders – and will lie somewhere between zero and the value forgone by not investing. Hence, there is no underinvestment problem. Optimal investment strategy (and thus firm value) is no matter of corporate capital structure. Note that the fact that the price ultimately paid for the claims is uncertain (as it depends on one's ability to negotiate) leads to a new problem: how to determine the ex-ante value of both debt and equity? The authors dedicate the remainder of their article to the solution of this problem.

[59] Jensen and Meckling (1976), for example, point out that *both* equity and debt come with agency costs. Therefore, debt may simply be the better of two bad options. Once tax considerations come into play, the story changes significantly in favor of the issuance of debt because valuable tax shields are created. Evolving out of a debate (see, e.g., Durand, 1959) over their famous Propositions I-III, this tax benefit was first acknowledged by Modigliani and Miller (1963) in a correction of their seminal 1958 paper on the irrelevance of capital structure in perfect capital markets. Miller (1977) later on rationalizes why this does not mean every company should be maximally levered. He provides an equilibrium theory of the aggregate amount of firm debt in an economy where personal taxes paid offset the gains enjoyed by corporations.

particular interest in long-term debt's role in controlling management's investment behavior. The latter deal with inefficiencies encountered in the attempt to solve the underinvestment problem by renegotiating the debt contract in a setting where investment choices are not verifiable. Possibilities to overcome these impediments are discussed as well.

Philippon and Schnabl (2012) do not consider debt overhang in the corporate sector, but rather in the banking sector. Drawing parallels to the recent global financial crisis, the authors consider an entire financial sector that is crippled by too much leverage (due to a negative shock). One can imagine the devastating potential of debt overhang on investment (say, profitable bank lending to firms) in the financial sector, since its adverse effects would multiply by spilling over to other parts of the economy. The model focuses on the interactions between banks carrying risky debt and households, who are assumed to own both the equity and the bonds issued by banks as part of their income portfolio. At the same time, they have loans outstanding to these institutions. A household will default if its income is lower than the face value of its loans owed to banks. The latter are assumed to own industrial projects (their AIPs) and, on top of that, must decide on undertaking new investment opportunities for which they need to borrow money from the households. A double effect occurs because too much debt in their capital structure is not only value-destroying for the banks themselves, but impacts once again by hindering repayments to households (debtholders receive some repayment, whereas shareholders get none). As part of their income has just been lost, households cannot repay their loans to other banks and default, which in turn intensifies the debt overhang problem among these institutions. Philippon and Schnabl (2012) underline the important role of debt overhang in the recent financial crisis and devote a great part of their paper to investigating the efficiency of various government intervention schemes (such as asset purchases or the injection of fresh equity) to stabilize the economy by reestablishing welfare-improving bank lending.

Leaving behind this model, one can easily think of another potentially disastrous scenario caused by debt overhang, but this time relating to the corporate sector. If banks face problems of underinvestment, they may be kept from lending to firms which are in urgent need of the funds to finance their operations and growth opportunities. Accordingly, the whole economy may face a downturn because firms are kept from executing the production process. Either way, debt overhang in the financial sector potentially has enormous consequences and may make government interventions necessary. Diamond and Rajan (2011) focus on underinvestment in the banking sector and its connection with potential fire sales of assets in case of a future financial crisis due to urgent need of liquidity.

Debt overhang even causes trouble at the individual/household level. In his empirical study, Melzer (2010) focuses on levered U.S. homeowners in a state of negative equity, which occurs when one's mortgage liabilities outweigh the value of one's home. The author uses data from 2006 to 2009 and argues that negative equity is a proxy for debt overhang and finds that such households indeed tend to invest less in their homes relative to households with positive equity, who are further away from strategic mortgage default because their asset is less levered. Investing in the home's maintenance and improvement to enhance its value constitutes an avoidable loss in such a situation, since the bank collects the home *including* the benefits from these investments in case of default.[60] Potential objections to this reasoning are addressed, and discarded: for example, liquidity constraints cannot be used as an explanation for reduced investment because high-income earners with negative equity cut back, too. Next, one might object that such investments may simply be poor in that they have negative NPV, regardless of whether the residence is highly levered. However, this is implausible because principal payments of underwater homeowners fall behind as well. Unlike measures of home improvement, such payments, which represent an investment from the mortgagor's perspective, do not boost the value of the house. Therefore, we expect a reduction in these payments only in the case of debt overhang. Finally, it is found that households do not cut back on investments that will not accrue to lenders upon default, such as cars or furniture. Accordingly, Melzer (2010) concludes that debt overhang is the likely cause of the problem. Olney (1999) hints at mortgage default behavior consistent with underinvestment during the Great Depression. Unlike with their home loans, households did honor their commitments in the matter of other consumer credits, e.g., car loans, despite being highly indebted. To accomplish this, they significantly cut back on consumption levels. Finally, Mulligan (2008) presents a model where depressed collateral values (say, due to a recession) create debt overhang in the mortgage market, which prompts a decline in the supply of labor on behalf of households. The reason is that homeowners' incentives to work fall because they know that part of their income goes to lenders to pay off the debt. The more negative the equity is, the lower becomes the incentive to supply labor. Worse still, as creditors maximize their

[60] Excluding the top ten percent income earners, an American family's residence generally made up for about 45% of all assets owned (the value drops to around 32% for the entire population) in 2007. It follows that investments in property are among the most important financial decisions made by families, cf. Bucks et al. (2009). Christie (2012) reports that the fraction of "underwater" homeowners in the U.S. has risen to 22.8% by the beginning of 2012. According to Gittelsohn (2011), the city of Las Vegas holds the saddest record with a stunning 85% of mortgaged homes in negative equity. Foote et al. (2008) examine the empirical relation between mortgage default and negative equity. In conclusion, underwater homeowners not only invest less, but default more often, too. In absolute terms, however, the majority will not experience foreclosure. In other words, "...negative equity is a necessary condition for default, but not a sufficient one" (Foote et al., 2008, p. 234). Guiso et al. (2011) provide survey evidence that the willingness to default is higher the more negative the equity position is.

income through optimal debt forgiveness depending on the household's income, stimuli for other households to renounce labor income in favor of higher debt relief are created, since higher-income households are "taxed" more heavily. Through this channel, excessive leverage creates unemployment — yet another negative characteristic of debt overhang. Mulligan's (2008) model is reported to be consistent with behavior during the Great Depression.

Kroszner (1998), in an interesting paper, provides empirical support for the positive effects affiliated with the removal of excessive debt burdens (as underinvestment is alleviated). During the times of the Great Depression, the U.S. Supreme Court dismissed a case filed by creditors in response to the U.S. government's decision to no longer enforce the so-called gold indexation clause, which, for reasons of claims protection, granted creditors the right to be repaid in gold in case the dollar devalued too much with respect to gold. When the depreciation took place indeed in the wake of U.S. President Roosevelt's 'New Deal' program to revive the economy, actually enforcing this right would have radically increased the burden for debtors (by nearly 70%), putting them into massive financial trouble. Interestingly, not only share prices rose upon the court's announcement of the effective haircut, but corporate bond values, too. Hence, the benefit to corporate creditors from eliminating the underinvestment problem must have outweighed the loss from potentially getting a higher repayment. Additionally, the price increase is positively related to the amount of debt a firm carries, indicating that the underinvestment problem becomes more severe with growing leverage, consistent with Myers' (1977) theory. Obviously, debt relief is everything but a perfect solution to the problem. Instead, it may simply be the better of two costly options. Once the debt overhang problem is pronounced in that a firm is highly levered, creditors are (likely) not going to get paid back in full. This circumstance will be reflected in the bond trading well below face value. Occhino (2010) states that a partial debt relief may be useful if it is sufficiently large, since it brings back the incentives for shareholders to undertake profitable investment projects. Thus, it supports the interest realignment of shareholders and debtholders (though not fully because usually not all risky debt is forgiven), which will ultimately lead to an increase in the market price of the remaining debt through value-generating investment. As in Kroszner's (1998) gold indexation example, the impact of this realignment may be so strong that debt, even though it has been cut, is worth more than in the case without a relief. This is not to be misunderstood as a general pleading for debt forgiveness. In real life, the outcome of this tradeoff needs to be determined on a case-by-case basis. The general rule for creditors must be to decide in favor of the haircut if it increases their expected repayment. Since such a procedure, if undertaken, will be beneficial to shareholders as well, debt forgiveness constitutes a Pareto improvement. Either way, it is clear that a loss remains for debtholders relative to being paid back in full.

In a related paper, Giroud et al. (2012) second the potentially beneficial character of debt forgiveness, using an innovative approach. They examine the fates of 115 highly indebted Austrian ski hotels that undergo debt restructuring. Their approach is unique in that it allows the authors to differentiate between firms that indeed face financial distress because of debt overhang ("strategic defaulters") and those whose financial situation is simply accounted for by a streak of bad luck ("liquidity defaulters"). That is to say, several highly levered ski resorts may have simply suffered a series of adverse demand shocks. Unlike in the case of debt overhang, writing off some of the debt in favor of these creditors is uncalled for because the distressed situation is merely a problem of temporary illiquidity (rather than insolvency), which could be resolved, for example, by extending the debt's time to maturity. The big question is, of course, how to assign a firm to its respective group.[61] The answer is: snowfall. Obviously, the amount of snow significantly determines a ski hotel's performance. The authors measure "unexpected snow" for each hotel, that is, the average snowfall in the two years prior to the restructuring relative to the average snowfall in the previous ten years. The reasoning is that a liquidity defaulter has experienced two bad years, whereas a strategic defaulter goes into restructuring despite having had lots of snow and, thus, good prospects for business (under normal circumstances). Hence, such kind of bad performance is *not* accidental, making underinvestment (undermaintanance) the likely cause. Two results are especially noteworthy. First, Austrian banks apparently are capable of distinguishing between strategic and liquidity defaulters. Despite having had similar leverage ratios prior to the restructuring, no substantial debt relief is granted to hotels that experienced negative unexpected snow (roughly half of the sample), while for those with a lot of unexpected snowfall, i.e., strategic defaulters, creditors agree to significant reductions (23% of the debt owed is forgiven on average). It seems that leverage cuts are only awarded to firms who truly need them. Second, for the hotels suffering from debt overhang, the result is qualitatively similar to Kroszner (1998) and, thus, consistent with Myers (1977). Larger write-offs are significantly associated with larger increases in operating performance (as measured by return on assets), supporting a beneficial role of debt relief in the presence of debt overhang.

What is more, one can also adopt a macroeconomic perspective on the debt overhang issue.

[61] In an analysis of homeowners' attitudes towards defaulting on their mortgage in the wake of the recent global financial crisis, Guiso et al. (2011, p. 2) annotate: "[T]he main problem in studying strategic defaults is that this is de facto an unobservable event. While we do observe defaults, we cannot observe whether a default is strategic".

Occhino and Pescatori (2010) apply the underinvestment problem in a standard business cycle model that includes households, firms, banks and the government. The novelty is that debt overhang intensifies and prolongs the already adverse effects of negative macroeconomic shocks (to technology and/or productivity) on the economy by transporting them onto the firms' balance sheets. In a (shock-induced) recession, firms' asset values are depressed, increasing the leverage ratio and, thus, the probability of default. This brings (amplified) debt overhang to the scene, which in turn further decreases firm value by distorting investment as firms do not favor investment that would merely boost their creditors' claims, leading to an even greater probability of default. Firms find themselves trapped in a vicious circle. Accordingly, an already bad economic situation is made worse. This calls for government interventions, for example expansive fiscal policy, in order to trigger off investment and, thus, partly offset the underinvestment problem. Two other models provide similar conclusions. First, Lamont (1995) considers a general equilibrium model where investment activity depends on agents' expectations on the economy's well-being: in good times, investment opportunities have high returns, whereas the opposite holds true during recessions. One and the same (sufficiently high) level of preexisting leverage in firms' balance sheets may trigger underinvestment. Sunspots determine the outcome, giving rise to multiple equilibria. If a recession is expected, firms will refrain from investing because returns would not suffice to support their own claims (but accrue to debtholders instead), and the economic activity indeed turns out low. Thus, owing to corporate debt, pessimistic expectations cause a shock to the economy in the model. Second, Philippon (2010) presents a theoretical model that considers a double debt overhang, both in the market for mortgages on the borrower level and in the market for bank bonds on the lender level. Due to interdependencies between these two, exogenous shocks loom larger because underinvestment in one of the markets intensifies its counterpart in the other.

Leaving the corporate environment for a moment, Krugman (1988), surprisingly without mentioning Myers (1977), engages himself in development economics and applies the underinvestment problem in a macroeconomic setting where the best way for creditors to deal with heavily indebted (development) countries is explored. In Krugman's (1988, p. 255) definition, "[A] country has a debt overhang problem when the expected present value of potential future resource transfers is less than its debt". The resource transfer that creditors expect to receive can roughly be compared to a company's cash flow stream out of which it finances its current debt payments. In conclusion, it may in some circumstances be better for creditors to reduce the adverse incentives of debt financing instead of insisting on the settlement of the claims in full. By forgiving part of the debt, they may actually end up receiving a higher expected repayment in comparison to maintaining the original face value. The reason is that not backing down from their full entitlement is equivalent to gambling for the country to strike lucky economically.[62] Note, however, that in the presence of a multiplicity of investors coordination among them is vital for efficient debt relief because otherwise there exist high incentives to free ride individually by holding out and having others write off their claims.[63] This is stated by Fischer (1989), for example. Sachs (1989) also considers the problems of debt overhang faced by developing countries, for which, in contrast to the corporate sector, there is no bankruptcy code equivalent that would provide legal security and protection for creditors. Instead, such insolvencies have to be addressed through (politically motivated) negotiations between creditors and debtors, giving rise to inefficient outcomes. The author, too, concludes that there are good reasons to partly cancel a country's debt when it is deep under water. Sachs (2002) further provides suggestions for reformation and formalization of the process of working out financially distressed poor countries with the help of international institutions, such as major U.N. agencies.

Overall, debt relief for poor and highly indebted countries is a major field of research in development economics. This is partly due to the fact that its effectiveness is controversial empirically. Easterly (2002) reviews the track record of two decades of relief efforts, and his results are mixed. He finds that debt forgiveness is only an effective instrument for development assistance if it is granted to countries that at the same time fundamentally change their economic policies for the better (which should be subject to monitoring). In that case, it may spark good long-term investment that is actually welfare-increasing to the public. If, however, it is provided to heavily indebted poor countries [HIPCs][64] that adhere to their bad economic behavior subsequently, its consequences can easily leave the country

[62] Apart from the debt overhang rationale, there is another channel through which debt relief fosters investment and, thus, growth. As pointed out by Cohen (1993), it frees up valuable resources. Given a development country is in financial trouble, but actually pays back some of its debt, the author finds that debt service itself suppresses (urgently needed) investment. The funds used for paying off the liabilities are obviously not available for financing investment. Cohen (1993) argues that generally ascribing the crowding out of investment solely to debt overhang is a naive point of view. If a highly indebted country is not expected to pay back (part of) its debt due to its bad reputation anyway, then there should be no (large) adverse effect on investment.

[63] The debt restructuring of Greece, which likely suffers from large debt overhang, provides a recent example. After tough negotiations, 85.8% of private investors initially agreed to the restructuring in March of 2012 to provide Greece with much needed debt relief. The Greek government did not stop there, however. By enacting so-called collective action clauses, it forced all holders of bonds falling under Greek jurisdiction to participate, raising the percentage to 95.7 (nearly €200 billion). This action effectively ruled out free riding behavior for all investors under Greek law. The missing 4.3% covered by non-Greek law have been given an extension to voluntarily join the restructuring. Free riding could pay off for this minority. See Petrakis and Christie (2012).

[64] The International Monetary Fund [IMF] and the World Bank jointly established the so-called "HIPC Initiative" in 1996 with the objective of providing reasonable debt relief to poor countries. As of December 2011, 36 countries have been granted a total of $ 76 billion in debt forgiveness. For more information on the program and a definition of an HIPC, see the associated IMF Factsheet (2011)

in a situation worse than before the cut. By re-accumulating more new debt, it ends up with a higher public debt quota. There are several reasons. For example, it gives rise to moral hazard, in that developing countries may borrow generously, being confident that their debt will be relieved in the future yet again. Furthermore, it postpones urgently needed economic reforms. Thus, debt relief may end up reducing its aim to absurdity. To overcome these inefficiencies of debt forgiveness, the author suggests a policy of a one-time-only offer to cut debt in conjunction with a credible commitment not to grant future write-offs. Of course, this is not easy to put into practice.

Cordella and Missale (2011) also point to the shortcomings of a policy of providing debt relief to every HIPC. They establish a (costly) mechanism that separates good from bad governments. In their model, creditworthy countries distinguish themselves from their bad counterparts via the choice between debt relief and foreign aid. The idea is that good governments will opt for debt forgiveness because it provides them with a fresh start.

Cordella et al. (2005) go about empirically examining the influence of debt on growth for HIPCs versus non-HIPCs, using a panel data set of 79 developing countries over a period of 32 years. At first, it might come as a surprise that debt does not have a significant effect on growth in the HIPC group, whereas there is a significant and robust negative impact of debt on non-HIPCs.[65] This, however, is merely indicative of the fact that debt ceases to exert influence on public sector investment above some threshold level. It does not imply that a major debt relief is not beneficial to heavily indebted developing countries. The cut needs to be large enough to push the amount of debt below the "irrelevance threshold". To come to this conclusion, the authors concentrate on debt levels over the entire sample, i.e., irrespective of whether a country is an HIPC or non-HIPC. They find a significant and robust negative debt-growth relationship at intermediate liability levels, implying that debt overhang only occurs within a certain debt interval, namely above the "debt overhang" threshold and below the irrelevance threshold. In addition, the size of this interval is found to be bigger for countries with better institutions and policies. In a similar way, Imbs and Ranciere (2005) conduct an empirical study of 87 developing countries for the years 1969 through to 2002. They also find a negative relation between initial external debt and growth. However, this impact of debt overhang only starts to take effect once the face value of debt passes the average threshold of 55% of GDP. Consistent with this result, Reinhart and Rogoff (2010) determine an external debt threshold of 60% of GDP above which growth starts to slow down notably, using a sample of 20 emerging markets for the years 1970-2009. Outcomes

[65] Chowdhury (2001), in a smaller sample which spans a shorter time period, finds a significant (and robust) relationship in both the HIPC and the non-HIPC group.

such as these have led to the establishment of the concept of a debt-growth Laffer curve in the literature (or at least the downward sloping part that corresponds to higher liability levels), with debt overhang setting in once the peak of the curve has been passed. Pattillo et al. (2002) also support this view. From a panel data set of 93 developing countries, they find that high levels of external indebtedness are counterproductive for growth.[66]

Arslanalp and Henry (2005) make use of the stock market to assess the effectiveness of haircuts. For a group of 16 developing economies that receive a reduction of their liabilities under a program initiated by the U.S. government, they find that debt relief is indeed beneficial to both parties involved. In the 12 months prior to the cut's announcement, the stock market index of a participating debtor country on average rises by 60%, while the share prices of the western debtor banks appreciate by 35% on average in the corresponding period.

Finally, moving on from HIPCs, Brown and Lane (2011) examine whether debt overhang endangers the economies of emerging Europe, i.e., Eastern European countries, as a consequence of the recent global financial crisis. They find that the great majority of these countries does not face serious distortions due to underinvestment. On the macroeconomic level, this holds true because public debt levels are mostly low in emerging Europe. The same basically applies to the sector level, both for households and enterprises. Merely the financial sector constitutes a partial exception. Due to the crisis, a good deal of loans is in default in some of the countries, representing a potential danger in the future. Overall, however, debt overhang does not pose a major threat to Eastern Europe. This concludes the side trip to the field of risky debt and its effect on public sector investment in development economics.

Let us return to the underinvestment problem in the context of corporate financing one more time. So far, we have explored how (debt) financing negatively influences corporate investment decisions in that it harms *overall* firm value. A natural question to ask is whether it is possible to quantify this underinvestment effect. In other words, how much firm value is actually lost? This is not a straightforward task and requires quite a bit of abstracting from the original model framework to also include other effects affecting firm value. Further, it requires quite a bit of explaining. Arguably, the most sophisticated approach to quantifying debt overhang is provided by Moyen (2007). The author examines a firm's investment decision in a dynamic stochastic framework with infinite horizon. This means that, unlike

[66] The World Bank (2012) provides an extensive overview of external debt for 129 developing countries. In recent years, total outstanding debt has steadily risen, exceeding $4 trillion at the end of 2010. However, at the country level, outstanding liabilities remain low as a percentage of gross national income. As a matter of fact, debt levels have been on the decline, making up 21% on average in 2010. Lane and Milesi-Ferretti (2006) report that developing economies increasingly substitute external debt for equity-type liabilities, such as foreign direct investment.

in Myers (1977), there is more than one point in time where investment is decided upon. The model is embedded in an environment where both taxes and bankruptcy are present. In making a decision on investment, the firm has to balance the positive effect of interest tax shields generated by corporate debt against a deadweight cost associated with the firm's bankruptcy, incurred by the firm when shareholders default and debtholders take over as the new and sole owners. To understand the idea of how investment is actually put to use in the model, here is a basic sketch of what is happening: in order to describe a firm's income-generating process, two functions are modeled explicitly. The capital accumulation process is one of them. Investment in the firm's capital stock (which depreciates over time) is endogenous and is decided upon every period . Then, capital enters into the corporate income production function. Additionally, there is an exogenous, time-varying income shock, which also enters into the production function. Shocks stand for the investment opportunities that the firm encounters as time passes: the better opportunities there are, the higher the income. From this, the value of debt (incorporating the deadweight cost in case of default) and equity can be calculated. Firm value accounts for taxes, depreciation tax shields, interest tax shields (given the presence of corporate debt)[67] and all other variables relevant to value. Most notably, a major innovation of Moyen's (2007) work is that it allows investment to be completely flexible. That is, investment in the capital stock can be fully reversed, so that it generally may be positive or negative. In other words, the firm may sell some of its assets. Since underinvestment is due to shareholders' self-interest when deciding on investments, the objective function of the levered firm is to maximize its equity value (and not firm value). It does so by choosing an optimal investment amount every period after the income shock has been observed. Debt overhang is then quantified as the value lost relative to first-best value. Of course, this raises the question which benchmark to use as first-best. The author considers both an all-equity firm and a levered total-value-maximizing firm for this purpose. Counter-intuitively, the latter is the correct choice. Even though Myers (1977) employs the former, using an all-equity firm would be an understatement in this model. The reason is that it does not consider financing frictions caused by debt. Only the levered total-value-maximizing firm incorporates the (tax) benefits and (default) detriments of debt. Such a company counters the threat of default by investing more than the all-equity firm today in order to achieve higher cash flows and, thus, a lower probability of default tomorrow. This benchmark leads

[67] Using an enormous sample of U.S. firms, Graham (2000) empirically calculates the tax benefit of corporate debt and concludes that it is worth 9.7% of the market value of an average firm. A second finding is that, ironically, especially large and healthy corporations could utilize a good deal more debt in their capital structure. A typical firm in the sample could double its tax benefits by levering up. In doing so, it would increase its value by 15.7%. For a literature review on the significance of taxes on corporate financing decisions, see Graham (2003).

to a greater debt overhang. Note that other agency costs of debt, for example Jensen and Meckling's (1978) asset substitution (cf. fn. 52), are ruled out in the model. The value lost is thus accredited solely to debt overhang.[68] Additionally, Moyen (2007) considers both short-term and long-term debt. This is done for purposes of verifying that underinvestment is mainly a problem of long-term debt, as mentioned in fn. 56. Given that two different benchmarks and two different kinds of debt are considered, a specification of five differing models is required — one for the unlevered firm, two for the equity-value-maximizing firm (one each for short- and long-term debt) and two for the total-value-maximizing corporation. As the models cannot be solved analytically, they are first calibrated and then solved numerically. From this procedure, the author concludes that debt indeed causes large overhang losses. Notably, the result remains by and large independent of whether short-term or long-term liabilities are used.[69] This argues against conventional wisdom that debt overhang is mainly a problem of long-term debt. Specifically, given the total-value-maximizing firm as the benchmark, results show that the costs of underinvestment amount to 4.7% of firm value for long-term debt, while the respective costs are even slightly higher for short-term liabilities, totaling 5.12% (when defining the unlevered firm as the benchmark, the values are a mere 0.49% and 0.46% of the all-equity firm value, respectively). Moyen (2007) attributes the circumstance that costs are so high to the investment flexibility enjoyed by firms in her model.

A paper that is closely related comes from Titman and Tsyplakov (2007). They consider a similar model, where (continuous and less flexible) investment and financing decisions determine the value of a levered firm in the presence of taxes and costs associated with financial distress. The main goal of their paper is to explore how quickly a firm moves towards its target debt ratio, which is flexible over time. The authors specifically address the effects of debt overhang on the firm's adjustment behavior. In the course of this undertaking, they also quantify the underinvestment problem, once again determined by comparing the values of the equity-value-maximizing firm and the total-value-maximizing firm. In line with Moyen (2007), their numerical results state that long-term debt causes an agency cost of 5.27% of the total-value-maximizing firm value (short-term debt is not considered).

The losses calculated by Moyen (2007) and Titman and Tsyplakov (2007) are larger than those reported in the earlier literature on the extent of underinvestment. For example, Mello and Parsons (1992) report a very low agency cost of debt, even though costs other than debt

[68] We refer the interested reader to Leland (1998), Ericsson (2000) and Décamps and Djembissi (2007) for studies that model and quantify the adverse effects of asset substitution.

[69] In case one is wondering what "short-term" and "long-term" actually means in reality, Johnson (2003), among others, uses a threshold level of three years of maturity to differentiate between the two.

overhang are not explicitly excluded. They build on a contingent claims model originally used by Brennan and Schwartz (1985) and consider the decision to operate a mine (and extract a natural resource) or not and how this decision is influenced by the presence of leverage. A modification to the original model permits the incorporation of agency problems of debt. Tax benefits and costs of financial distress are present. Following the approach described above, the authors conclude that the agency cost amounts to a mere 0.8% of first-best firm value (for a firm whose debt-to-value ratio is 18%). In a related model, Mauer and Ott (2000) do not consider the option to operate, but the (irreversible) option to expand operations. Their findings indicate only a slightly higher agency cost of debt of about 1.3% of total-value-maximizing firm value.
Parrino and Weisbach (1999) use a different approach by applying Monte Carlo simulations to numerically quantify the adverse effect of corporate liabilities. Their approach is more general in that they do not focus on a particular cost, but measure every kind of conflict between shareholders and bondholders arising from equity-value-maximizing investment behavior. For instance, a transfer of wealth from debtholders to shareholders may take place by both refusing to invest in a safe positive-NPV project (underinvestment) and taking on risky negative-NPV investments (asset substitution/overinvestment). Accordingly, one cannot disentangle the impact of debt overhang from that of other possible agency distortions. Notwithstanding this multitude of effects, the authors reason that "[R]esults imply that distortions for the projects in these simulations are not large enough to explain capital structure decisions in most cases" (Parrino and Weisbach, 1999, p. 39). This holds true even though they are found to increase with leverage. These results are inconsistent with the large and unfavorable effects reported by Moyen (2007) and Titman and Tsyplakov (2007). The latter two allow for more flexible investment, however.

Finally, the importance of investment flexibility for agency cost calculations is also seized on by Manso (2008), who demonstrates, applying a short mathematical proof, that the magnitude of the agency cost of debt (both underinvestment and asset substitution) varies negatively with the degree of investment reversibility in a model of dynamic investment. The author considers a firm that has a (risky) consol bond outstanding, where no bankruptcy costs or tax advantages to debt are present.[70] A firm possesses a certain technology that has a specific cash flow process associated with it (think of a production line for a consumption

[70] A consol bond is a bond that makes coupon payments in perpetuity and, hence, never repays its face value. This type of financial instrument is chosen in order to focus on long-term debt in the model, thus accommodating the notion that debt overhang is primarily associated with liabilities of longer maturities, cf. fn. 56. Though extremely rare, perpetual bonds are in fact issued, cf. The Wall Street Journal (2012).

good). As time passes, the firm is free to invest in another technology, but incurs a cost every time it switches from one to the other. In the presence of debt, a firm may, for example, experience underinvestment by sticking too long to a poor technology because it wants to evade the switching cost. If the firm defaults, bondholders continue operations and may opt for another technology. Investment reversibility is defined over the size of the switching cost. Given perfect reversibility, i.e., no switching cost, the author proves that there are no inefficiencies induced by debt financing. The first-best investment scheme (as benchmarked by all-equity financing) is implemented accordingly. In that case, debt overhang does not matter. Mathematically, it is shown that the present value of agency costs is always less than the present value of the highest possible switching cost incurred at default. Therefore, when there is no switching cost, there cannot be any agency cost and, thus, no inefficient investment in such a circumstance.

3.3 Empirical evidence on underinvestment

Establishing quantifications of the underinvestment problem from numerical model solutions has one major advantage: it allows for the determination of both the first-best value (according to whatever standard) and the fim's value when shareholders are in charge. All that is left to do is determine debt overhang from a comparison of the two. Unfortunately, we are not blessed with this luxury in reality. How is one to establish the first-best value of a firm when all we have at hand is real-world observations? We cannot use two different values, but can merely work with the one (and only one) observable. Therefore, quantifying the debt overhang effect empirically suffers from the circumstance that we generally do not have the proper benchmark, i.e., first-best firm value. It is possible, however, to determine whether debt and, thus, underinvestment exert a significant (negative) influence on corporate investment by running a regression with the help of panel data. Given the complex quantification of debt overhang above, one can imagine that deriving empirical results is not simple and far from straightforward. Once again, the most recent research is (arguably) the most sophisticated. A pioneering study is conducted by Hennessy (2004), who provides a direct empirical test of Myers' (1977) underinvestment problem.

Before we present results, however, we need to make sure that we have a proper understanding of the theory involved in the author's model, which is then validated by the use of data. In order to assess the impact of debt overhang empirically, we are interested in the question of how financing decisions influence investment (and, thus, growth). That is, investment represents the dependent variable in a regression.

But how is a firm's investment actually determined? This is not a trivial task. Let us go back in time and provide a sketch of the theory of investment essential to comprehending Hennessy (2004). It all starts with James Tobin and his famous q theory, developed in an influential paper in 1969. Usually, people will refer to "Tobin's q" as a firm's market value over its book value.[71] This is because, unfortunately, people are usually inexact. We need to be more precise. Specifically, we must distinguish between *average q* and *marginal q*. As described by Hayashi (1982, p. 214), "[R]emember that q, which we call marginal q, is the ratio of the market value of an additional unit of capital to its replacement cost. What we can observe is average q, namely the ratio of the market value of existing capital to its replacement cost". Hence, people usually have average q in mind when talking about Tobin's q.[72] Tobin (1969) shows that the optimal corporate investment policy is an increasing function of q (be just a little patient as to the adjective before "q"). If a firm's q is above one, then it should adjust its capital stock accordingly, i.e., increase the stock through investment until q equals unity (given there are no adjustment costs to the capital stock), when all profitable growth projects have been exhausted. The decisive point is that, in economic theory, a firm's investment decision is decided upon at the margin. That is, investment should be carried out when a marginal dollar of investment in the capital stock is worth more than it costs to replace. Therefore, Tobin (1969) is really referring to marginal q as a measure of optimal investment, cf. Mussa (1977). This provides the basis for empirical studies. Now, the problem is that, in contrast to average q which can be computed rather easily with the help of publicly available data, we cannot observe marginal q in reality.[73] Fortunately, they *can* be identical under certain conditions. This result is first established by Hayashi (1982), who formulates both a direct relationship between marginal and average q and furthermore sets out the conditions under which they are equivalent, given the presence of adjustment costs. Abel and Eberly (1994) also provide conditions for the equality of average and marginal

[71] Growth firms will usually have a high q. This is because valuable future growth opportunities are capitalized into the a firm's share price, but not its book value. Firms in saturated industries, where profits come increasingly from cost savings, will have lower values of q on average.

[72] Erickson and Whited (2000) are even more precise in their q-definitions. They state that average q is the value the manager assigns to its firm's existing capital stock divided by its replacement cost. *Tobin's q*, on the other hand, is the ratio of the market value of the existing capital stock over replacement cost. Given efficient markets, these valuations will coincide. In that case, average q and Tobin's q will be one and the same.

[73] Ang and Beck (2000) state that many researchers disregard this fact and use average q as a proxy for investment nevertheless. Caballero (1999) reports that regression results are frequently dissatisfactory in that the coefficient on average q is insignificant, while other measures, such as cash flows, turn out to be significant in determining investment. Erickson and Whited (2000) indicate that there have been a lot of incorrect conclusions in measuring investment via marginal q because there is huge potential for measurement errors. It seems a lot of studies haven not been conducted thoroughly enough (the authors' entire paper is devoted to this issue and provides a good "overview"). The authors note that, if applied correctly, "q theory" works fine. Hayashi (1982) also advises extreme caution in thoughtlessly using average q as a proxy for marginal q.

q, but do so in an extended framework where fixed costs of investment are incorporated into the adjustment costs.[74] If these conditions are honored when working with data, then empirical validation should lead to reliable results. In that case, the beauty of the theory is that marginal q is a "...sufficient statistic for investment" (Hennessy, 2004, p. 1717) and comprises the entire set of relevant factors to investment (cf. Erickson and Whited, 2000, p. 1027). Hence, in principle, a single independent variable determines optimal investment in a correctly conducted regression.

Which finally brings us back to Hennessy (2004), who makes use of Abel and Eberly's (1994) model (before testing it empirically) — though not without applying some necessary and important changes. The "problem" with both Hayashi's (1982) and Abel and Eberly's (1994) work is that they do not consider leverage in their setup, but act on the assumption of an unlevered firm. We, however, are interested in testing for investment distortions caused by leverage. Therefore, Hennessy (2004) considers a firm that initially has a consol bond outstanding. Investment decisions are made with the aim of maximizing shareholder value, prompting the issue of additional stocks in case internal funds are insufficient. In comparison to an all-equity firm, the difficulty with debt is that it raises the possibility of default, in which case creditors would take over as the new sole (equity) owners and follow the first-best investment scheme, bringing us back to Hayashi's (1982) and Abel and Eberly's (1994) equity-only theory. Prior to a potential default, however, this inconsistency in considering an unlevered and a levered firm has serious consequences for marginal q. This is worth emphasizing again: as in Hayashi (1982), the original theory on the conditions for average q to be equal to marginal q (which in turn is a measure of optimal investment) is based on an all-equity firm. Once initial debt financing is considered in the capital structure, circumstances change in that marginal q does not equal average q anymore. Before producing regression results, marginal q of the levered firm must therefore be adopted to incorporate the effects of debt financing, such as the possibility of default and its associated bankruptcy costs.

Exactly this discrepancy between average and marginal q is utilized by Hennessy (2004) to build a testable theory of the adverse effects of debt financing on corporate investment (i.e., debt overhang). Importantly, since the firm's management, as in Myers (1977), is assumed to work exclusively in the interest of shareholders and, thus, maximizes equity value, it is not anymore marginal q that is relevant to optimal investment, but *levered equity's* marginal q. And Hennessy (2004) argues that average q overestimates levered equity's marginal q: when

[74] Most importantly, in both Hayashi (1982) and Abel and Eberly (1994), the firm must act as a price taker (perfect competition), plus the production function and the adjustment cost function of the capital stock need to be linearly homogeneous (constant returns to scale).

shareholders make use of their default option in the model, lenders take over and recover the firm net of some value lost (the bankruptcy cost) during the process of reorganizing the company. The post-default recovery value is irrelevant to shareholders because they only care about cash flows beneficial to themselves, i.e., *before* default. To debtholders, however, this value is relevant as they seize it upon default. In efficient capital markets, it will be reflected in the market value of debt. The market value of debt in turn enters into the computation of average q (in the numerator). Therefore, average q is large relative to levered equity's marginal q because part of the market value of debt captures post-default cash flows from pre-default investments, to be recovered by lenders when shareholders bail out. Since these investments are decided upon by shareholders, who simply do not care about recovery values, average q does not represent a satisfying statistic anymore. That is, "...financial frictions drive a wedge between marginal and average Q" (Hennessy et al., 2007, p. 700). To account for this effect, and in order to reestablish a proper measure for optimal investment, Hennessy (2004) shows that the market value of recoveries in the event of default (normalized by capital) must be subtracted from average q. The result is levered equity's marginal q[75] — the relevant measure for determining investment in the presence of initial debt. Most importantly, the (normalized) recovery values constitute the proxy for the debt overhang correction term in the regression. The greater the magnitude of the correction term, the more severe the underinvestment. Here is the intuition behind this procedure: in subtracting recovery values from average q, we correct corporate investment for returns accruing to debtholders. In other words, the firm's investment, which is decided on by shareholders, is lowered due to the presence of leverage. This should sound familiar: we have got ourselves a test for Myers' (1977) underinvestment problem — and the good news is

[75] In other words, we adjust the statistic known to be a measure of first-best investment in the benchmark case of an all-equity firm, as provided by Hayashi (1982) and Abel and Eberly (1994), for the (debt overhang) effect of leverage. Taking a firm that is completely financed with equity as the benchmark may potentially not be without limitation, however. Remember that Moyen (2007), in her numerical quantification of the debt overhang described in the last section, noted that the preferable benchmark in measuring underinvestment is not the all-equity firm, but the levered total-value-maximizing firm, since the latter incorporates interest tax shields and other effects. This may, of course, be due to her model specifications. Nevertheless, it could turn out to be an interesting area of future research for measuring debt overhang empirically. Note that Hayashi (1982) does consider the effects of tax and depreciation in establishing the equality of average q and marginal q in his all-equity theory. Poterba and Summers (1983) set on extending Hayashi's (1982) results to incorporate tax effects of dividends paid out by the firm. Edwards and Keen (1985) consider the effects of debt financing on the value of marginal q, but do not specify the relationship between average and marginal q. Recently, Bustamante (2011) considers a firm, having initial long-term debt outstanding, which faces costs of adjustment, investment and financing. The author finds that marginal q is merely a necessary (but not sufficient) statistic because both the correction for debt overhang *and* the available corporate cash flows have explanatory power. The exact discrepancy between average and marginal q is not established by the author. Rather, it is acknowledged that average q is a noisy proxy of marginal q. Bolton et al. (2011) present a model of investment and q in the presence of financing frictions which stresses the critical role of cash for corporate investment and financing decisions.

that recovery values are observable (as well as capital, by which they are normalized). Thus, when added in a regression as an independent variable, its coefficient should enter with a negative sign — if the theory is correct. This constitutes a testable hypothesis (and brings to an end our "short" chronological sketch of the theory involved). Note that the wedge between average and levered equity's marginal q should be smaller for high bankruptcy costs because they imply lower recovery values for debtholders, resulting in a smaller correctional term subtracted from average q. Also take note that the inclusion of another regressor, i.e., the correction term, makes marginal q a necessary statistic, but no longer a sufficient one.
The theoretical model of the firm used by Hennessy (2004) for empirical testing furthermore includes (endogenous) adjustment costs as well as financial distress. Other distortions, such as asset substitution, are excluded. Roughly speaking, the firm optimally invests in the capital stock in the presence of adjustment costs, and capital then enters into the production function, which is used to determine operating profits. Investment is then shown to depend on marginal q and recovery values.[76] Finally, a specific estimator is used in order to account for measurement error in average q. The author considers a set of panel data of U.S. manufacturing firms that spans four years and yields a total of 1,112 firm-year observations. Results indeed endorse the existence of corporate underinvestment. The coefficient on the correction term for debt overhang is negative and significant. Robustness is ensured, too. What is more, regarding economic significance, it is found that the correction term takes on considerably larger values for firms with a low bond rating. This yields further support in that firms that already are in deep debt-trouble (and have a low rating accordingly) invest a lot less. In other words, consistent with Myers' (1977) theoretical predictions, firms that have lots of debt outstanding face a greater underinvestment problem. Summing up, "[T]his lends support to the Myers (1977) contention that firms tend to underinvest because of the failure of managers to account for investment returns accruing to lenders" (Hennessy et al., 2007, pp. 706-07). Finally, it is shown that debt not only distorts the level of investment, but alters its composition, too. Specifically, debt overhang causes a preference on behalf of shareholders to invest in short-lived assets. This is reasonable, once considering that the correction term consists of the normalized market value of recoveries received by bondholders

[76] Few other regressors are included. On the one hand, this is done to warrant correct econometric implementation of the regression procedure. On the other, additional regressors are also implemented to allow for more specific conclusions. For instance, a dummy variable is introduced that divides the firm-year observations in the sample into two groups according to their bond rating. If it is above investment grade (S&P rating of BB+), the firm is considered to have a high rating, which in turn is used as a proxy for the ability to issue additional secured debt in the future. This is done because Myers (1977, p. 165-66) shows that financing the investment project with new secured debt (instead of equity) may mitigate the underinvestment problem because it dilutes the investment benefits to old bondholders in favor of new bondholders. Counter to this reasoning, the coefficient on the dummy variable does not turn out statistically significant in the regression.

upon (the expected time of) default: roughly speaking, an asset whose value depreciates slowly will usually have a higher value at a given time of default relative to an asset installed at the same time for the same price, but with a higher rate of depreciation. Shareholders, who are only interested in pre-default values, therefore tend to invest in shorter-lived assets, changing the composition of the firm's capital stock.

In a related model, Hennessy et al. (2007) generalize Hennessy's (2004) work in that they consider two further investment distortions caused by external financing in addition to the influence of debt overhang. For one, they cover the effects of collateral constraints, which place a limit on the amount of future corporate borrowing and, thus, on the amount of future debt-based investment. The idea is that firms which face such constraints will invest more today, reasoning that the increased capital stock acts as collateral for tomorrow's debt. Second, focusing on an equity-related friction, convex costs of issuing fresh equity are regarded as well. This is meant to account for the adverse effects of asymmetric information, like in Myers and Majluf (1984). The idea behind convex costs is that a firm has a harder time raising funds with each additional dollar of new equity, with the result that it will ultimately invest less than a firm with enough cash at hand to finance an investment project by itself. Albeit we do not concentrate on asymmetric information in this section, it may be noted that the data lend support to Myers and Majluf's (1984) theory, since the coefficient turns out negative (and significant) in the investment regression. Along the lines of Hennessy (2004), where the extra regressor (alongside q) captures the effects of debt overhang, the authors add two more terms to the regression of investment on q, each representing one of the two new distortions introduced. The regressor that corrects for debt overhang, caused by initial debt financing with a consol bond, is adopted from Hennessy (2004) without modification. The result is a regression of investment on q and three additional explanatory variables. The data set used is considerably larger than in Hennessy (2004). Roughly 46,000 firm-year observations from the years 1968 to 2003 are applied. Here, too, the authors find a significantly negative influence of debt overhang (asset substitution is excluded yet again). The coefficient on the correction term endures tests of robustness. Taken together, the two studies presented above strongly support that firms indeed invest less when facing debt overhang.

An earlier, less sophisticated empirical study on debt overhang comes from Lang et al. (1996), who provide consistent evidence. Without going too much into detail, the authors examine the data of 142 firms over a period of twenty years. Growth, measured by different key figures in multiple regressions, is regressed on average q and, among other explanatory variables, the book value of leverage. The result is that there is a strong negative relation between debt and growth, but only significantly so for firms having a low q (< 1). For such firms, book leverage acts as a (noisy) correction term, so to speak. Accordingly, the authors conclude that debt overhang is solely a problem for low-q firms, i.e., enterprises that either have bad investment opportunities or whose good investment projects are not properly appreciated by the market (an instance which may well be realistic, but is not intended in Myers' (1977) work because symmetric information is assumed). Be aware that the approach chosen by the authors is not unproblematic, for the reasons mentioned. Using Hennessy's (2004, p. 1719) words, "...the mapping between their tests and the underlying theory is unclear since the leverage ratio is an imperfect proxy for the overhang correction". Notwithstanding this critique, the findings may be viewed as being consistent with the studies above. Bad firms are bad because they have poor investment opportunities (proxied by low q): the results of the regression thus state that leverage will further reduce corporate investment for firms that are in trouble already.[77] This explicitly includes financial trouble, for firms with low values of q on average have higher levels of debt in the sample. The authors' results receive support from a study from Aivazian et al. (2005), who use a sample of corporate panel data from Canada. Consistent with the findings for U.S. firms just presented, there is a significant negative relationship between corporate debt and investment, and the adverse impact of leverage is significantly larger for low-q firms, i.e., for firms with poor investment opportunities. One distinction to Lang et al. (1996) is that the negative effect of leverage is always significant, irrespective of whether a firm has high or low q. This suggests that leverage generally distorts investment for Canadian firms.

Even earlier studies include Whited (1992). The author uses a different approach to examine the impact of financing on investment in that optimal investment and capital stock are modeled by means of an Euler equation. In the empirical part of the paper, the author finds that financially distressed firms experience a significant negative impact on investment. However, it is not specifically tested for debt overhang, but for distortions caused by leverage in gen-

[77] Note that we cannot attribute this result to debt overhang with complete certainty. The finding of a negative relation only for low-q firms could also be interpreted as support for Jensen's (1986) agency theory, which promotes the beneficial role of leverage in curbing unnecessary investment when no good opportunities are left to invest in. Agency problems between shareholders and managers are the driving force behind this *over*investment problem. The latter, being in charge of corporate decision making, have an incentive to use available corporate funds to invest in a poor project in order to reinforce their own position in the company ("empire building"), hereby inflicting a loss on shareholders. Debt provides the advantage that it forces management to periodically pay out funds that would otherwise be used for poor investments. Hence, which theory prevails ultimately depends on how bad the projects considered by the firms in the sample really are — something we cannot possibly determine. If it is mostly negative-NPV projects, the decline in investment may be beneficial as it prevents overinvestment. If, on the other hand, the majority of projects has low, but positive NPV, then underinvestment is likely to be the source of the distortion of investment. "Presumably, both the positive and negative effects of debt are present for all firms" (McConnell and Servaes, 1995, p. 134). Recently, Harris and Raviv (2010) argue that shareholders would fare better anyway if they, instead of management, controlled some of the corporate decisions.

eral. Hence, it cannot be ruled out that other agency costs of debt are responsible for this effect. In general, the early studies, which may not yet have had the necessary econometric means, do not test specifically for underinvestment. Therefore, they are merely indicative of support for Myers' (1977) theory. For example, Opler and Titman (1994) concentrate on distressed industries, i.e., industries experiencing a downturn in the form of reduced overall output. In such industries, the most highly levered firms incur the largest declines in sales. Furthermore, the operating profits of such highly indebted firms are lower compared to their less levered counterparts on average.

This concludes this section, in which we focused on the real-world impact of underinvestment. Taken together, especially the more recent empirical findings strongly suggest that "...the Myers underinvestment problem is more than a theoretical curiosity. Instead, debt overhang creates a large drag on the investment of distressed firms" (Hennessy et al., 2007, p. 707). We have learned that high levels of corporate debt are worrisome in reality. Carlson (1993), for example, refers to a survey carried out in 1992 among 50 blue-chip companies according to which the amount of debt carried by the government, corporations and also households is cited as the most influential factor on economic outlook.

Now that we know that underinvestment is indeed a real problem, and not merely a theoretical curiosity that is of no practical use, we move on with a good feeling to the centerpiece of this dissertation, that provides new theoretical insight into underinvestment.

4 Underinvestment in the reconstitution of damaged assets

Mayers and Smith (1987) slightly alter the underinvestment problem by embedding it into a somewhat different environment. They consider a firm that does not face a valuable new investment opportunity, but rather suffers a reduction in its value by suffering a casualty loss to its assets (say, a fire destroys a production hall). At the same time, this loss creates a positive-NPV investment opportunity: firm value can be reconstituted at a cost that is lower than the loss. The only decision the firm has to make is: to rebuild or not to rebuild. As in Myers (1977), the existence of risky debt is responsible for less-than-ideal investment as it will in some states hinder managers, who once again act in shareholders' best interest, to replace the assets. The firm underinvests. However, the authors propose an easy and costless solution to the problem. An appropriately structured insurance policy leaves firm value unchanged relative to pure equity or risk-free debt financing. The similarities to the original problem are obvious: risky debt creates incentive incompatibility between share- and bondholders, resulting in a lower firm value. After the presentation of the original model, we will consider insurance that includes safety loadings. In this context, considerable new theoretical insights into the interrelation between underinvestment and insurance will be provided.

4.1 The model and its assumptions and model setup

Markets are assumed perfect and complete. Shareholders control the firm in that managers act in their best interest. Thus, if not stated otherwise, the terms "shareholders' actions" and "managers' actions" are used synonymously. There are two dates. States of nature at the latter date are indexed by $S \in \left[0, \overline{S}\right]$, where $\overline{S} > 0$. The only source of uncertainty in the model is the possibility of a casualty loss at the second date. Should this event not occur, firm value at the latter date is a constant V^* (> 0). If it does, a state-dependent casualty loss $L(S)$ destroys/damages corporate assets, reducing firm value to $V^* - L(S)$ (≥ 0). Along with the loss comes the opportunity to reconstitute the firm's assets. Doing so requires a discretionary state-dependent investment $I(S)$ at the second date. Investing, i.e., rebuilding the firm, always has positive NPV: $L(S) > I(S)$ for all loss states.

Importantly, the decision to invest is made ex post — that is, after state S has materialized. Managers thus are in a comfortable situation. They can wait and see if a loss state occurs, and *then* decide whether to invest on behalf of their shareholders. This also implies that debt matures *after* this decision has been made. For if it did not, debtholders, in an underinvestment situation in which shareholders would rather not invest, but let the firm go bankrupt instead, would simply take over the firm and undertake the positive-NPV investment. This would rule out underinvestment in the first place.[78]

Market completeness implies the existence of a full set of Arrow-Debreu securities. To value second-date payoffs at the first date, we thus use state prices $g(S)$. $g(S)$ is the price for the delivery of one dollar at the second date in state S, and is positive and atomless for all $S \in \left[0, \overline{S}\right]$. Consequently, the price of a safe asset, i.e., one that pays one dollar in every state at the second date, is $\int_0^{\overline{S}} g(S)dS$. One can think of state prices as accounting for both time value and risk in discounting one second-date dollar. For states of the world $S > S_c$ $(0 < S_c < \overline{S})$, the firm is in luck. No loss occurs at the latter date, and firm value is V^*. For the remaining states $S \leq S_c$, the firm suffers a casualty loss $L(S)$ at the second date. The firm can be rebuilt in these states, requiring an investment $I(S)$, where $0 < I(S) < L(S) \leq V^*$ for all $0 \leq S < S_c$, and $L(S_c) = I(S_c) = 0$. $L(S)$ and $I(S)$ are twice continuously differentiable. All loss states are in order of increasing firm value (decreasing loss and, respectively, investment). In other words, $L(S)$ and $I(S)$ are strictly decreasing over the loss interval $[0, S_c]$ with $I'(0) > -\infty$. In short, states indexed with a higher S are better.

Let us begin with the case of all-equity and/or risk-free debt financing, which we will be referring to as "status quo" once again. As we will see, no risky debt means no conflict of interest, means no underinvestment problem. Figure 4.1 provides a graphical representation of the scenario faced by managers, as first seen in Mayers and Smith (1987).

As already mentioned, for the no-loss states $S > S_c$, firm value is V^*, represented by the horizontal line. For $S \leq S_c$, the lower line, $V^* - L(S)$, displays the second-date firm value if the damage is not repaired. The upper line, $V^* - I(S)$, indicates the firm value with investment to reconstitute the assets. Obviously, since NPV (the vertical distance between the upper and the lower line) is non-negative in all loss states, the firm's value is higher with investment. As shareholders are the only claimholders in this scenario, NPV will fully accrue to them. Thus, the firm will always decide to repair the damage. Doing so increases shareholder value, which, in this case, equals firm value. There is no underinvestment. Consequently, the value of the unlevered firm as of the first date is

$$\begin{aligned} V_u &= \int_0^{\overline{S}} V^* g(S)dS - \int_0^{S_c} L(S)g(S)dS + \int_0^{S_c} \left[L(S) - I(S)\right] g(S)dS \\ &= \int_0^{S_c} \left[V^* - I(S)\right] g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS. \end{aligned} \tag{4.1}$$

[78] See Myers (1977), p. 152–53, for more information.

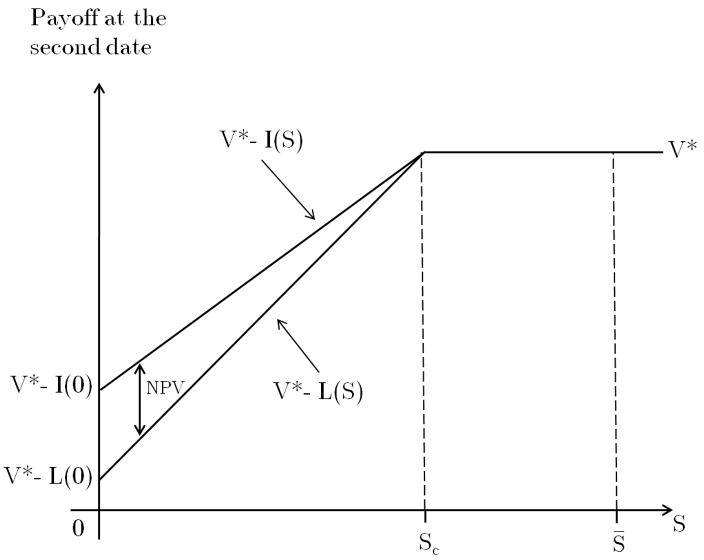

Figure 4.1: Status Quo – All-Equity Financing

This is the first-best firm value. It does *not* get better than this.

An important note: one is tempted to interpret (4.1) as the area below line $V^* - I(S)$ for $S \leq S_c$ and below line V^* for $S_c < S \leq \overline{S}$. This is indeed the most intuitive way to grasp the problem — but only for uniform state prices. If $g(S)$ is not uniform, this reasoning is not correct. If we want to compare *different* areas by the use of integrals, we can only do so for uniform state prices. Interestingly, this is never mentioned in the original model of Mayers and Smith (1987). To the contrary, the authors promote the geometry of the figure to explain the problem. Garven and MacMinn (1993, fn. 4, p. 638), who present an extension of the model (see below), invoke the Mean Value Theorem of Integral Calculus to justify using areas. Note that this is correct for a *given* interval of states, i.e., areas that span that particular interval may be compared. However, it does not hold true when comparing areas for different sets of states. If we want to relate such areas, we have to assume uniform state prices $g(S)\,(= g)$ on $\left[0, \overline{S}\right]$. Otherwise, we cannot interpret payoffs at the latter date as of the former date by making use of areas. Thus, when using the graphical approach to the problem by referring to figures in the following, we implicitly assume uniform state prices (if not stated explicitly). We will deal with this issue extensively later in the text when we present new results using a linear-uniform special case of the model. But we will also derive general results algebraically. Linearity of both $L(S)$ and $I(S)$, as assumed implicitly in Figure 1, is of no importance. We merely use it to facilitate interpretation. With this in mind, the first-best value in equation (4.1) is represented by the area under the line $V^* - I(S)$ for $S \leq S_c$ and under the horizontal line V^* for $S > S_c$ in Figure 4.1.

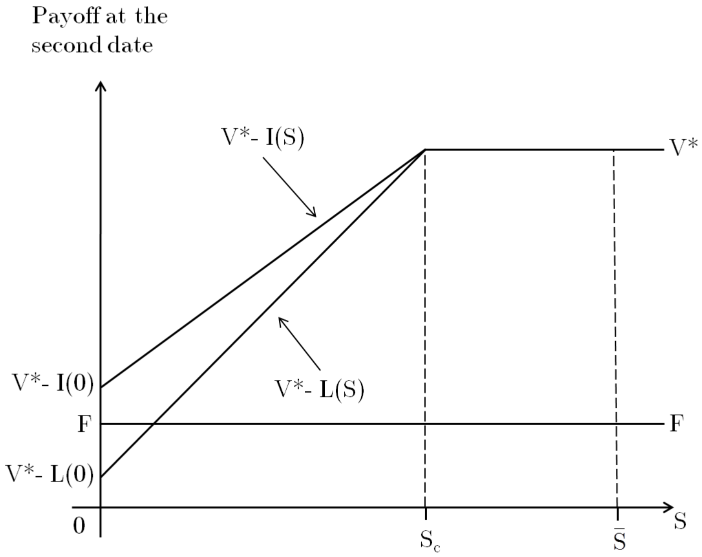

Figure 4.2: Status Quo – Risk-Free Debt Financing

Next comes financing with equity and risk-free debt. Suppose the firm has debt with a face value of F (where $V^* - L(0) \leq F < V^* - I(0)$) outstanding, due at the second date. Given investment, debt is risk-free if $F < V^* - I(0)$. In this case, firm payoff when investing suffices to pay off debtholders in *every* state at the second date. Managers will decide to invest if, and only if, shareholder value is not reduced by doing so. Figure 4.2 provides a graphical representation. As can be seen, in states of the world with very high losses, say $L(0)$, firm value without investment would not suffice to repay debtholders. The company would go bankrupt, debtholders would be entitled to the insolvency mass $V^* - L(0)$ ($< F$) and shareholders, as residual claimants, would receive nothing. Their residual claim $V^* - L(0) - F$ would actually be negative, but limited liability protects them from the obligation to inject fresh capital, so that their claims become worthless. If the firm decides to invest, however, it does not go bankrupt, since its value rises to $V^* - I(0) > F$, as pictured in Figure 4.2. But remember that firm value is not what managers care about. They are concerned about shareholder value. Notwithstanding this argument, shareholders are better off by investing even in the worst state when debt is risk-free. Unlike in the case with pure equity financing, they do not receive the entire NPV, $L(0) - I(0)$, but only a portion $V^* - I(0) - F > 0$. The remainder $F - [V^* - L(0)]$ goes to bondholders in order to fulfill the firm's debt obligation.[79] But at least they get *some* residual claim, as opposed to the case without investment. Hence, shareholders have an incentive to reconstitute in *every* loss state when $F < V^* - I(0)$.

[79] If the promised repayment were even lower, such that $F < V^* - L(0)$, shareholders would receive the NPV in full. Our analysis of safe debt remains unaffected as long as $F < V^* - I(0)$.

Managers will always decide to invest in case of riskless debt. Underinvestment does not occur. Regarding values as of the first date, investing makes the debt safe. Consequently, debtholder value is given by

$$D_u = \int_0^{\overline{S}} Fg(S)dS. \tag{4.2}$$

Shareholders are entitled to the firm's value net of the promised payment to bondholders. Equity value is

$$E_u = \int_0^{S_c} \left[V^* - I(S) - F\right] g(S)dS + \int_{S_c}^{\overline{S}} \left(V^* - F\right) g(S)dS.$$

Firm value as of the first date is simply defined as the sum of shareholder and bondholder value, for there are no third parties, such as insurance companies, involved.

$$D_u + E_u \equiv V_u = \int_0^{S_c} \left[V^* - I(S)\right] g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS.$$

Note that this is the status quo value defined in equation (4.1). It must be. In both scenarios, managers invest in every loss state. The only difference is that second-date firm payoffs now have to be divided between two parties. Status quo therefore encompasses two settings: all equity financing and financing partially with risk-free debt. Either way, the investment to reconstitute damaged assets is always undertaken, and firm value is first-best.

This concludes the "easy" part. Let us now turn our attention to risky debt, the ensuing underinvestment problem, and ways to solve it. To begin with, ignore corporate insurance. Consider once again a levered firm. Obviously, debt becomes risky for high levels of face value, in that $F \geq V^* - I(0)$. Now, firm payoff will *not* suffice to repay debtholders in some states at the second date even if the firm decides to rebuild: bankruptcy occurs because the firm's (second date) value drops below the face value of the outstanding debt, making it a risky means of financing.

While Figure 4.3 illustrates the scenario for an arbitrary level or risky debt, we deduce from it that, for every F in $[V^* - I(0), V^*]$,[80] there is a state S_a implicitly determined by the equation

$$V^* - I(S_a) = F. \tag{4.3}$$

Graphically, this is the state for which the horizontal line indicating the face value of debt

[80] Obviously, a face value $F > V^*$ would not make sense as the firm would be bankrupt to begin with.

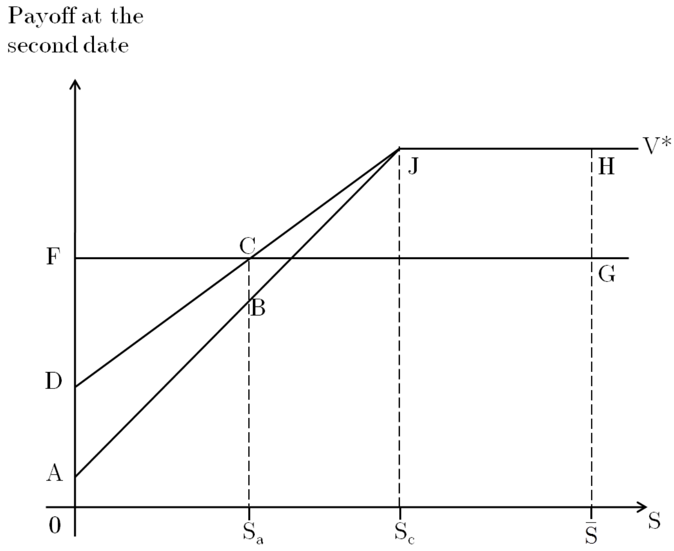

Figure 4.3: Underinvestment

F intersects the line $V^* - I(S)$. S_a obviously varies with the level of debt. For higher levels of F, it is situated further to the right, and vice versa. S_a is the threshold state of the underinvestment problem: for all lower states, underinvestment occurs. Why? Recall that in the case of riskless debt financing, shareholders at least get part of the positive NPV, even in state $S = 0$. Here, firm value at the second date falls short of the promised repayment in states $S < S_a$. That is, the firm is bankrupt, even if it decides to repair the damage (the investment's NPV is smaller than the debt overhang). For $S < S_a$, we have $V^* - I(S) - F < 0$. Shareholders have no incentive to invest in these states. They would have to provide the outlays $I(S)$ for the investment, yet would receive nothing in return because all the benefits would accrue to bondholders (and still not suffice to pay them off), cf. Figure 4.3. Shares in any state $S < S_a$ become worthless whether or not the firm decides to invest. Providing the funds for the investment represents a loss for shareholders — and limited liability allows them to avoid it. Even though it is not to the firm, to shareholders repairing the damage is a negative-NPV project in states $S < S_a$. Managers will decide to let a valuable opportunity pass by, lowering firm value relative to status quo.

Here we have the incentive incompatibility. Here we have the underinvestment problem, as identified by Myers (1977, p. 153) and Mayers and Smith (1987, p. 48). It is caused by the presence of risky debt, coupled with limited liability. "The underinvestment problem will not arise in the absence of limited liability because a rise in company value due to asset reconstitution will relieve some shareholders' debt responsibilities" (Hau, 2007, p. 5).

The minimum shareholders require for themselves to invest is an NPV of zero. This is exactly the case in state S_a. In this state, shares are only just worthless as we have $V^* - I(S_a) - F = 0$ per equation (4.3), and shareholders are indifferent between rebuilding or not. We assume that they will decide to go ahead with the investment in this case. For it is just like any other investment in an efficient capital market in that is has zero NPV.[81]

What about the proceeds of the debt issue that makes the firm levered in the first place? Mayers and Smith (1987) do not go into detail regarding the use they are put to. Merely stating that the firm is levered may be misleading. For underinvestment to occur, it is essential that the proceeds of the issue are not held as cash or any other marketable asset that debtholders could get their hands on in case of bankruptcy, as noted by Myers (1977, p. 152). That is, the proceeds have gone to support the firm's operations, so that they cannot be used to increase the insolvency mass and alleviate the underinvestment problem if a state $S < S_a$ materializes. Debt repayment is supported by the investment opportunity only, there are no other means for debtholders to acquire their promised payment.

This leads to another relevant point: the debt proceeds thus cannot be used to finance the investment outlays $I(S)$. Besides, the model structure would not allow for this anyway. The decision to invest is made after the loss occurs at the second date. Debt is issued at the first date, however. Managers cannot know ex-ante which state of the world will materialize. If they really wanted to make sure to always have enough funds at hand, they would have to issue $I(0)$ in debt at the first date, i.e., prepare for the worst. If they did so, promised repayment F at the second date would be at a maximum level: the more you want to borrow, the more you have to promise to pay back. This in turn would intensify the underinvestment problem as S_a would be situated further to the right graphically, implying the existence of even more underinvestment states. If managers, on the other hand, were to issue less debt (and consequently promise a lower repayment at the second date), there would be some states in which funds would not suffice to meet the required investment (a different form of underinvestment). What is important for us is to realize that shareholders provide the funds necessary for the investment ex-post.

[81] This fact is considered basic finance knowledge. In fact, it is considered so basic that – it seems – it is mentioned in the finance and capital markets literature without ever explaining it. Should you ask yourself why an investment in an *efficient* market has zero NPV, here is the answer: in equilibrium, expected return equals required return (the opportunity cost of capital). For if it were not, buying or selling pressure would force expected and required return back into their equilibrium value (via the equilibrium price). Say, for example, we find the expected return from an investment in some sort of asset to be greater than the required return: the investment overcompensates investors for the perceived risk they take by investing in it (according to which the required return is set in the market). Therefore, smart investors will instantly buy the asset. This demand causes the price of the asset to rise and its expected return to fall, respectively. It falls until expected return at last equals required return; only then does the investment not seem too good. At the end of the day, expected payoffs from the investment are discounted with the required rate of return, yielding an NPV of zero (see, e.g., Brealey et al., 2003, p. 18).

Since the firm does not invest in all states, values as of the first date differ compared to their status quo counterparts. Debt is risky and will not be paid back in full for $S < S_a$. In any such state, its holders take over the firm due to bankruptcy and are entitled to the entire insolvency mass $V^* - L(S)$. Debt value of the uninsured firm levered with risky debt thus is given by

$$D_0 = \int_0^{S_a} [V^* - L(S)]\, g(S)dS + \int_{S_a}^{\overline{S}} Fg(s)dS. \tag{4.4}$$

The risk of bankruptcy is reflected in the fact that debt trades at less than (the present value of) its face value, unlike in equation (4.2). Not investing in states $S < S_a$ leaves shareholders with

$$E_0 = \int_{S_a}^{S_c} [V^* - I(S) - F]\, g(S)dS + \int_{S_c}^{\overline{S}} (V^* - F)\, g(S)dS. \tag{4.5}$$

The first-date value of the uninsured firm which has risky debt in its capital structure, $V_0 = D_0 + E_0$, is

$$V_0 = \int_0^{S_a} [V^* - L(S)]\, g(S)dS + \int_{S_a}^{S_c} [V^* - I(S)]\, g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS. \tag{4.6}$$

In the special case with uniform state prices, which allows for the neat graphical interpretation, D_0 is proportional to the area of $0\overline{S}$GCBA, while shareholder value E_0 is proportional to CGHJ in Figure 4.3. Taken together, the value of the firm as of the first date, V_0, is represented by $0\overline{S}$HJCBA in the presence of underinvestment. The factor of proportionality in either case is the uniform state price $g(S) = g$. We have already mentioned that the underinvestment problem lowers firm value relative to status quo. Now, given (4.1) and (4.6), we can calculate this reduction that is caused by risky debt in the firm's capital structure. Define it as R_0 such that:

$$V_u - V_0 \equiv R_0 = \int_0^{S_a} [L(S) - I(S)]\, g(S)dS. \tag{4.7}$$

This deadweight loss in firm value is caused by incentive incompatibility between shareholders and bondholders. It is positive whenever $F > V^* - I(0)$ (and zero for $F = V^* - I(0)$). R_0 constitutes the agency cost of the underinvestment problem and it is represented by the tetragon ABCD in Figure 4.3. Obviously, the deadweight loss R_0 increases with F.

4.2 Introducing insurance

A natural question to ask is this: are we stuck with the underinvestment problem? Do we have to accept that, from some point onwards, debt in the capital structure inevitably leads to a loss in firm value and nothing can be done about it? Luckily, the answer is "no". There are actually two ways of solving the problem. The first one is obvious. We know the problem exists exclusively for risky debt. Thus, make use of risk-free debt only by limiting face value to levels $F < V^* - I(0)$, as in Figure 4.2. Admittedly, though this will solve the problem, it may neither be a practical nor a satisfying approach. Firms may simply need more initial debt financing — for whatever reason. In reality, quite a few firms certainly default on their debt obligations. Highly levered firms do exist. They obviously have not taken the advice of limiting debt. Hence, if it is just for a look at real-life firms, we should not be satisfied with this approach and find another one that accommodates high levels of debt.

Mayers and Smith (1987) provide just that. An appropriately structured corporate casualty insurance (think of, e.g., property insurance) completely solves the underinvestment problem. There are two ways to look at this. One, to return to status quo, essentially, shareholders need to be "persuaded" to rebuild in all underinvestment states, since not doing so causes the problem in the first place. And we know what they require to do so, too. They demand an NPV of no less than zero. The problem is that they do *not* invest for $S < S_a$ because NPV is not zero to them, but negative — unless somebody else steps in in these states and "fills up the gap" to make the NPV zero, (as it is in state S_a). Put simply: from shareholders' point of view, all states have to be converted into an equivalent of state S_a from a cash flow perspective. As Mayers and Smith (1987, p. 49) put it: "[E]ssentially, $V^* - I(S)$ has to be raised above F... by purchasing some critical amount of coverage". The way to accomplish this is to buy (actuarially fair) insurance for all underinvestment states.

Let us work out the minimum required insurance coverage consistent with solving the problem. We know that we have $V^* - I(S) - F < 0$ in states $S < S_a$. As noted above, for shareholders to be willing to still invest, we need a residual claim of 0, cf. equation (4.3). Thus, minimum insurance coverage needs to amount to $I(S) - I(S_a)$ in any given state $S \leq S_a$, for this guarantees a second-date firm payoff to shareholders of $V^* - I(S) + [I(S) - I(S_a)] - F = 0$. This is illustrated in Figure 4.4, that depicts the deadweight loss R_0 as the shaded area.

As is customary for insurance policies, total replacement cost, $I(S)$, equals coverage, $I(S) - I(S_a)$, plus deductible. Thus, we have implicitly worked out the maximum deductible, namely $I(S_a)$, consistent with removing debt overhang. From Figure 4.4, this deductible is the same for every underinvestment state (given a certain amount of risky debt in the firm's capital

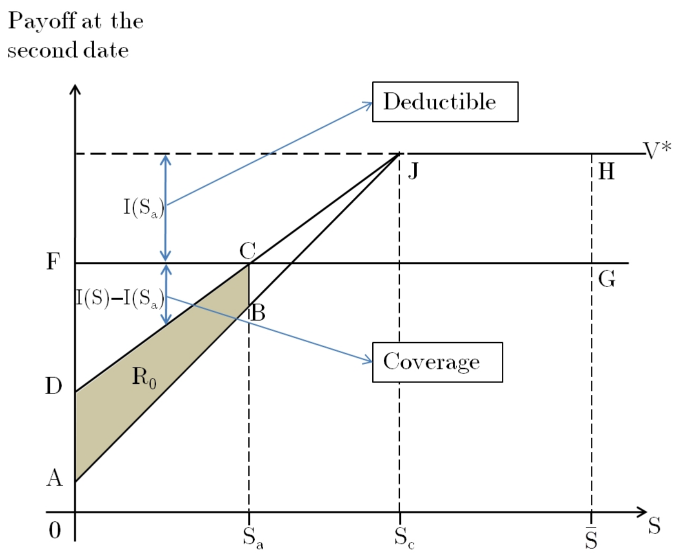

Figure 4.4: Actuarially Fair Insurance

structure). Just as $I(S) - I(S_a)$ represents the minimum coverage, $I(S_a)$ conversely equals the maximum deductible to still provide managers with an incentive to invest to reconstitute damaged assets in an underinvestment state.

We still owe the second interpretation. Underinvestment requires *risky* debt in the capital structure. Consequently, if insurance can be bought such that debt becomes *safe*, the problem is solved. Note that this is exactly what the insurance policy just introduced does. For a given underinvestment state, the shortfall in promised repayment, i.e., the vertical distance between $V^* - I(S)$ and F in the figures, is contributed by the insurance company in the form of the coverage $I(S) - I(S_a)$. Thus, no matter what happens, debtholders can always be sure to receive their promised repayment in full, provided that insurance is bought for every underinvestment state. Insurance makes the debt safe. Bankruptcy is avoided. “Therefore, the risky debt/insurance decision is essentially a reformulation of the ‘safe debt’ decision” (Garven and MacMinn, 1993, p. 640). Of course, these interpretations are just two sides of the same coin. Insurance coverage provides shareholders with an incentive to invest, and, by doing so, firm payoff at the latter date suffices to repay debtholders, even in underinvestment states. The risk of bankruptcy has been removed, and debt becomes safe.

Since we want to eliminate the problem *entirely*, insurance needs to be bought for every underinvestment state. Sticking with Mayers and Smith (1987) for the moment, we assume actuarially fair insurance policies. That is, competition is perfect in the insurance market, so that no insurance company earns an economic rent in the form of charging a safety loading. Hence, the fair insurance premium equals the risk adjusted present value of the insurance payoff over all states $S \leq S_a$, i.e.,

$$P_i = \int_0^{S_a} [I(S) - I(S_a)]\, g(S) dS. \tag{4.8}$$

The premium is proportional to the triangle DCF in Figure 4.4 in the special case with uniform state prices. Note that we could alternatively assume full coverage. This would solve the underinvestment problem, too. Since we would not have a deductible in that case, the premium for such a policy would of course be higher, namely $\int_0^{S_a} I(S)g(S)dS$. However, it is not necessary to have full coverage for our purpose of getting rid of underinvestment. Generally, reducing the deductible below $I(S_a)$ – or, equivalently, increasing the coverage and, thus, the premium – does not alter the firm's decision to insure when the insurance premium is fair (Mayers and Smith, 1987, p. 51). $I(S_a)$ is the maximum deductible consistent with this aim, and we will adhere to it throughout the entire analysis.

Deductibles certainly are nothing out of the ordinary in insurance policies. Automobile insurance comes to mind, arguably the most prominent type of insurance to fall into this category. In case of damage, the insurance plan normally only starts to pay out after some prespecified amount (the deductible) has been paid by the insured party.

Insurance coverage affects the first-date value of debt because it makes it safe. Debtholders now receive their promised payment regardless of which state materializes. The first-date value of the insured debt is consequently given by

$$D_i = \int_0^{\overline{S}} F g(S) dS, \tag{4.9}$$

proportional to the rectangle to $0\overline{S}$GF in Figure 4.4. Using (4.4), (4.3) and (4.9), we can quantify, for a given risky F, the change in debt value induced by the insurance coverage:

$$\begin{aligned} D_i - D_0 &= \int_0^{\overline{S}} F g(S) dS - \int_0^{S_a} [V^* - L(S)]\, g(S) dS - \int_{S_a}^{\overline{S}} F g(S) dS \\ &= \int_0^{S_a} \{F - [V^* - L(S)]\}\, g(S) dS \\ &= \int_0^{S_a} [V^* - I(S_a) - V^* + L(S)]\, g(S) dS \\ &= \int_0^{S_a} [L(S) - I(S)]\, g(S) dS + \int_0^{S_a} [I(S) - I(S_a)]\, g(S) dS \\ &= R_0 + P_i. \end{aligned} \tag{4.10}$$

The difference in debt values is clearly non-negative. Because insurance makes the debt safe, potential holders are willing to pay more for an issue with a given face value F when it comes with insurance. In short, upon issue at the first date, the insured debt raises more funds than the uninsured issue. Graphically, debt value has risen by the areas ABCD and DCF in Figure 4.4.

It is important to realize that firm value as of the first date is no longer merely the value of equity plus debt. Now, there is a third party involved. The firm has to pay the insurance premium to the insurance company at date one. In terms of Figure 4.4, insurance adds R_0 and P_i, but costs P_i. Netting out, we are left with a gain proportional to area ABCD relative to the uninsured case. Firm value is given by

$$\begin{aligned} V_i &= \int_0^{\overline{S}} Fg(S)ds + \int_{S_a}^{S_c} \left[V^* - I(S) - F\right] g(S)dS + \int_{S_c}^{\overline{S}} \left[V^* - F\right] g(S)dS \\ &\quad - \int_0^{S_a} \left[I(S) - I(S_a)\right] g(S)dS \end{aligned} \tag{4.11}$$

The first term on the right-hand side is the value of insured debt defined in (4.9). The last term is the insurance premium paid to the insurance company, cf. (4.8). What about the two summands in the middle? One is tempted to think of them as shareholder value, as in (4.5). Let us not go there yet, we will turn to that in a short moment. Graphically speaking, simply take them as the area CGHJ in Figure 4.4 for the time being. Using (4.3), rewrite the first summand in (4.11) as $\int_0^{\overline{S}} \left[V^* - I(S_a)\right] g(S)dS$ and further split up this integral into $\int_0^{S_a} \left[V^* - I(S)\right] g(S)dS + \int_0^{S_a} \left[I(S) - I(S_a)\right] g(S)dS + \int_{S_a}^{S_c} Fg(S)dS + \int_{S_c}^{\overline{S}} Fg(S)dS$. After inserting this into the equation (4.11), we simplify to

$$\begin{aligned} V_i &= \int_0^{S_a} \left[V^* - I(S)\right] g(S)dS + \int_{S_a}^{S_c} \left[V^* - I(S)\right] g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS \\ &= \int_0^{S_c} \left[V^* - I(S)\right] g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS. \end{aligned} \tag{4.12}$$

This proves that a fair casualty insurance policy completely removes the deadweight loss in firm value associated with the underinvestment problem, since $V_i = V_u$, cf. (4.1). It also implies that $V_i - V_0 = R_0$. Insurance causes firm value to rise by ABCD in terms of Figure 4.4. V_i is proportional to $0\overline{S}$HJD.

This result further tells us that the P_i's in fact cancel out, as concluded above from the graphical analysis. Insurance costs P_i, but also adds P_i (plus R_0) in value. In other words, a fair insurance policy is self-financing. Note that this also explains why reducing the deductible below $I\left(S_a\right)$ would not change the firm's decision to invest: if the price of the insurance were higher because of greater coverage, it would still be self-financing as long as the contract is actuarially fair. Furthermore, the fact that it is self-financing leads to an MM-style firm value result (in a world where only equity and debt and insurance are considered, admittedly). Fair insurance completely removes the underinvestment cost irrespective of the amount of leverage in the firm's capital structure. If the level of initial debt F were higher, the premium would be higher, too — but it would still be self-financing. Status quo value is thus always restored. The value of the firm is independent of the mode of financing in the presence of fair insurance. Most importantly, we have to consider shareholder value. This is the decisive determinant. The above equations will only be valid if shareholder value is not lowered by buying insurance and investing. Only then will managers decide to reconstitute. In determining equity value, we follow – for now – Mayers and Smith (1987), who assume that the promised repayment F is fixed from the beginning and does not change whether or not the firm insures. This approach to the model is called the "cum dividend interpretation" by Garven and MacMinn (1993, p. 636). It requires some careful interpretation: thus far, we have (at least implicitly) assumed that shareholder value is the present value of the residual claim on the firm's cash flows at the second date. There were no cash flows to shareholders in the first period. With insurance coverage, this changes. Why? When the firm issued bonds with a promised repayment F in the uninsured case, it must have done so for a reason. Regardless of what the proceeds were intended for exactly, they must have been enough to do so. And since F does not change, the insured debt consequently raises more than these required funds, cf. (4.10). Garven and MacMinn (1993) point out that there is a lack of clarification in Mayers and Smith (1987) regarding the use these excess funds are put to: "[A]lthough Mayers and Smith assert that the gains associated with resolving the underinvestment problem are enjoyed by shareholders, their analysis does not explicitly provide the mechanism to show how this is accomplished" (Garven and MacMinn, 1993, p. 636). The authors go on to assume that, given that F is unchanged, the excess amount net of the insurance premium is paid out as a dividend to shareholders. Shareholders as residual claimants are indeed the only party to be eligible to receive such a dividend. The insurance company receives the premium P_i, and debtholders, who pay a fair price for the issue, can be sure to be paid back F in any state at the second date. These two parties are thus not entitled to any further cash flows.

Hence, a second component to shareholder value is introduced, namely the first-date cash flow in the form of a dividend. We have worked out the amount already. Out of the additional funds raised by the insured debt, $R_0 + P_i$, the premium P_i is required to pay off the insurance company. By (4.10), this leaves $R_0 = D_i - D_0 - P_i$ as additional funds to be paid out to shareholders. Thus, the new equity value E_i must amount to $E_0 + R_0$ when the firm insures. To prove this, rewrite equation (4.11) as $V_i = D_i + E_0 - P_i$ using (4.5), (4.8) and (4.9). From (4.10), we know that the value of insured debt is $D_i = D_0 + R_0 + P_i$. Substituting and canceling out the insurance premium, we are left with

$$V_i = D_0 + R_0 + E_0.$$

The last two summands on the right-hand side must constitute the new equity value — the insurance premium has been accounted for already and there are no other parties left that are entitled to any cash flows, so

$$E_i = E_0 + R_0. \tag{4.13}$$

Exactly as we predicted.[82] Since $R_0 \geq 0$, shareholder value is never diminished by buying insurance. Managers will always buy actuarially fair casualty insurance when debt is risky. The underinvestment problem is averted.

We are led to another point that requires consideration. Would managers not do an even "better" job if they were to fool debtholders? After all, all they care about is the well-being of shareholders. Therefore, could they not lie to the market by promising potential debtholders to buy insurance without actually doing so? Presumably, they could still attract the same amount that the (de facto) insured debt raises, but pass on more to shareholders. The answer is: no — no, they could not raise the same amount. We are assuming rational and perfect markets. In these markets, debtholders would anticipate managers' (in-) actions and adjust downwards the price they are willing to pay for the bonds accordingly, until it represents a zero-NPV investment for them. In a more realistic scenario (with more than two periods), committing this fraud would not be a worthwhile action on behalf of managers either. It may work in the short-run. But just think of the negative long-term consequences that these gains would have to be traded off against. Think of the immense loss in reputation that would accompany this event. Think of how hard it would be for the firm to raise funds in the public debt market in any future debt issue. Think of how the elevated required return would force the company to offer future debt cheaply (given a certain face value F), if it could at all, in order to compensate potential buyers for the perceived risk of another fraud.

In our model, an uninsured debt issue raises less funds than an insured offering. The cost of

[82] Note that V_i is *not* $D_i + E_i - P_i$, i.e., debtholder plus shareholder value given insurance, net of the premium payment, as one might be tempted to think at first. For this would overstate firm value by accounting for R_0 twice: $D_i = D_0 + R_0 + P_i$ and $E_i = E_0 + R_0$, cf. (4.10) and (4.13), respectively. R_0, however, may only be accounted for once in determining firm value: D_i raises $R_0 + P_i$ more than D_0 at the first date. P_i is used to pay the insurance premium, and R_0 is passed on to shareholders as a dividend.

this underinvestment problem will always be reflected in the debt proceeds upon issue, for debtholders pay a "fair" price only. By implication, shareholders bear this cost at the end of the day. But they have a choice. If they buy insurance, they receive a dividend on top of the value generated by second-date payoffs. If they do not, they suffer a loss in share value because they receive no cash flow at date one. Therefore, given the objective of shareholder value maximization, it is in shareholders' own interest to contractually commit to solving the problem. Since a bond *is* merely a contract between the firm and its lenders, they do so by including a covenant in the bond indenture that guarantees the purchase of the required level of insurance along with the bond issue. "By writing bond covenants, shareholders, in essence, offer guarantees to bondholders against certain value-reducing future actions. These guarantees induce bondholders to pay a higher price for the debt they purchase and thus they increase *ex ante* firm value" (Malitz, 1986, p. 18). This also explains why, as stated before, the insurance is self-financing: if insurance is guaranteed, enough money is raised to pay for the premium (and R_0 to shareholders).[83] Smith and Warner (1979) and Mayers and Smith (1982) point out that covenants forcing firms to acquire prespecified levels of insurance do in fact exist, and they are a common feature of debt indentures.

Before we continue with the underinvestment problem, a quick note on overinvestment. Just as we described underinvestment as the decision to let a valuable investment opportunity pass by, overinvestment, in this sense, must be defined as taking on an investment project that is *not* valuable (NPV<0). In the model, we would have to allow for the possibility that rebuilding after a damage *decreases* firm value. Hau (2007) finds that, in addition to underinvestment, this may well happen once asset reconstitution is risky. That is, unlike in Mayers and Smith's (1989) deterministic scenario, one cannot be certain that repairing increases firm value in Hau's (2007) model. It might. But it also might not. For example, reconstitution may turn out to be a source of (liquidity) risk to firm value if it requires cash to be diverted from other productive activities.[84] In order to make repairing the firm a risky investment, the author introduces a further set of states, namely "reconstitution states". Now, rebuilding in any given loss state may have either positive or negative *expected* NPV. Imagine a state in which the firm defaults on its debt obligation if it does not invest ($V^* - L(S) < F$). Further, assume that the expected NPV is negative for the firm in this state, but that $V^* - I(S) > F$ in at least one favorable reconstitution state. That is, if

[83] The numerical example provided by Mayers and Smith (1987, p. 52–53) is somewhat misleading in this regard. There, shareholders first pay the fair premium (for *full* insurance coverage) out of their own pockets, and later recover this advance payment from the debt issue. This is unnecessary. By committing through a covenant, the premium could be paid out of the proceeds of the issue right away.

[84] Note that this relaxes the assumption that debt is not supported by cash.

shareholders are lucky, they might not have to default, but are left with a valuable residual claim instead (their shares would not be worthless). Given limited liability, what do they have to lose? Exactly, nothing. And remember that managers act in favor of shareholders. Therefore, they will decide to go ahead with an investment that is expected to decrease firm value. While expected NPV is negative to the firm (and thus to bondholders), it is positive for shareholders in this case — exactly the other way round than in our model. Hau (2007) goes on to show that both the under- and the overinvestment problem can be solved by an appropriately structured insurance contract.

4.3 Empirical findings on the underinvestment problem

Unfortunately, empirical evidence is scarce. A major reason for this is the fact that in the U.S. (and many other developed countries) corporations are not obligated to disclose insurance premium expenditures in their financial statements (cf. Regan and Hur, 2007). This makes the data collection process cumbersome and costly. Among the few studies conducted, there is no single one that concentrates on the underinvestment problem exclusively. For obvious reasons: even though we focus on it here, firms' demand for corporate insurance is motivated by other considerations than avoiding underinvestment as well in real life. Among these are tax effects, a firm's ownership structure, expected bankruptcy costs, firm size, managerial incentives, state ownership, incentives to other stakeholders of the corporation and a firm's risk class.[85] Notably, risk aversion as a motive for firms to buy insurance is not one of them. This is because, for widely held public corporations, share- and bondholders in an efficient market can hold highly diversified portfolios of financial instruments and can, thus, eliminate idiosyncratic insurable risks on their own account (Mayers and Smith, 1982; Main, 1983). Even though they may be risk-averse on an individual basis, they do not want the firm to eliminate unsystematic risk for them, especially when insurance coverage comes with a safety loading attached. While risk aversion can explain an individual's desire to obtain insurance, it should not be listed as a reason for insurance demand on the corporate level.

Mayers and Smith (1990), Core (1997) and Yamori (1999) are the first to conduct empirical analyses of corporate demand for insurance coverage.[86] Interestingly, the former two mention

[85] Explaining every single motive for insurance demand is beyond our scope. Literally every one of the studies to be mentioned in the following have a section explaining various insurance demand theories. See, e.g., Mayers and Smith (1990) and Regan and Hur (2007).

[86] There is another study by Davidson III et al. (1992). This study is different in that it focuses exclusively on the hypothesis that the purchase of insurance does not have any effect on a firm's equity cost of capital. For if it would lower it, this would lead firms to demand insurance as they could increase equity and, thus, firm value. It is indeed found that no such relationship exists, i.e., insurance purchase is not motivated by cost of equity considerations. This leads to the conclusion that an explanation in the fashion of Mayers and

the significance of underinvestment for corporate insurance demand (it would be strange if Mayers and Smith would not), but do not investigate its impact by controlling for leverage directly. Additionally, their results cannot be characterized as general. They concentrate on specific industries/products, namely reinsurance purchases on behalf of U.S. insurance companies (who have to report these expenditures) and Canadian firms' demand for a highly specialized type of insurance (required to be reported, too), respectively. Yamori (1999) is the first to include a leverage measure for a cross sectional data set of 504 Japanese non-financial firms. Prior to changes in national accounting regulation in 1987, (some) Japanese companies published information on general insurance purchases. The author, however, does not find significant evidence to support the existing underinvestment theory. He acknowledges that there are unique features to the Japanese economy, most notably the special relationship among Japanese financial and non-financial firms named "keiretsu". This may lead Japanese firms to demand more insurance per se compared to other industrialized nations (Yamori, 1999, p. 242). The study is notable in that it is the first attempt to investigate firms' demand for insurance in a more general way, as it focuses on non-financial firms and general, i.e., not highly specialized, insurance products.

In terms of significant explanatory power, Hoyt and Khang (2000) provide the first meaningful study with regard to the underinvestment problem. They focus solely on property insurance. Due to data unavailability for U.S. firms, they design a questionnaire – answered by 187 U.S. companies in different industries for the fiscal year 1989 – to examine possible determinants of corporate demand for property insurance. Among others, empirical support for the underinvestment hypothesis is found. To test this hypothesis, they deploy two proxy variables, one for leverage (debt to equity ratio) and one for growth opportunities[87] (ratio of firm market to book value), in a cross-sectional ordinary least squares regression model. For the former, the idea is that firms with a lot of debt in their capital structure will, on average, purchase more insurance coverage (measured by the amount paid in insurance premiums divided by the value of insurable corporate property). As we have seen in the model above, high levels of debt cause the problem in the first place — and even higher levels of debt intensify the problem and should, hence, go along with more insurance bought. The coefficients on both proxy variables turn out positive and significant and are thus "...consistent with insurance playing an important role in controlling the underinvestment problem" (Hoyt and Khang, 2000, p. 101).

Smith (1987) must be the reason for corporate insurance demand. The problem is that the authors do not provide empirical proof for this claim.

[87] For more information on AIPs versus growth opportunities in the original underinvestment problem, see Myers (1977). We are more interested in the first proxy.

Unfortunately, not only are there few studies available, even worse, they contradict each other, too. Zou and Adams (2008), in a similar way as Hoyt and Khang (2000), examine firms' demand for property insurance and control for the underinvestment problem, too. The proxy used for leverage is the ratio of book value of debt to total assets. The authors focus on publicly listed non-financial Chinese firms across different industries that voluntarily disclose information on their insurance purchases. The study is somewhat more sophisticated in that it uses panel data for the years 1997 to 2003. It is thus able to incorporate potential time effects, such as overall economic development. Results contradict theory. Unlike hypothesized, high leverage does not lead to an increase in insurance coverage among Chinese firms. Quite the opposite: the coefficient turns out both negative and significant. Zou et al. (2003) and Zou and Adams (2006) had already investigated Chinese corporations' property insurance demand in two prior studies that are very similar in design. And results are similar, too. Neither one provides evidence supportive of the underinvestment theory in China. Using the same 1997-1999 panel data set, both studies examine a sample of 235 publicly listed non-financial companies, comprising a total of 668 observations. In the former study, once again, the coefficient of the leverage measure (debt to equity ratio) turns out significantly negative, i.e., there is evidence for a negative correlation between the amount of insurance coverage obtained and the indebtedness of Chinese firms. In the latter, the coefficient is actually slightly positive, but insignificant. Again, no persuasive evidence confirming the underinvestment hypothesis can be presented. Zou and Adams (2008) argue that these unexpected results may be explained by the unique features of the Chinese market, especially the high proportion of state ownership in Chinese enterprises. The central government is said to have an incentive to save Chinese firms from bankruptcy and liquidation in order to uphold national social stability and, thus, its own power. Therefore, the "... underinvestment problem is likely to be of the second order" (Zou, 2010, fn. 10, p. 968). For the case of China, this does not sound implausible. Unfortunately, Regan and Hur (2007) conduct a cross-industry study with South Korean non-financial firms and come to similar conclusions — and in the case of South Korea you cannot easily argue with special institutional settings like in China. Using a large sample of panel data over an even more extensive period of time (1990-2001), and making use of the (lucky) fact that firms in Korea do report their insurance expenditures, the authors find that insurance demand (insurance bought scaled by total tangible assets) is significantly inversely related to the measure of indebtedness of South Korean firms (debt to equity ratio). Again, this is contrary to what the theory predicts.

A first step towards empirically testing the underinvestment problem has been made. However, given both the very limited number of studies available and their conflicting outcomes, one must clearly hope for further research in this area before any conclusions on the validity of theoretical predictions can be drawn. At the same time, it may well be that this question will not be settled empirically for a long time to come. Data unavailability for developed countries is a major problem.

4.4 Insurance premium with a safety loading

We are far from done with the underinvestment problem. What we have seen so far is the use of insurance to overcome the underinvestment problem — the usage of actuarially fair insurance premiums in an economically perfect world where insurance companies do not make any profits because they can only charge a fair price. What if we were to relax these assumptions to allow for a bit more reality in the model? What if insurance companies were trying to make some profits along with the services they provide? Schnabel and Roumi (1989) intend to examine just that in a follow-up paper to Mayers and Smith (1987). They incorporate a safety loading into the insurance premium in (4.8). We are now faced with an actuarially "unfair" insurance premium:

$$P_\lambda = (1+\lambda) \int_0^{S_a} \left[I(S) - I(S_a)\right] g(S) dS. \tag{4.14}$$

λ (≥ 0) is the safety loading and λP_i is called the loading premium. In other words: $P_\lambda = (1+\lambda) P_i$. Hence, Mayers and Smith (1987) examine a special case of the underinvestment problem, where $\lambda = 0$. With a safety loading, the insurance offers the same protection as before, but it costs more. This should justify the use of the term "unfair". Let us examine the consequences of having a safety loading. Remember that we are in the *cum* dividend case, i.e., F is unaffected by the decision to purchase insurance. Adjusting firm value as of the first date is quite simple. Compare the firm value in (4.11), and recall that the final summand is the insurance premium paid. All we have to do now is to insert the new premium P_λ instead of P_i, so that

$$\begin{aligned} V_\lambda &= \int_0^{\overline{S}} F g(S) ds + \int_{S_a}^{S_c} \left[V^* - I(S) - F\right] g(S) dS + \int_{S_c}^{\overline{S}} \left[V^* - F\right] g(S) dS \\ &\quad - (1+\lambda) \int_0^{S_a} \left[I(S) - I(S_a)\right] g(S) dS \end{aligned}$$

Making use of the same modifications to the first summand as in the derivation of (4.12), we can simplify to obtain

$$V_\lambda = \int_0^{S_c} [V^* - I(S)]\, g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS - \lambda \int_0^{S_a} [I(S) - I(S_a)]\, g(S)dS. \tag{4.15}$$

Put simply, we have $V_\lambda = V_u - \lambda P_i$. What does this mean for us? The equation tells us that, given a positive safety loading, we have departed from the status quo value yet again. You could say that we have a new problem: second-date cash flows are unchanged, but the insurance company now asks for more from the firm without providing more itself. This *must* drag down firm value. Specifically, firm value is less by the very amount that the insurance company additionally requires, i.e., λP_i. This is a new deadweight loss from the firm's perspective. This time, however, it comes with insurance. We now face two deadweight losses: one that arises if we do not insure, and the other that arises if we do insure. This obviously comes down to a tradeoff. But before we go ahead, let us first define this new loss. Similar to R_0 in (4.7), define the deadweight loss to be the safety-loading induced reduction in firm value of the insured firm relative to status quo. With the help of (4.1) and (4.15), it follows that

$$\begin{aligned} R_\lambda &= V_u - V_\lambda \\ &= \lambda \int_0^{S_a} [I(S) - I(S_a)]\, g(S)dS. \end{aligned} \tag{4.16}$$

From (4.8), the loading premium is the deadweight loss, i.e., $R_\lambda = \lambda P_i$. Guess who pays for it? Correct, shareholders do. If the firm buys unfair insurance, the insurance company is paid off and debtholders are still safe, so their claims are taken care of. The value of debt with unfair insurance is unchanged compared to the case with actuarially fair insurance ($D_\lambda = D_i$):

$$D_\lambda = \int_0^{\overline{S}} F g(S)dS.$$

Just as shareholders enjoy the benefits of insurance through the dividend paid at the first date, they have to endure the costs that come with it at the first date. That said, the deadweight loss reduces the dividend shareholders are entitled to: the increase in proceeds from the debt issue, $D_\lambda - D_0$, is now used to pay for the fair insurance premium *and* the safety premium. This leaves a dividend of $D_\lambda - D_0 - (1 + \lambda)\, P_i$ or, equivalently, $R_0 - R_\lambda$, cf. (4.10). Since shareholders' second-date residual claim is unchanged compared to the uninsured case, cf. (4.5), the equity value with unfair insurance becomes

$$E_\lambda = E_0 + R_0 - R_\lambda. \tag{4.17}$$

As shareholder value maximization is managers' only interest, the firm will now insure if, and only if, $E_\lambda \geq E_0$ or, equivalently, $R_0 \geq R_\lambda$. This is the aforementioned tradeoff. As long as the deadweight loss induced by insuring, R_λ, is no greater than the loss induced by not doing so, R_0, managers will still decide to insure as shareholder (and firm) value will be higher than in the uninsured case.

Note that this also provides a rationale for actually choosing the deductible $I(S_a)$ (as opposed to, say, full coverage) once insurance becomes unfair: given $\lambda > 0$, the use of $I(S_a)$ is efficient because it minimizes the fair premium P_i and, accordingly, the loading cost R_λ, cf. (4.14) and (4.16). Thus, while there is no need for assuming $I(S_a)$ as the deductible if one wants to eliminate the underinvestment problem with fair insurance, cost minimization requires so in the presence of an unfair premium.[88]

Note that insurance is no longer self-financing, for shareholders have to chip in the unfair part of it out of their own pockets (the more so, the higher the safety loading). A look at equation (4.15) tells us that firm value is not anymore consistent with the MM irrelevance proposition (as a safety loading is inconsistent with perfect markets). That is, financing matters. As long as debt is safe, status quo is reached. But once it becomes risky, the optimal value is not reached despite having insurance coverage. The safety loading draws down firm value relative to status quo. It does the more so, the higher the level of debt and/or the safety loading.

The graphical representation for the uniform special case is not that simple anymore. For ease of explanation, let $\lambda < 1$, i.e., the actual premium paid is less than double the fair premium. This should not be an unrealistic assumption. In this case, $R_\lambda\,(= \lambda P_i)$ is represented by a part of the triangle DCF, i.e., the deadweight loss is displayed as "λ times the area DCF" (Schnabel and Roumi, 1989, p. 157). Unfortunately, the authors do not have to say more about this issue. A more rigorous depiction of the loading premium would be desirable. Arnold and Hartl (2011) provide a handy graphical approach, see Figure 4.5.

Let us define point E such that line segment FE divided by segment FC is λ, i.e., $\lambda = \frac{FE}{FC}$. We know that the fair insurance premium P_i is represented by DCF. Using the formula for the area of a triangle, we may write this area as $\frac{DF \cdot FC}{2}$. Furthermore, we know that R_λ is represented by λ times this area, i.e., $\lambda \frac{DF \cdot FC}{2}$. This is where our definition of λ becomes

[88] A counter-argument, leaving the confines of the model, is that the firm would be most dependent on a *low* deductible in states with the highest losses (i.e., when S is close to zero) as the company is most cash-strained in these states.

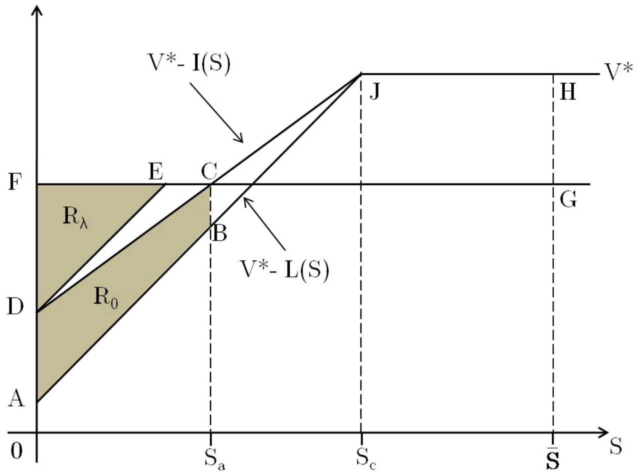

Figure 4.5: Loading Premium

useful. Substituting for λ yields $\frac{FE}{FC}\frac{DF \cdot FC}{2}$, which simplifies to $\frac{DF \cdot FE}{2}$. This fraction expresses exactly the area of triangle DEF. In other words, if we choose λ the way we do, then our deadweight loss R_λ is represented by the triangle DEF in Figure 4.5, as illustrated by the upper shaded area. We will come to another benefit of this way of illustrating later on. The entire insurance premium P_λ is thus represented by DCF (the fair part) *plus* DEF (the loading premium) "sitting on top of that". As we said, cash flows at the latter date remain unchanged such that the second-date component of shareholder value is still proportional to CGHJ in Figure 4.5. Since debt has become safe due to insuring, it is, once again, represented by the tetragon $0\overline{S}$GF. Compared to the uninsured-risky case ($0\overline{S}$GCBA), debt value has risen by ABCF, i.e., ABCD plus DCF. In the presence of a safety loading, this increase comes at an expense of P_λ, i.e., DCF plus DEF. The fair insurance premium part (DCF) cancels out, so that we are left with a net gain to shareholders of ABCD minus DEF: the removal of the deadweight loss R_0 comes at a deadweight loss of R_λ. Insurance will be bought as long as the gain is non-negative ($R_0 \geq R_\lambda$) — there is our tradeoff again. Graphically, managers will decide to repair the damage to its assets for a given F in every state if, and only if, triangle DEF is no greater than tetragon ABCD. We are left with a simple decision rule:

$$\begin{aligned} R_0 &\geq R_\lambda \Rightarrow \text{buy insurance}, \\ R_0 &< R_\lambda \Rightarrow \text{do not buy insurance}. \end{aligned}$$

That is, go for whatever action yields the lower deadweight loss.

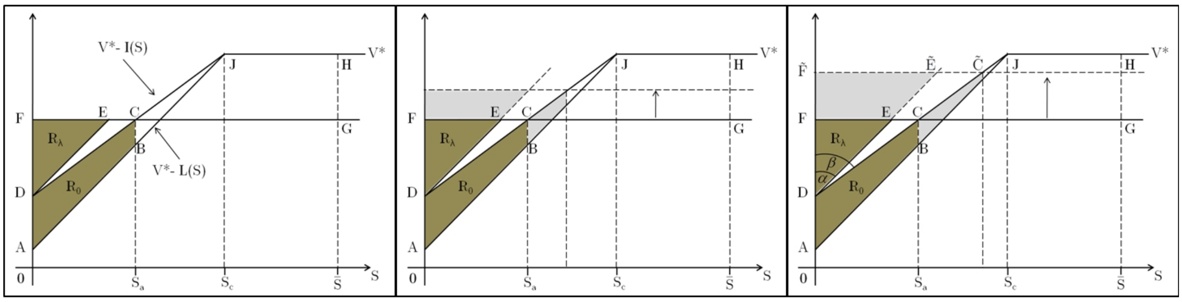

Figure 4.6: Increase in Debt Levels

4.5 The influence of changing debt levels on a firm's decision to insure — a graphical correction

Schnabel and Roumi (1989) go on to establish their paper's main point by asking an interesting question: *given the presence of a safety loading, will the firm's decision to buy insurance be influenced if the level of debt F changes?*

Granted, we said that F is unchanged under the *cum* dividend interpretation. But the way they mean it is: what if the initial level of debt were to be higher *from the outset*? If the firm needs to raise more (less) money at the first date, for whatever reason, then it has to promise a higher (lower) F to its debtholders. What are the implications?

Schnabel and Roumi (1989, p. 157) offer the following conclusion: "A visual inspection of the figure makes clear that there is a critical value of F, call it F^*, where $R_0 = R_\lambda$. For $F < F^*$, $R_0 < R_\lambda$ and it is optimal for the firm not to obtain coverage, whereas for $F > F^*$, $R_0 > R_\lambda$ and it is optimal for the firm to obtain coverage". In other words, the authors claim that as F rises from $V^* - I(0)$, it passes some critical level F^*, for which $R_0 = R_\lambda$ or, equivalently, areas ABCD and DEF are equal in size in Figure 4.5. Once it is greater than F^*, the tetragon (the deadweight loss R_0 of not investing) is said to exceed the triangle (the deadweight loss R_λ of insuring). Therefore, the firm should buy insurance for high enough levels of debt.

To cut a long story short: their conclusion is wrong. First, such an F^* need not necessarily exist. Second, if it does, the conclusion should be exactly the other way round. Before we get into the algebra involved, let us first perform a visual inspection. Have a look at Figure 4.6, which illustrates the increase in F for the case of uniform state prices.

The graph on the left is identical to Figure 4.5. R_0 and R_λ are marked as the shaded areas. The two remaining graphs display the impact of raising the debt level F in steps. The resulting increases in both R_0 and R_λ are depicted as the lightly shaded areas in each graph.

It is obvious that both ABCD (S_a is moved further to the right) and DEF (more insurance coverage is needed) grow bigger as F increases. The crucial point is that they do not do so at the same pace. Since states of the world are in order of decreasing $L(S)$ and $I(S)$, the distance between $V^* - I(S)$ and $V^* - L(S)$ becomes smaller as we move up in states. Line segment BC is exactly that difference for state S_a, i.e., $V^* - I(S_a) - [V^* - L(S_a)]$, in the left graph in Figure 4.6. As F and, thus, S_a rise marginally, the accompanying increase in ABCD, proportional to BC, becomes smaller and smaller. In other words, BC goes to zero as F moves towards V^*, and S_a towards S_c, respectively. Conversely, the marginal increase is the highest for low levels of risky debt. For $F = V^* - I(0)$, the underinvestment problem just commences, and ABCD is zero. So is DEF, such that $R_0 = R_\lambda = 0$. When F rises slightly above $V^* - I(0)$, BC is almost AD. The situation presents itself in reverse for the triangle DEF. The marginal increase in size, proportional to line segment FE, grows *bigger* as F keeps increasing. For F slightly above $V^* - I(0)$, FE is approximately zero. Thus, a marginal change in F has an impact on R_0 that is an order of magnitude greater than the impact on R_λ for levels of debt close enough to $V^* - I(0)$. As F approaches its highest possible level V^*, FE also approaches its maximum, namely FJ. Taken together, for levels of risky debt close enough to $V^* - I(0)$, we have $R_0 > R_\lambda$, and the firm takes insurance. As F rises further, due to the mentioned characteristics of the two geometrical figures, R_λ grows faster than R_0 from some large-enough debt level on, so that $R_0 - R_\lambda$ starts to fall. There are two possible outcomes for large F. $R_0 - R_\lambda$ may stay positive in value such that the firm takes insurance even for large levels of debt. Note that this alone would prove Schnabel and Roumi's (1989) quoted statement wrong, for it means that F^* does not always exist. The alternative is that $R_0 - R_\lambda$ becomes negative above some F^*. In this case, the firm will decide not to take insurance for high levels of debt because $R_0 < R_\lambda$. This is the case where we have the exact opposite conclusion compared to Schnabel and Roumi (1989): the firm generally demands insurance for low levels of risky debt, while it decides *not* to insure for high levels. One question remains. What determines whether $R_0 - R_\lambda$ actually becomes negative? The magnitude of the safety loading does. A look at Figure 4.6 provides some intuition. Ceteris paribus, the bigger λ, the longer the line segment FE, the bigger the area of DEF, and the more likely that R_λ takes over R_0 in size before F reaches V^*. Common sense will do the trick, too: a higher safety loading leads to a bigger cost (deadweight loss) of insuring. Insurance becomes less attractive.

Finally, having examined Figure 4.6, we can now also state the second benefit of illustrating the loading premium by triangle DEF. Note how in the graph to the right we have included

$\widetilde{F}$ as the new debt level along with the corresponding points $\widetilde{E}$ and $\widetilde{C}$ as well as the angles α and β belonging triangles DEF and DCF, respectively. The major advantage is that when we raise F to $\widetilde{F}$ to obtain the (new) fair insurance premium $D\widetilde{C}\widetilde{F}$, the area $D\widetilde{E}\widetilde{F}$ still represents the (new) deadweight loss of insuring. In other words, the area of $D\widetilde{E}\widetilde{F}$ equals $\lambda \cdot D\widetilde{C}\widetilde{F}$. By use of the corresponding line segments, this means that $\frac{D\widetilde{F} \cdot \widetilde{F}\widetilde{E}}{2} = \lambda \frac{D\widetilde{F} \cdot \widetilde{F}\widetilde{C}}{2}$ or, put more simply, $\lambda = \frac{\widetilde{F}\widetilde{E}}{\widetilde{F}\widetilde{C}}$. Since we defined $\lambda = \frac{FE}{FC}$, the proof of this assertion comes down to showing $\frac{\widetilde{F}\widetilde{E}}{\widetilde{F}\widetilde{C}} = \frac{FE}{FC}$. By the trigonometric function, we have $\tan \alpha = \frac{FE}{DF}$ for triangle DEF. Enlarging DEF to $D\widetilde{E}\widetilde{F}$ leaves the angle α unchanged, so that we must also have $\tan \alpha = \frac{\widetilde{F}\widetilde{E}}{D\widetilde{F}}$. Provided that the slopes of $V^* - I(S)$ and $V^* - L(S)$ are constant, it holds true that $\frac{FE}{DF} = \frac{\widetilde{F}\widetilde{E}}{D\widetilde{F}}$. Rearranging yields $\widetilde{F}\widetilde{E} = \frac{D\widetilde{F} \cdot FE}{DF}$. Using the same logic for angle β of the bigger triangle DCF, we have $\tan \beta = \frac{FC}{DF}$ and, thus, $\tan \beta = \frac{\widetilde{F}\widetilde{C}}{D\widetilde{F}}$. Hence, $\frac{FC}{DF} = \frac{\widetilde{F}\widetilde{C}}{D\widetilde{F}}$ or, equivalently, $\widetilde{F}\widetilde{C} = \frac{D\widetilde{F} \cdot FC}{DF}$. All that is left to do is write out the ratio of the line segments $\widetilde{F}\widetilde{E}$ and $\widetilde{F}\widetilde{C}$ and insert the equations just derived:

$$\frac{\widetilde{F}\widetilde{E}}{\widetilde{F}\widetilde{C}} = \frac{\frac{D\widetilde{F} \cdot FE}{DF}}{\frac{D\widetilde{F} \cdot FC}{DF}}.$$

Canceling out yields $\frac{\widetilde{F}\widetilde{E}}{\widetilde{F}\widetilde{C}} = \frac{FE}{FC} = \lambda$. This proves that the new triangle $D\widetilde{E}\widetilde{F}$ represents the new loading premium. It is correct to state $\frac{D\widetilde{F} \cdot \widetilde{F}\widetilde{E}}{2} = \lambda \frac{D\widetilde{F} \cdot \widetilde{F}\widetilde{C}}{2}$.

4.6 A mathematical correction

We will proceed as follows: we will mathematically prove that Schnabel and Roumi's (1989) conclusion is wrong for two scenarios. We will start with the linear-uniform special case, which has so far been used exclusively to justify graphical analysis of the model. We do so as it is the most intuitive way to grasp the results that follow. This will facilitate understanding. As this layout is arguably quite restrictive, we will show that the conclusions by and large carry over to a general setting in a second step. We will make our case for the non-restrictive setting by stating a theorem and proving it. The proof in the general setting represents an extended version of Arnold and Hartl (2011).

The mathematical procedure to come to conclusions is the same in logic for both scenarios. We are interested in finding out how the firm's decision to take out insurance varies with different levels of risky debt in the presence of a safety loading. We know the firm demands insurance if, and only if, $R_0 - R_\lambda \geq 0$. Keep in mind that in the following we focus on risky debt levels only, i.e., $F \geq V^* - I(0)$. Recall that for safe debt there is no underinvestment problem (the firm will always rebuild without insurance coverage) and, consequently, no tradeoff to be made as both R_0 and R_λ are non-existent. Therefore, we will examine $R_0 - R_\lambda$ as a composite function of F over the interval $[V^* - I(0), V^*]$

Before we do so, however, we have to lay ground for our claims first. Stating that Schnabel and Roumi (1989) provide wrong results means, by implication, that they must have made a mistake somewhere in their paper that leads to the (wrong) conclusions. To illustrate this, we will now go through the mathematics of the derivatives of both R_0 and R_λ with respect to F, similar to Schnabel and Roumi's (1989, fn. 1, p. 157) equations (8) and (9). Here, we will do so rather in detail as the mathematics involved may not be easy to understand for everyone. The derivatives require us to invoke the Leibniz integral rule. This is because the upper limit in the integral in R_0 and R_λ is S_a, cf. (4.7) and (4.16); and S_a, given implicitly by (4.3), is a continuously differentiable function of F, i.e., $S_a(F)$.[89] Put simply, what happens when we increase F is that S_a increases, too (by being moved to the right, graphically). From (4.3), we have $\frac{dF}{dS_a} = -I'(S_a)$ and, thus, $\frac{dS_a}{dF} = -\frac{1}{I'(S_a)}$. $I'(S_a) < 0$ because $I(S)$ is strictly decreasing. Hence, $\frac{dS_a}{dF} > 0$. From (4.7) and (4.16), this increase in S_a, caused by an increase in F, has an impact on both R_0 and R_λ (which we will examine in a moment).[90] This is also the reason why R_0 and R_λ are *composite* functions of F, i.e., $\frac{dR_0}{dF} = \frac{dR_0}{dS_a}\frac{dS_a}{dF}$ and $\frac{dR_\lambda}{dF} = \frac{dR_\lambda}{dS_a}\frac{dS_a}{dF}$.

Let us begin with R_0. We have worked out $\frac{dS_a}{dF}$ already. From (4.7), applying the Leibniz rule in differentiating R_0 with respect to S_a yields

$$\frac{dR_0}{dS_a} = [L(S_a) - I(S_a)]\, g(S_a).$$

Combining the established derivatives, the effect of a marginal change in F on R_0 is

$$\frac{dR_0}{dF} = [L(S_a) - I(S_a)]\, g(S_a)\left[-\frac{1}{I'(S_a)}\right]. \tag{4.18}$$

This is the same outcome as in Schnabel and Roumi's (1989) equation (8). Note that $\frac{dR_0}{dS_a} \geq 0$. The only thing that may come as a little bit of a surprise is that the inequality is not strict. We know that rebuilding is assumed to always be a positive-NPV project in all states $S < S_c$, i.e., $L(S) - I(S) > 0$ for $0 \leq S < S_c$. For state S_c, both $L(S)$ and $I(S)$ become zero ($L(S_c) = I(S_c) = 0$). What is the highest value that S_a can take on? Clearly, this happens

[89] We will stick to writing S_a instead of $S_a(F)$ for reasons of simplicity.

[90] The easiest way to intuitively grasp the mathematics involved is that increasing S_a entails two effects (at least for R_λ). One, the upper integration limit rises, i.e. R_0 and R_λ now comprise more states. Two, the integrand in R_λ is affected by an increase as well. The Leibniz integral rule accounts for both of these effects. Since the integrand of R_0 does not depend on S_a, the latter effect is of no relevance for R_0.

for the highest possible level of debt F as we said that S_a increases with F. We know this is $F = V^*$. From (4.3), for $F = V^*$, we have $I(S_a) = 0$. But $I(S)$ becomes zero only for $S = S_c$. Thus, we must have $S_a = S_c$ for $F = V^*$, and $S_a < S_c$ for $F < V^*$ because S_a rises with F. The highest value S_a can take on in S_c. Taken together, we have $L(S_a) - I(S_a) > 0$ and thus $\frac{dR_0}{dS_a} > 0$ for $S_a < S_c$ (i.e., $F < V^*$) and $\frac{dR_0}{dS_a} \geq 0$ for $S_a \leq S_c$ (i.e., $F \leq V^*$). Since $\frac{dR_0}{dS_a} \geq 0$ and $\frac{dS_a}{dF} > 0$, it follows that $\frac{dR_0}{dF} \geq 0$. Schnabel and Roumi (1989, fn.1 , p. 158) also come to this conclusion.[91]

By implication, the fact that our result is the same as theirs only leaves the derivative of R_λ with respect to F as a possible source of error. Applying the Leibniz rule to (4.16) yields

$$\frac{dR_\lambda}{dS_a} = \lambda \left\{ \int_0^{S_a} \left[g(S) \frac{\partial}{\partial S_a} [I(S) - I(S_a)] \right] dS + [I(S_a) - I(S_a)]\, g(S_a) \right\}.$$

The last summand obviously cancels out. All that remains is

$$\frac{dR_\lambda}{dS_a} = \lambda \int_0^{S_a} \left\{ g(S) \frac{\partial}{\partial S_a} [I(S) - I(S_a)] \right\} dS.$$

Regarding $\frac{\partial I(S)}{\partial S_a}$, we said before that $I(S)$ is not a function of S_a, so that

$$\frac{dR_\lambda}{dS_a} = -\lambda \int_0^{S_a} I'(S_a)\, g(S)\, dS.$$

We shift $I'(S_a)$ outside the integral sign (we are not integrating over S_a, but S), which leaves us with

$$\frac{dR_\lambda}{dS_a} = -\lambda I'(S_a) \int_0^{S_a} g(S)\, dS.$$

This may equivalently be written as $\frac{dR_\lambda}{dS_a} = -\lambda I'(S_a)\, G(S_a)$, where $G(S_a) = \int_0^{S_a} g(S)\, dS$. Due to $I'(S_a) < 0$, we have $\frac{dR_\lambda}{dS_a} > 0$ for positive safety loadings. Recall that $\frac{dR_\lambda}{dF} = \frac{dR_\lambda}{dS_a}\frac{dS_a}{dF}$ and $\frac{dS_a}{dF} = -\frac{1}{I'(S_a)}$. Hence, a final step yields

$$\begin{aligned} \frac{dR_\lambda}{dF} &= -\lambda I'(S_a) \int_0^{S_a} g(S)\, dS \left(-\frac{1}{I'(S_a)} \right) \\ &= \lambda \int_0^{S_a} g(S)\, dS. \end{aligned} \tag{4.19}$$

$\frac{dR_\lambda}{dF} > 0$ for positive λ. As we predicted: the deadweight loss of insuring increases with F. This is a first important finding: we have proven, in a general setting, that both R_0 and R_λ increase with F.

[91] For the sake of correctness, they state that "...equation (8) is always positive..." (Schnabel and Roumi, 1989, fn. 1, p. 158). But let us not be pedantic here.

What we are more interested in here, however, is whether we have derived the same outcome as Schnabel and Roumi (1989, fn.1, p. 157) in their equation (9). Let us check it out. They claim that

$$\frac{dR_\lambda}{dF} = -\lambda \int_0^{S_a} \frac{dS_a}{dF} g\left(S\right) dS,$$

and conclude (correctly) that this term is negative. Obviously, their result is different in appearance and algebraic sign from our equation (4.19). Given our derivations established above, their derivative is incorrect. And this has far-reaching implications. Schnabel and Roumi (1989) go on to state that because $\frac{dR_0}{dF} > 0$ and (their) $\frac{dR_\lambda}{dF} < 0$, $R_0 - R_\lambda$ must obviously increase monotonically with F. That is, the deadweight loss of not insuring becomes greater when F rises, while the deadweight loss associated with buying insurance becomes smaller.[92] Obtaining insurance therefore becomes relatively more appealing as F rises. This leads to the conclusion that the company should insure for low F. According to the authors, when F rises, it *always* passes a critical value F^* for which $R_0 = R_\lambda$, and above which $R_0 > R_\lambda$, so that the firm buys insurance. Note that Schnabel and Roumi (1989) make a second mistake here. Even if their statement were correct, this does not imply the existence of F^*. For it may not lie within the interval $[V^* - I(0), V^*]$, but above F^*. As F reaches V^*, R_0 may still be smaller than R_λ in their model. True, if V^* were large enough, say infinity, F at some point would pass the level for which the tetragon ABCD and the triangle DEF have the same surface area.[93] But we cannot be sure in the current scenario. Mathematically, one cannot make inferences about the absolute values of R_0 and R_λ from the (above) considerations of slopes.

Let us dig just a little deeper. What would the economic intuition of Schnabel and Roumi's (1989) conclusions be? They state that a firm will buy insurance only for sufficiently high levels of debt in the presence of a safety loading. That is to say managers of underwater firms demand insurance, while those of barely levered companies will rather go without. Remind yourself that managers are agents of shareholders. By this course of action, managers would not be doing them any favor. When levels of risky debt are low, shareholders have a bigger stake in the corporation relative to high levels. They should thus have an interest in protecting their claims in the firm. On the other hand, why bother insuring when the firm basically belongs to debtholders anyway? Therefore, shareholders should want to protect themselves through insurance purchases only for *low* levels of risky debt. Again, Schnabel and Roumi's (1989) conclusion should be the other way round.

[92] Graphically, this implies that triangle DEF becomes *smaller* as we raise the horizontal F line.

[93] As debt keeps rising, R_λ would have to become zero at some point according to Schnabel and Roumi (1989). But R_λ must be positive for such high values of F per equation (4.16). A contradiction.

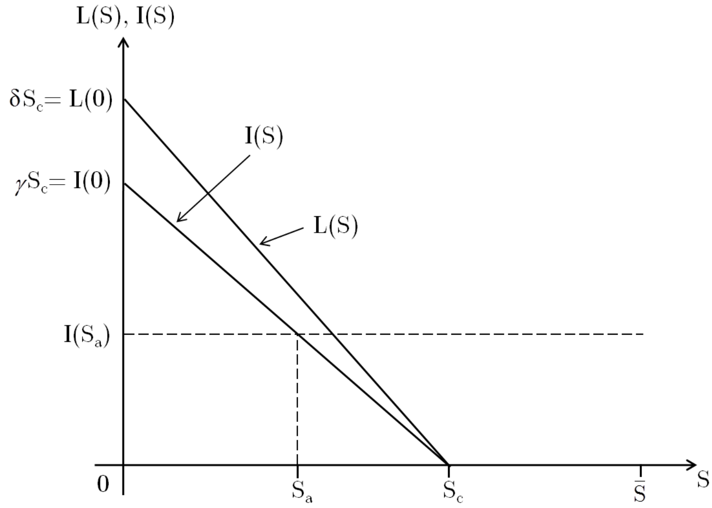

Figure 4.7: Loss and Investment Cost Function

We will provide corrections for the two aforementioned errors in the following. That is, we will show that $R_0 - R_\lambda$ is not monotonic, and we will establish the conditions for which F^* actually exists in $[V^* - I(0), V^*]$.

4.7 The linear-uniform special case

Let us begin by stating the relevant assumptions. Assume that state prices are uniform, i.e., $g(S) = g$ on the entire interval $\left[0, \overline{S}\right]$. To account for linearity, define the loss and the investment cost function by

$$L(S) = \delta\left(S_c - S\right), \tag{4.20}$$

$$I(S) = \gamma\left(S_c - S\right). \tag{4.21}$$

Note that both $L(S)$ and $I(S)$ become zero for $S = S_c$. As stated before, the maximum loss and rebuilding cost occur in state $S = 0$. The respective values are $L(0) = \delta S_c$ and $I(0) = \gamma S_c$. To account for $0 < I(S) < L(S) \leq V^*$ for all $0 \leq S < S_c$, let $0 < \gamma < \delta \leq \frac{V^*}{S_c}$. A graphical representation of the two functions, akin to Garven and MacMinn (1993, p. 639), is provided in Figure 4.7.

Equation (4.3), which defines the threshold state, becomes $V^* - \gamma\left(S_c - S_a\right) = F$. Solving for S_a yields:

$$S_a = S_c - \frac{V^* - F}{\gamma}. \tag{4.22}$$

We have to work out the derivative of $R_0 - R_\lambda$ with respect to F. To do so, we first write out R_0 and R_λ using the above equations. From (4.7), R_0 becomes

$$\begin{aligned} R_0 &= \int_0^{S_a} \left[\delta\left(S_c - S\right) - \gamma\left(S_c - S\right)\right] g dS \\ &= \left(\delta - \gamma\right) g \int_0^{S_a} \left(S_c - S\right) dS \end{aligned}$$

We get rid of the integral sign such that

$$\begin{aligned} R_0 &= \left(\delta - \gamma\right) g \left[S_c S - \frac{S^2}{2}\right]_0^{S_a} \\ &= \left(\delta - \gamma\right) g \left[S_c S_a - \frac{S_a^2}{2}\right]. \end{aligned} \tag{4.23}$$

Using (4.16) and performing the respective operations, the equation for R_λ is

$$\begin{aligned} R_\lambda &= \lambda \int_0^{S_a} \left[\gamma\left(S_c - S\right) - \gamma\left(S_c - S_a\right)\right] g dS \\ &= \lambda\gamma g \left[S_a S - \frac{S^2}{2}\right]_0^{S_a} \\ &= \lambda\gamma g \frac{S_a^2}{2}. \end{aligned} \tag{4.24}$$

What is left to do is to subtract the latter expression from the former.

$$\begin{aligned} R_0 - R_\lambda &= \left(\delta - \gamma\right) g \left[S_c S_a - \frac{S_a^2}{2}\right] - \lambda\gamma g \frac{S_a^2}{2} \\ &= g\frac{S_a}{2}\left[\left(\delta - \gamma\right)\left(2S_c - S_a\right) - \lambda\gamma S_a\right]. \end{aligned} \tag{4.25}$$

Since we are interested in assessing the derivavtive of $R_0 - R_\lambda$ with respect to F, replace S_a with the right-hand side of equation (4.22):

$$\begin{aligned} R_0 - R_\lambda &= \frac{g}{2}\left(S_c - \frac{V^* - F}{\gamma}\right)\left[\left(\delta - \gamma\right)\left(2S_c - S_c + \frac{V^* - F}{\gamma}\right) - \lambda\gamma\left(S_c - \frac{V^* - F}{\gamma}\right)\right] \\ &= \frac{g}{2}\left(S_c - \frac{V^* - F}{\gamma}\right)\left[\left(\delta - \gamma - \lambda\gamma\right) S_c + \left(\delta - \gamma + \lambda\gamma\right)\frac{V^* - F}{\gamma}\right]. \end{aligned} \tag{4.26}$$

This is the equation that we will work with to support our graphical argument mathematically. We start by examining it for the lower boundary of our interval. The lowest possible level of risky debt is $F = V^* - I(0)$ or, equivalently, $F = V^* - \gamma S_c$. From equation (4.22) above, it follows that $S_a = 0$ for $F = V^* - \gamma S_c$. Using (4.7) and (4.16), we have $R_0 = R_\lambda = 0$. But this is nothing new: for this level of debt, the underinvestment problem just commences and, therefore, the areas proportional to ABCD and DEF are both zero. The interesting question is: what happens to these areas when we start to increase F? Mathematically, this means taking the derivative.

To put things into perspective: the idea is that the derivative is positive for $F = V^* - I(0)$ as this would indeed imply that $R_0 > R_\lambda$ for low levels of debt. If both areas start to grow from an initial size of zero, but R_0 grows faster than R_λ, then it must also be larger than R_λ — and it must stay larger at least until $\frac{d(R_0 - R_\lambda)}{dF}$ alters its mathematical sign to negative (if it ever turns negative).

The derivative of (4.26) with respect to F is

$$\begin{aligned}
\frac{d\left(R_0 - R_\lambda\right)}{dF} &= \frac{g}{2\gamma}\left[\left(\delta-\gamma-\lambda\gamma\right)S_c + \left(\delta-\gamma+\lambda\gamma\right)\frac{V^*-F}{\gamma}\right] \\
&\quad + \frac{g}{2}\left(S_c - \frac{V^*-F}{\gamma}\right)\left(\delta-\gamma+\lambda\gamma\right)\left(-\frac{1}{\gamma}\right) \\
&= \frac{g}{2\gamma}\left[\left(\delta-\gamma-\lambda\gamma\right)S_c + \left(\delta-\gamma+\lambda\gamma\right)\frac{V^*-F}{\gamma} - S_c\left(\delta-\gamma+\lambda\gamma\right)\right. \\
&\quad \left. + \frac{V^*-F}{\gamma}\left(\delta-\gamma+\lambda\gamma\right)\right] \\
&= \frac{g}{2\gamma}\left[2\left(\delta-\gamma+\lambda\gamma\right)\frac{V^*-F}{\gamma} - 2\lambda\gamma S_c\right] \\
&= \frac{g}{\gamma}\left[\left(\delta-\gamma+\lambda\gamma\right)\frac{V^*-F}{\gamma} - \lambda\gamma S_c\right]. \qquad (4.27)
\end{aligned}$$

How do we show that $\frac{d(R_0 - R_\lambda)}{dF} > 0$ for $F = V^* - \gamma S_c$? The obvious way is to substitute this level of debt into the equation above.[94] The result is $\frac{g}{\gamma}\left[\left(\delta-\gamma\right)S_c\right]$, which is indeed positive as $\delta > \gamma$. But there is a smarter way to show this result (and more). Equation (4.26) tells us that $R_0 - R_\lambda$ is strictly concave.[95] Strict concavity in turn implies the existence of a unique maximum. Now, all we have to do is to show that the function takes on its maximum in (or above) the interval $[V^* - I(0), V^*]$ as this implies that, starting from $F = V^* - \gamma S_c$, $R_0 - R_\lambda$ increases with F from a value of zero and that, consequently, $R_0 > R_\lambda$, at least for sufficiently low levels of risky debt. This is a "smarter way" because showing that $R_0 - R_\lambda$ is strictly concave excludes the possibility of multiple solutions F to $R_0 = R_\lambda$. In other words, if R_0 becomes smaller than R_λ from a certain level F^* on, then it will also stay smaller for

[94] Here is yet another benefit of illustrating the deadweight loss R_λ as introduced in Figure 4.5. One can verify that $\frac{dR_0}{dF}$ is equal to $\frac{g}{\gamma}$ times line segment BC, i.e., $L\left(S_a\right) - I\left(S_a\right)$, while $\frac{dR_\lambda}{dF}$ is equal to $g\lambda\left(S_c - \frac{V^*-F}{\gamma}\right)$. The former is, equivalently, g times the horizontal line segment that connects point B and the curve $V^* - I\left(S\right)$, while the latter is equal to $g\lambda$ times FC or, equivalently, g times FE. Thus, we simply have to compare the line segment that connects point B and $V^* - I\left(S\right)$ to FE in interpreting the derivatives graphically.

[95] In case one should ask why: $R_0 - R_\lambda$ is obviously a quadratic function of F, cf. (4.26). With that said, rewrite it such that its appearance is in the form of $aF^2 + bF + c$, where $a \equiv -\frac{g}{2\gamma^2}\left(\delta-\gamma+\lambda\gamma\right)$ is negative. This implies that $R_0 - R_\lambda$ appears as a parabola that opens downward, i.e., it is strictly concave.

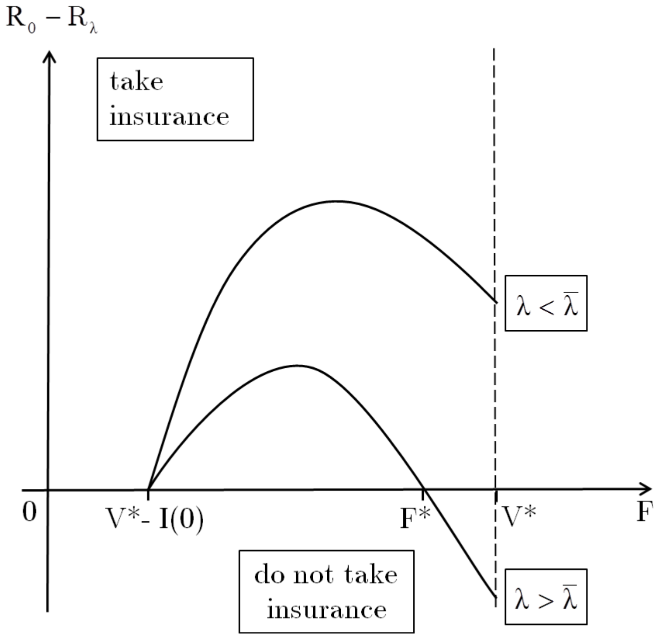

Figure 4.8: $R_0 - R_\lambda$ as a Function of F.

any greater level of debt. Figure 4.8 helps to clarify. If F^* exists, that is, if $R_0 - R_\lambda$ crosses the F-axis within the interval $[V^* - I(0), V^*]$, it will never cross the F-axis again, but will depart from it even further. The critical level of debt F^* – if it exists – is unique in the linear-uniform special case.

To determine the maximum, the term in square brackets in (4.27) becomes zero for

$$F = V^* - \frac{\lambda\gamma^2 S_c}{\delta - \gamma + \lambda\gamma}. \tag{4.28}$$

From this level of debt on, the increase of R_λ with F is relatively larger than that of R_0 ($\frac{d(R_0-R_\lambda)}{dF} \lesseqqgtr 0 \iff F \gtreqqless V^* - \frac{\lambda\gamma^2 S_c}{\delta-\gamma+\lambda\gamma}$). Does the maximum fall into our interval? The expression is obviously smaller than the upper limit $F = V^*$ as the second summand is positive. For the lower limit, we have to check $V^* - \gamma S_c \frac{\lambda\gamma}{\delta-\gamma+\lambda\gamma} > V^* - \gamma S_c$? It is a true statement because $\delta - \gamma$ in the denominator is positive, making the whole fraction positive, but less than one. The extremum lies in the interval.

The final task is to determine under which circumstances the firm switches to not taking out insurance. To do so, we examine $R_0 - R_\lambda$ for $F = V^*$. If we find that $R_0 - R_\lambda < 0$, then it must have crossed the F-axis at a unique debt level $F^* < V^*$. Note that we have $S_a = S_c$ for $F = V^*$ by equation (4.22). Plugging this into (4.26) yields

$$R_0 - R_\lambda = \frac{g}{2} S_c^2 \left(\delta - \gamma - \lambda\gamma\right).$$

Obviously, it depends on the safety loading λ whether this equation turns out positive or negative. To make things easy, let us define

$$\overline{\lambda} = \frac{\delta - \gamma}{\gamma} \tag{4.29}$$

as the value of the safety loading for which $R_0 = R_\lambda$ at $F = V^*$. We have to distinguish two cases (compare Figure 4.8). $R_0 - R_\lambda \geq 0$ for $\lambda \leq \overline{\lambda}$, and the firm consequently takes out insurance for all levels of risky debt F in the interval. This is the case where we prove Schnabel and Roumi (1989) wrong in that F^* does not exist, contrary to their statement. In fact, the result is in the fashion of Mayers and Smith (1989): for low-enough safety loadings, the firm always insures, regardless of its indebtedness. The second case is more interesting. For $\lambda > \overline{\lambda}$, we have $R_0 - R_\lambda < 0$ at $F = V^*$ (compare the lower curve in Figure 4.8). Given continuity, this implies that the function must have crossed the F-axis at F^* in the interval $(V^* - \gamma S_c, V^*)$. Our findings can be summarized as follows:

The firm decides to buy insurance for low levels of risky debt, i.e., $V^* - \gamma S_c < F \leq F^*$, because the deadweight loss in firm value is smaller with insurance than without ($R_0 - R_\lambda \geq 0$). Conversely, for high levels of debt, i.e., $F^* < F \leq V^*$, it is optimal not to obtain insurance coverage as $R_0 - R_\lambda < 0$ — the exact opposite of Schnabel and Roumi's (1989) conclusion quoted before.

Given a high enough safety loading, the firm's decision to demand insurance is influenced by the level of debt F. Taken together, *two* components jointly keep the firm from taking out insurance: the combination of a high safety loading *and* high indebtedness prompts the firm to refrain from buying insurance.
Summing up, the conclusion originally made by Schnabel and Roumi (1989) should read correctly: generally, the firm will demand insurance coverage for low levels of risky debt. The magnitude of the safety loading determines whether it also does so for high levels of debt.

For the sake of completeness, let us determine F^*. We are looking for that $F = F^*$ which makes $R_0 - R_\lambda = 0$ or, equivalently, for which the areas proportional to tetragon ABCD and the triangle DEF, respectively, have the same surface area. (4.26) becomes zero if one of the two factors turns out to be zero. The first one does so for $F = V^* - \gamma S_c$. We know that this is *cannot* be the debt level we are looking for as it is the lower boundary of the debt interval. We stated before that both R_0 and R_λ are zero and that $R_0 - R_\lambda$ starts to increase from this level of debt on. Thus, it must be the second factor. We are looking for the level of debt such that

$$(\delta - \gamma - \lambda\gamma)\, S_c + (\delta - \gamma + \lambda\gamma)\, \frac{V^* - F}{\gamma} = 0.$$

A little rearranging yields the critical level from which on the firm starts to switch to not insuring, provided $\lambda > \overline{\lambda}$:

$$F^* \equiv F = V^* + \gamma S_c \frac{\delta - \gamma - \lambda\gamma}{\delta - \gamma + \lambda\gamma}. \tag{4.30}$$

We can easily verify that F^* is in in the interval $(V^* - \gamma S_c, V^*)$. First, the expression is smaller than V^* as the numerator is negative due to $\lambda > \overline{\lambda}$. Second, writing out $V^* + \gamma S_c \frac{\delta-\gamma-\lambda\gamma}{\delta-\gamma+\lambda\gamma} > V^* - \gamma S_c$ and simplifying also yields a true statement (as $\delta > \gamma$), so that $F^* \in (V^* - \gamma S_c, V^*)$. This implies that we have $R_0 - R_\lambda > 0$ for $F < F^*$ and $R_0 - R_\lambda < 0$ for $F > F^*$, i.e., the firm does not insure for high levels of debt. This completes the proof for the linear-uniform special case.

4.8 The general case

Some people may argue that the assumptions imposed in the special case above are too restrictive. Therefore, we will now relax them and discuss the model in a more general setting. Specifically, we are back to $g\,(S)$ instead of g in our equations, plus $L(S)$ and $I(S)$ are not linear any more. In essence, we return to where we were before turning to the linear-uniform special case. Thus, everything we said up to that point remains unchanged. The proof is more challenging. This is because now we will not be able to generally exclude the possibility of $R_0 - R_\lambda$ crossing the F-axis just once. In other words, the equation $R_0 - R_\lambda = 0$ may have multiple solutions F in the general setting, i.e., the firm may switch back and forth between insuring and not insuring for different levels of F. That is why we started out with the special case above. The beauty of it is – was – that the strict concavity of $R_0 - R_\lambda$ rules out exactly this possibility. Fortunately, we have already mastered a large part of the work needed by deriving equations (4.18) and (4.19).

The logic is similar to that applied in the linear-uniform special case. Therefore, let us first write out the (twice continuously differentiable) function $R_0 - R_\lambda$. From (4.7) and (4.16), it follows that

$$R_0 - R_\lambda = \int_0^{S_a} [L(S) - I(S)]\, g(S) dS - \lambda \int_0^{S_a} [I(S) - I(S_a)]\, g(S) dS. \tag{4.31}$$

Let us begin by determining $\overline{\lambda}$ for the general case. Remember that it is defined as the safety loading for which $R_0 - R_\lambda = 0$ at $F = V^*$. We have $S_a = S_c$ for this level of debt, and the equation above becomes

$$0=\int_0^{S_c}\left[L(S)-I(S)\right]g(S)dS-\lambda\int_0^{S_c}\left[I(S)-I(S_c)\right]g(S)dS.$$

We know that $I\left(S_c\right)=0$, so it can be dropped from the equation. Solving for the safety loading, we find

$$\begin{aligned}\overline{\lambda} &= \frac{\int_0^{S_c}\left[L(S)-I(S)\right]g(S)dS}{\int_0^{S_c}I\left(S\right)g(S)dS}\\ &= \frac{\int_0^{S_c}L(S)g(S)dS}{\int_0^{S_c}I\left(S\right)g(S)dS}-1,\end{aligned} \tag{4.32}$$

which is positive as $L\left(S\right)>I\left(S\right)$ for $0\leq S<S_c$. R_0-R_λ is positive for $F=V^*$ if $\lambda<\overline{\lambda}$, and negative if $\lambda>\overline{\lambda}$.

Theorem: *(a) For $\lambda>\overline{\lambda}$, there are F^* and F^{**} ($V^*-I\left(0\right)<F^*\leq F^{**}<V^*$) such that the firm takes insurance for $F\leq F^*$ and does not take insurance for $F>F^{**}$. (b) For $\lambda\leq\overline{\lambda}$, there are F^* and F^{**} ($V^*-I\left(0\right)<F^*\leq F^{**}<V^*$) such that the firm takes insurance both for $F\leq F^*$ and for $F\geq F^{**}$.*

Before going on to establish the proof, let us pause here for a second and have a closer look at the theorem and its implications. It may appear as somewhat cumbersome. The main reason for this is the introduction of yet another debt level, namely F^{**}. Why do we need it to begin with? Obviously, F^* and F^{**} are the levels of debt in between which the firm may switch (multiple times) between insuring and not insuring. In other words, given a firm switches on multiple occasions as F rises, there has to be a debt level for which it does so for the first time, and one for which it does so for the last time. The theorem states that these levels are F^* and F^{**}, respectively. It also states, in contrast to Schnabel and Roumi (1989), that the firm will generally take out insurance for levels of risky debt that are sufficiently *low* (no greater than F^*), cf. (a) and (b) in the theorem. Provided that the firm switches on several occasions, there are two possibilities. First, R_0-R_λ, as assumed in part (a) of the theorem, may end up negative, i.e., it crosses through the F-axis at F^{**} with negative slope. This implies that the firm does not take insurance for debt levels greater than F^{**}. Second, the function may cross the axis for the last time at F^{**} with positive slope, as asserted in (b). The firm decides to buy insurance for levels in excess of F^{**}, just like it does for levels no greater than F^*. The theorem states that the former case arises for a sufficiently high safety loading ($\lambda>\overline{\lambda}$), while the latter occurs if it is sufficiently low ($\lambda\leq\overline{\lambda}$). So, again, the magnitude of the safety loading determines whether or not a firm insures for high levels of debt, whereas the firm always insures for low levels of debt. We will see in the next section that the theorem greatly simplifies in that it has a rather close resemblance with the linear-uniform case once we impose concavity of $R_0 - R_\lambda$ as a function of F, for this ensures that $F^* = F^{**}$.

From (4.32), $\lambda > \overline{\lambda}$ arises for a large enough loading λ and large-enough rebuilding costs $I(S)$ relative to the casualty losses $L(S)$. By contrast, $\lambda \leq \overline{\lambda}$ requires a sufficiently high critical magnitude $\overline{\lambda}$ in connection with a low λ.

Proof: As before, we will examine $R_0 - R_\lambda$ as a composite function of F over the interval $[V^* - I(0), V^*]$. From (4.3), it follows for $F = V^* - I(0)$ that

$$\begin{aligned} V^* - I(S_a) &= V^* - I(0) \\ I(S_a) &= I(0). \end{aligned}$$

This means that $S_a = 0$ for $F = V^* - I(0)$. Just as in the linear case, this implies that $R_0 = R_\lambda = 0$ and, hence, $R_0 - R_\lambda = 0$ for the lower boundary of the interval, cf. (4.7), (4.16) and (4.31). The aim is to show that $R_0 - R_\lambda$ increases with F from this level of debt on. Luckily, we have already done the hard work for the derivative. We merely need to combine (4.18) and (4.19) to obtain

$$\frac{d(R_0 - R_\lambda)}{dF} = [L(S_a) - I(S_a)]\, g(S_a) \left[-\frac{1}{I'(S_a)}\right] - \lambda \int_0^{S_a} g(S)\, dS. \qquad (4.33)$$

Remember that $\frac{dS_a}{dF} = -\frac{1}{I'(S_a)}$ is positive (graphically, increasing F pushes S_a further to the right). All that is left to do is to insert $S_a = 0$ such that

$$\frac{d(R_0 - R_\lambda)}{dF} = [L(0) - I(0)]\, g(0) \left[-\frac{1}{I'(0)}\right] > 0$$

for $F = V^* - I(0)$. Just as in the linear case, both R_0 and R_λ increase with F from $R_0 = R_\lambda = 0$, but R_0 grows faster, implying that R_0 must be greater than R_λ for low-enough levels of debt. Hence, the firm takes out insurance for such levels. "Low enough" relates to F^*, it is merely another way of stating the assertion that there exists $F^* > V^* - I(0)$ such that $R_0 - R_\lambda > 0$ for $F < F^*$, as stated in both parts (a) and (b) of the theorem.

Let us examine $R_0 - R_\lambda$ for the upper boundary of the debt interval and address the question whether it is positive or negative. Since both $S_a = S_c$ for $F = V^*$ and $I(S_c) = 0$ by (4.3), (4.31) becomes

$$\begin{aligned} R_0 - R_\lambda &= \int_0^{S_c} \left[L(S) - I(S)\right] g(S)dS - \lambda \int_0^{S_c} I\left(S\right) g(S)dS \\ &= \int_0^{S_c} L(S)g(S)dS - (1+\lambda) \int_0^{S_c} I\left(S\right) g(S)dS. \end{aligned}$$

Again, the answer is: it depends. We know from above that $\lambda = \overline{\lambda}$ makes the equation zero. Greater magnitudes of the safety loading result in negative values. Relating to our theorem, this yields the following statement: (a) $R_0 - R_\lambda < 0$ for $F = V^*$, provided that the safety loading is sufficiently large in that $\lambda > \overline{\lambda}$. This implies the existence of $F^{**} < V^*$ above which ($F > F^{**}$) the firm will not buy insurance. Bring Figure 4.8 to mind for a better understanding. Since the function is positive for F close to $V^* - I(0)$, but negative for $F = V^*$, it must have crossed the F-axis with negative slope at some level $F^{**} < V^*$ (regardless of whether the firm crosses the axis multiple times for intermediate debt levels). (b) For a sufficiently small loading, i.e., $\lambda \leq \overline{\lambda}$, it follows that $R_0 - R_\lambda \geq 0$ for $F = V^*$, and the firm buys insurance for $F = V^*$. What about function values for levels of debt slightly lower than V^*? To answer, let us check out the derivative of $R_0 - R_\lambda$ at the highest possible level of debt. We have to substitute $F = V^*$ into (4.33). This implies $S_a = S_c$, and recall that $I\left(S_c\right) = L\left(S_c\right) = 0$ such that

$$\frac{d\left(R_0 - R_\lambda\right)}{dF} = -\lambda \int_0^{S_c} g\left(S\right) dS < 0.$$

The derivative is negative ($R_0 - R_\lambda$ is decreasing at $F = V^*$). This means the function $R_0 - R_\lambda$ takes on even higher positive values than at $F = V^*$ for levels (slightly) below $F = V^*$. Consequently, there exists an F^{**} such that the firm buys insurance for $F \geq F^{**}$. This concludes the proof of the theorem.

Let us come back to F^* and F^{**} for a moment. Although most intuitive for one's understanding, the critical level of debt for which the firm switches form taking insurance to not doing so generally need not be unique (such that $F^* \neq F^{**}$). In that case, the firm will switch between buying and not buying insurance more than once as F increases. One example is sufficient to prove this assertion. As in Arnold and Hartl (2011, p. 6), set $S_c = 1$, $V^* = 1$, $I(S) = 0.9004498875 - 0.9(S + 0.001)^{0.5}$, $L(S) = I(S) + (-S^3 + S^2) + 0.001(1 - S)$, and

$$g(S) = \frac{e^{-0.5\left(\frac{S-0.2}{0.1}\right)^2}}{0.1\sqrt{2\pi}}$$

for S in [0, 1], i.e., the distribution of state prices is truncated normal. (a) Given $\lambda = 0.1$ (a safety loading of ten percent), the function $R_0 - R_\lambda$ crosses the F-axis (with negative slope) at $F^* = 0.1502631825$ for the first time, turns positive again at $F = 0.4160717224$, then becomes negative for the second and last time at $F^{**} = 0.8714716708$ and finally terminates at $R_0 - R_\lambda = -0.01256042295$ for $F = V^* = 1$. In other words, the firm does not take out insurance with moderate indebtedness $F \in (0.1502631825,\ 0.4160717224)$ and at high levels $F > F^{**}$. The example is constructed in such a manner that $L(S) - I(S)$ is small and $I'(S)$ is large for S small, for this implies by (4.33) that $\frac{d(R_0 - R_\lambda)}{dF} < 0$ for F and, thus, S_a small enough. This ensures that $R_0 - R_\lambda$ becomes negative for the first time at $F^* = 0.1502631825$. (b) Redoing the calculations with $\lambda = 0.05$, the function becomes negative first at $F^* = 0.1769684113$ and turns positive again at $F^{**} = 0.3433426436$. It terminates at $R_0 - R_\lambda = 0.01207642332$ for $F = 1$. That is, the firm does insure for debt levels $F \leq F^*$ and $F \geq F^{**}$, but not for an intermediate range of $F \in (0.1769684113,\ 0.3433426436)$.

4.9 Conditions for concavity

As an "intermediate way" between the restrictive linear-uniform special case and the rather cumbersome general case, the theorem simplifies significantly once we impose concavity (cf. Arnold and Hartl, 2011, p.4).

Theorem: *Suppose* $\frac{d^2(R_0-R_\lambda)}{dF^2} < 0$ *for all* $F \in [V^* - I(0), V^*]$. *(a) For* $\lambda > \overline{\lambda}$*, there is* F^* *(*$V^* - I(0) < F^* < V^*$*) such that the firm takes insurance for* $F \leq F^*$ *and does not take insurance for* $F > F^*$*. (b) For* $\lambda \leq \overline{\lambda}$*, the firm takes out insurance for all levels of risky debt* $F \in [V^* - I(0), V^*]$.

Concavity rules out multiple solutions F to $R_0 - R_\lambda = 0$ for intermediate levels of risky debt, which implies that $F^* = F^{**}$, as was the case in the linear-uniform special case. We have already provided the proof for the theorem in the general setting in the section above: all we have to do now is to set $F^* = F^{**}$.

Linearity of $L(S)$ and $I(S)$ and uniformly distributed state prices are not the only means by which one ensures concavity of the function $R_0 - R_\lambda$ (i.e., $\frac{d^2(R_0-R_\lambda)}{dF^2} < 0$). To see this, we first have to establish the second derivative of $R_0 - R_\lambda$ with respect to F for the general case. It follows from (4.33) that

$$\frac{d^2(R_0 - R_\lambda)}{dF^2} = \frac{1}{I'(S_a)} \left\{ \frac{L(S_a) - I(S_a)}{I'(S_a)} g'(S_a) + \frac{d}{dS_a}\left[\frac{L(S_a) - I(S_a)}{I'(S_a)}\right] g(S_a) + \lambda g(S_a) \right\},$$

where use is once again made of the Leibniz rule. Next, we have to apply the quotient rule for the explicit derivation of the derivative in the second summand, resulting in

$$\begin{aligned} \frac{d^2(R_0 - R_\lambda)}{dF^2} &= \frac{1}{I'(S_a)} \left\{ \frac{L(S_a) - I(S_a)}{I'(S_a)} g'(S_a) \right. \\ &\quad \left. + \frac{[L'(S_a) - I'(S_a)]\, I'(S_a) - [L(S_a) - I(S_a)]\, I''(S_a)}{[I'(S_a)]^2} g(S_a) + \lambda g(S_a) \right\}. \end{aligned}$$

Since we require the right-hand side to be negative, we need to establish a set of sufficient conditions that warrants the generalization of the concavity result obtained in the linear-uniform special case. Imposing the simple conditions $L'(S) - I'(S) \leq 0$, $I''(S) \leq 0$ and $g'(S) \leq 0$ for all $S \in [0, S_c]$ leads to such a result. The latter inequality guarantees that the first term in the sum in braces is non-negative, while the former two provide for the non-negativity of the second summand. Combined with the positivity ($g(S) > 0$) of the third expression, the term in braces is positive, which implies that the overall result is negative due to $I'(S) < 0$, so that $\frac{d^2(R_0 - R_\lambda)}{dF^2} < 0$.

Time for a summary. The most important point we have made is that a firm will refrain from insuring for a combination of a high safety loading and high indebtedness. We have shown that the outcome of the model is "continuous" in the sense that different model parameter combinations will lead to different corporate decisions regarding the purchase of insurance. Generally, a firm takes out actuarially fair casualty insurance. Once a positive safety loading comes into play, insurance is bought if the deadweight loss of insuring (R_λ) is less than that of not insuring (R_0). Given concavity of $R_0 - R_\lambda$, the firm keeps demanding insurance for all levels of risky debt for a low-enough magnitude of the safety loading. It will stop taking out insurance if, and only if, both the safety loading and the level of debt surpass their respective critical values.

4.10 Introducing bankruptcy costs

The main premise for the underinvestment problem to occur is the existence of *risky* debt. Risky in the sense that bankruptcy occurs in states $S < S_a$ if no insurance is bought. "Bankruptcy occurs when the fixed obligations to creditors cannot be met" (Haugen and Senbet, 1978, p. 384). In other words, there is a possibility that the firm will default on its debt due to the fact that firm value is insufficient to cover it even with asset reconstitution (but without insurance). Shares become worthless and, ultimately, debtholders take over as the new owners of the firm because "[B]ankruptcy is merely the transfer of ownership from one securityholder to another" (Haugen and Senbet, 1988, p. 32). But this process is well known to be costly in reality (inconsistent with the notion of perfect markets). There may be controversy about how large these costs are, but the literature leaves no doubt that they exist.[96]

Therefore, we will incorporate another innovation into the underinvestment model. We will examine how the introduction of bankruptcy costs affects the model's conclusions. We will focus exclusively on the linear-uniform special case as this will suffice to grasp the main idea (we will plug in the specific values once we come to the derivatives later on). Since we are talking about *bankruptcy*, obviously, these costs are only encountered for states in

[96] Brealey et al. (2003) provide a nice textbook treatment. Generally, *costs of financial distress* can be both direct and indirect. The costs of the bankruptcy proceeding (such as Chapter 11) count towards the former because lawyers and courts have to be paid directly. The latter are hard to quantify as they correspond to a multiplicity of manifestations, such as deteriorating relationships with customers or suppliers. Importantly, they may well arise before bankruptcy because financial distress is first and foremost a condition where firms' "...cash flows are low relative to their debt obligations" (Titman and Tsyplakov, 2007, p. 401). Opler and Titman (1994) report large indirect costs. Warner (1977) is frequently quoted as the first to try and measure bankruptcy costs. He finds small direct costs. Bris et al. (2006) point to the difficulties in measuring even bankruptcy costs, stating that ranges between 2% and 20% of asset values are easily justifiable.

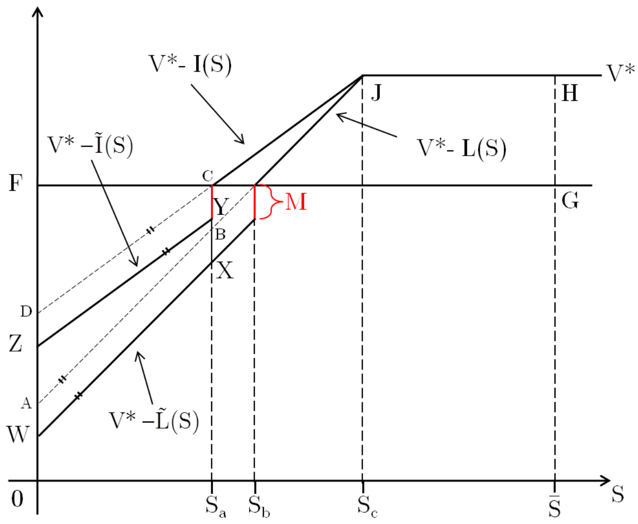

Figure 4.9: The Underinvestment Problem with Bankruptcy Costs

which firm value at the second date will not be enough to cover the promised repayment to bondholders. We will assume that firm value in bankruptcy states is depressed (even further) by an exogenous deadweight cost of M (> 0). For simplicity, we assume that the amount of bankruptcy costs M is fixed, along the lines of Stein (1992). Before continuing, though, we have to be clear about what "bankruptcy states" actually stands for. It means $S < S_a$ if the firm invests to rebuild, i.e., when talking about line $V^* - I(S)$ in the previous graphs. But for the lower line, $V^* - L(S)$, it does not. Have a look at Figure 4.9. Hypothetically, if the firm never rebuilds (function $V^* - L(S)$ is appropriate), bankruptcy arises in a state $S > S_a$ because $L(S) > I(S)$. Thus, we define a new state S_b for which the curve $V^* - L(S)$ crosses the horizontal F-line. This state is implicitly defined by the equation

$$V^* - L(S_b) = F.$$

Graphically, when we start to move down from $\overline{S}$, firm value with and without repairing remains unchanged to previous graphs until $V^* - I(S)$ and $V^* - L(S)$ reach F at S_a and S_b, respectively. From this state on, both values are depressed by a fixed amount M in every state until $S = 0$ is reached. The new functions run parallel to their original counterparts (as depicted by the dashed lines in Figure 4.9). Accordingly, the new loss function becomes

$$\begin{aligned} \widetilde{L}(S) &= L(S) + M \\ &= \delta(S_c - S) + M \text{ for } 0 \leq S < S_b, \end{aligned}$$

while it remains unchanged, i.e., $L(S)$, for $S_b \leq S \leq S_c$. Since $S_b > S_a$, $V^* - L(S)$ must cross the F line at a higher state than S_a because, graphically, it is situated below $V^* - I(S)$. Similarly, the investment cost function is given by

$$\begin{aligned} \widetilde{I}(S) &= I(S) + M \\ &= \gamma(S_c - S) + M \text{ for } 0 \leq S < S_b, \end{aligned}$$

and the usual $I(S)$ for $S_a \leq S \leq S_c$. Just as we assumed $0 < \gamma < \delta \leq \frac{V^*}{S_c}$ in the case without bankruptcy costs, we now impose $0 < \gamma < \delta \leq \frac{V^* - M}{S_c}$. The last inequality in this sequence makes sure that $V^* - \widetilde{L}(0) \geq 0$ such that the costs accrue in full in every bankruptcy state. Mathematically, the two functions now each have a jump discontinuity, one at $S = S_b$ and the other at $S = S_a$, respectively.

At first sight, Figure 4.9 may appear a little unfamiliar, especially the area enclosed by the function graphs between states S_a and S_b. Be aware that shareholders will still – as before – decide to invest deliberately in those states ($S_a \leq S \leq S_b$). By doing so, firm value jumps from $V^* - \widetilde{L}(S)$ to $V^* - I(S) \geq F$, and stockholders are left with a non-negative residual claim. Bankruptcy costs will not arise because firm value suffices to pay off debtholders after the investment is made. As before, the damage is always repaired for states $S \geq S_a$. Conversely, this implies that the underinvestment problem still becomes imminent only for states $S < S_a$. Furthermore, note that rebuilding has the same NPV as before because bankruptcy shifts *both* $V^* - L(S)$ and $V^* - I(S)$ downward by the same amount M. The distance between the two (i.e., the NPV) thus stays unchanged. One can easily verify by checking that $\widetilde{L}(S) - \widetilde{I}(S) = L(S) - I(S)$ for all underinvestment states $S < S_a$. One can also easily determine the firm value for a levered and uninsured company in the presence of bankruptcy costs. Note that we will indicate all values in the presence of these costs with superscript M. Since there is no insurance involved (yet), firm value is simply shareholder value plus debtholder value. As we said that managers decide to invest for states $S \geq S_a$, shareholder value (as the value of the residual claim) is unchanged, cf. (4.5), such that

$$E_0^M = E_0 = \int_{S_a}^{S_c} [V^* - I(S) - F]\, g(S)dS + \int_{S_c}^{\overline{S}} (V^* - F)\, g(S)dS. \tag{4.34}$$

Therefore, bankruptcy must affect debt value. Debtholders are entitled to the insolvency mass if bankruptcy occurs. They take over as the new owners. But since these costs depress firm value for states $S < S_a$, this mass has become smaller by amount M in every bankruptcy state. Consequently, debt value is

$$D_0^M = \int_0^{S_a} \left[V^* - \widetilde{L}(S)\right] g(S)dS + \int_{S_a}^{\overline{S}} Fg(S)dS. \tag{4.35}$$

It should be clear that the value of debt is lowered by exactly the present value of the bankruptcy costs. We can verify this by computing $D_0 - D_0^M$. From (4.4), the only difference in the two equations is the respective loss function in the first summand. Everything else remains unchanged. This included state S_a, for F is unchanged. Thus, in calculating the difference between the two debt values, all terms cancels out except for

$$\begin{aligned} D_0 - D_0^M &= \int_0^{S_a} \left[\widetilde{L}(S) - L(S)\right] g(S)dS \\ &= \int_0^{S_a} Mg(S)dS, \end{aligned}$$

i.e., the present value of the bankruptcy costs. Since shareholder value is the same, the value of the levered and uninsured firm as of the first date consequently is also lowered by the present value of these costs. We simply have to add up (4.34) and (4.35) such that

$$V_0^M = E_0 + D_0^M = \int_0^{S_a} \left[V^* - \widetilde{L}(S)\right] g(S)dS + \int_{S_a}^{S_c} \left[V^* - I(S)\right] g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS. \tag{4.36}$$

It follows that $V_0 - V_0^M = \int_0^{S_a} Mg(S)dS$. Graphically, firm value as of the first date is proportional to the area of $0\overline{S}$HJCXW in the presence of bankruptcy costs. Compared to V_0, which was given by $0\overline{S}$HJCBA, it is smaller by $\int_0^{S_a} \left\{V^* - L(S_a) - \left[V^* - \widetilde{L}(S_a)\right]\right\} g(S)\,dS$, i.e., the area proportional to the parallelogram WXBA in Figure 4.9.[97] The new debt value (which is also less by WXBA) is represented by $0\overline{S}$GCXW, while shareholder value is still proportional to CGHJ.

Again, the loss in debt value is not borne by debtholders, but ultimately comes out of shareholders' pockets. In an efficient market, bondholders will foresee these additional costs in case of bankruptcy. Since they cannot demand compensation in the form of higher payoffs in non-bankruptcy states (as F does not change), they will pay less for the debt issue relative to the case without bankruptcy costs, so that it becomes a zero-NPV investment to them. The issue raises less cash for shareholders; less by the amount of the present value of bankruptcy costs. Therefore, shareholders have an even stronger incentive to get rid of underinvestment. Before considering safety loadings and the mathematics involved, we will show that actuarially

[97] Line segment XB is $V^* - L(S_a) - \left[V^* - \widetilde{L}(S_a)\right]$ and, thus, equal to M. Accordingly, the area of the parallelogram WXBA is equal to $\int_0^{S_a} Mg(S)\,dS$, the present value of the bankruptcy costs.

fair insurance still solves the underinvestment problem. However, we need to address one question first. We have shown that, in comparison to V_0, the area under the curve in the underinvestment states is smaller with bankruptcy costs. So, either the deadweight loss of not insuring (R_0) or the fair insurance premium (P_i) has become bigger. Let us re-quote what the authors of the original model have to say about the purpose of insurance: "Essentially, $V^* - I(S)$ has to be raised above F,... by purchasing some critical amount of coverage" (Mayers and Smith, 1987, p. 49). Since we are now dealing with $\widetilde{I}\,(S)$ instead of $I\,(S)$ in bankruptcy states, one is tempted to think that the quote at present should read correctly that the intention of buying insurance is to lift $V^* - \widetilde{I}(S)$ above F; which would imply that the fair premium is more expensive, since it has to cover a higher amount ($\widetilde{I}\,(S) - I\,(S_a)$ versus the original $I\,(S) - I\,(S_a)$) in each underinvestment state. Hence, the deadweight loss of not insuring would be unaltered. This reasoning is incorrect, however. Let us go back to the definition of R_λ. We specified it as the loss in firm value due to the existence of risky debt in the firm's capital structure *relative* to the (status quo) value with pure equity (or risk-free debt) financing, namely V_u. This is an important point. We have to be aware of the fact that V_u still works as our benchmark. Note that the two functions $I\,(S)$ and $L\,(S)$ only exhibit a discontinuity jump if there is risky debt in the capital structure (for risk-free debt, $F < V^* - I\,(0)$, there are no states S_a and S_b). We assume pure equity or risk-free debt financing in our status quo, as depicted in Figure 4.1 and 4.2, respectively. There is no discontinuity jump involved in these two figures. The deadweight loss of not insuring must consequently be defined as $V_u - V_0^M$. From (4.1), (4.7) and (4.36), it follows that

$$\begin{aligned}
R_0^M &= \int_0^{S_c} \left[V^* - I(S)\right] g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS - \int_0^{S_a} \left[V^* - \widetilde{L}(S)\right] g(S)dS \\
&\quad - \int_{S_a}^{S_c} \left[V^* - I(S)\right] g(S)dS - \int_{S_c}^{\overline{S}} V^* g(S)dS \\
&= \int_0^{S_a} \left[V^* - I(S)\right] g(S)dS - \int_0^{S_a} \left[V^* - \widetilde{L}(S)\right] g(S)dS \\
&= \int_0^{S_a} \left[L\,(S) - I(S)\right] g(S)dS + \int_0^{S_a} Mg(S)dS \\
&= R_0 + \int_0^{S_a} Mg(S)dS. \qquad (4.37)
\end{aligned}$$

Thus, the agency cost of the underinvestment problem – and not the fair insurance premium – rises by the present value of the bankruptcy costs. Graphically, the new deadweight loss is represented by the old loss, ABCD, plus the present value of the bankruptcy costs, proportional to WXBA, combining to WXCD in Figure 4.9. Obviously, the fair premium is unchanged. It is still P_i, cf. (4.8).[98] In other words, it is not $V^* - \widetilde{I}(S)$, but still $V^* - I(S)$ that needs to be elevated to F. Think about it this way: solving the underinvestment problem, which shareholders now have an even bigger incentive to do, is still a mere reformulation of the "safe debt" decision. Safe debt means that insurance guarantees that firm value suffices to pay off debtholders in all states of the world. This in turn implies that bankruptcy never occurs. If bankruptcy never occurs, how can there be any bankruptcy costs? If there are no bankruptcy costs, then there is no $V^* - \widetilde{I}(S)$. Consequently, it has to be $V^* - I(S)$ that matters in buying insurance. By writing a covenant in the bond indenture that guarantees the purchase of the stipulated level of insurance (the same as without bankruptcy costs), the firm makes a credible promise to insure, i.e., it essentially makes a commitment to rebuild the damaged assets in *every* state the firm suffers a loss. Because of this commitment, financial distress will never occur. If the firm insures, bankruptcy costs will not be incurred. If the firm does not insure, firm value is represented by the curve $V^* - \widetilde{L}(S)$ in bankruptcy/underinvestment states $S < S_a$; without insurance, shareholders would never invest to jump to the curve $V^* - \widetilde{I}(S)$ as this would imply a sure loss for them: the entire NPV would be absorbed by debtholders, who enjoy higher seniority. But the firm has an incentive to remove underinvestment. It will hence always take out fair insurance and completely eliminate the underinvestment problem.

The firm has to pay the insurance premium at the first date. Graphically, insurance coverage adds R_0^M and P_i (as represented by WXCD and DCF, respectively) to V_0^M, but costs P_i. As a consequence, debtholders always receive F, even in states $S < S_a$. Using (4.36) and (4.37), we have

$$
\begin{aligned}
V_i^M &= V_0^M + R_0^M + P_i - P_i \\
&= \int_0^{S_a} \left[V^* - \widetilde{L}(S)\right] g(S)dS + \int_{S_a}^{S_c} \left[V^* - I(S)\right] g(S)dS + \int_{S_c}^{\overline{S}} V^* g(S)dS \\
&\quad + \int_0^{S_a} \left[V^* - I(S)\right] g(S)dS - \int_0^{S_a} \left[V^* - \widetilde{L}(S)\right] g(S)dS \\
&\quad + \int_0^{S_a} \left[I(S) - I(S_a)\right] g(S)dS - \int_0^{S_a} \left[I(S) - I(S_a)\right] g(S)dS.
\end{aligned}
$$

The first and the fifth summand cancel out. The fourth and the sixth summand can be

[98] So is the deductible $I(S_a)$: F is unchanged, so S_a is unchanged, so $I(S_a)$ is unchanged.

combined such that

$$\begin{aligned} V_i^M &= \int_0^{S_a} [V^* - I(S_a)]\, g(S)\, dS + \int_{S_a}^{S_c} [V^* - I(S) + F - F]\, g(S) dS \\ &\quad + \int_{S_c}^{\overline{S}} [V^* + F - F]\, g(S) dS - \int_0^{S_a} [I(S) - I(S_a)]\, g(S) dS. \end{aligned}$$

From (4.3), using $V^* - I(S_a) = F$, we receive

$$\begin{aligned} V_i^M &= \int_0^{\overline{S}} F g(S) dS + \int_{S_a}^{S_c} [V^* - I(S) - F]\, g(S) dS + \int_{S_c}^{\overline{S}} [V^* - F]\, g(S) dS \\ &\quad - \int_0^{S_a} [I(S) - I(S_a)]\, g(S) dS. \end{aligned}$$

Compare this equation to (4.11). They are identical. Since (4.11) leads to (4.12), the firm value with fair insurance and bankruptcy costs is thus given by

$$V_i^M = V_i = V_u,$$

i.e., status quo. Fair insurance completely removes the underinvestment problem (an MM-type irrelevance of financing holds yet again in the presence of fair insurance). Insurance makes the liabilities risk-free. Debt value as of the first date is once again

$$D_i^M = D_i = \int_0^{\overline{S}} F g(S) dS,$$

cf. (4.9). Lastly, we have shareholder value. Stockholders are yet again entitled to a first-day dividend by the fact that debt becomes safe through insuring. From (4.9) and (4.35), the proceeds of the debt issue increase by

$$D_i - D_0^M = \int_0^{S_a} [L(S) - I(S)]\, g(S) dS + \int_0^{S_a} M g(S) dS + \int_0^{S_a} [I(S) - I(S_a)]\, g(S) dS.$$

From (4.37) and (4.8), this corresponds to $R_0^M + P_i$, i.e., areas WXCD and DCF in Figure 4.9.[99] Accounting for the cost of the insurance premium, we are left with a first-date dividend of $R_0^M + P_i - P_i$ (≥ 0) to shareholders, as proportional to the area WXCD, i.e., the original

[99] Alternatively, we have $D_i - D_0 = R_0 + P_i$ and $D_0 - D_0^M = \int_0^{S_a} M g(S) dS$. Since $R_0^M = R_0 + \int_0^{S_a} M g(S) dS$ by (4.37), this implies $D_i - D_0^M = R_0^M + P_i$.

dividend ABCD plus WXBA. Hence,

$$E_i^M = E_0 + R_0^M.$$

This is the mathematical justification that the firm will always take out fair insurance, for the dividend, which is received on top of the present value of the residual claim on second-date cash flows, is non-negative.

The crucial part, however, is that the increase in debt value and, hence, the dividend is now higher than in the case without bankruptcy costs (provided F is strictly greater than $V^* - I(0)$, and not equal to it), cf. (4.13). At the first date, the uninsured debt issue with bankruptcy costs raises D_0^M, which is less than the proceeds D_0 of the uninsured issue without these costs. Hence, shareholders have more to gain by removing the problem.

It is important to understand that this implies that bankruptcy costs have one fundamental implication for the model the way we have considered it so far: we stated in the case without bankruptcy costs that the funds raised by the uninsured issue must have been enough for whatever use they were intended for (e.g., to buy an asset). We also stated that debt may not be supported by cash. Therefore, the proceeds must have been *just* enough. With bankruptcy costs, the firm cannot afford the same activity as without, for it raises a smaller amount. We should keep this in mind when comparing the impact of insurance on the values as of the first date for the two scenarios. If we wanted the firm to finance the same project as before, we would have to increase the initial F, but this would be irreconcilable with the *cum* dividend interpretation.

Hence, we formally state that, in the presence of bankruptcy costs, the firm raises the money for a different purpose, but promises to pay back the same amount at the second date to debtholders. Luckily, the use of the debt issue proceeds is of no importance. This is why we never specified it (except that it may not be held as cash). What matters is that we have a firm levered with risky debt that promises the same F as before.

Thus, our research question is still as valid as before. We want to find out how the firm's decision to buy insurance varies with the level of risky debt in the presence of both a safety loading and bankruptcy costs. Since the fair insurance premium P_i is unaffected by the presence of bankruptcy costs, so is the loading premium λP_i, that constitutes the deadweight loss of insuring, cf. (4.16). Hence,

$$R_\lambda^M = R_\lambda = \lambda \int_0^{S_a} [I(S) - I(S_a)]\, g(S) dS.$$

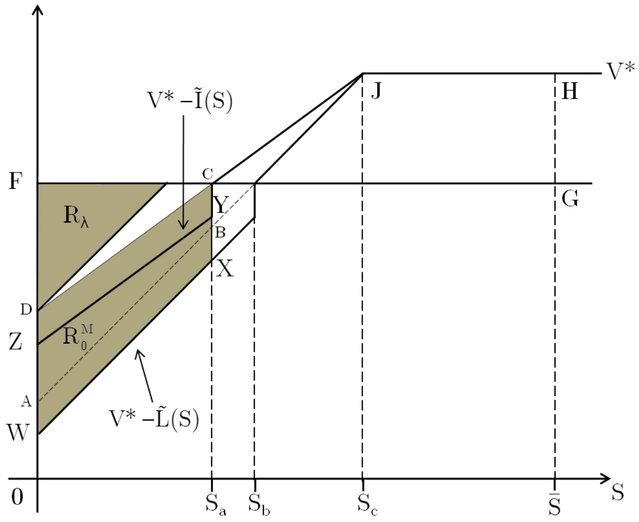

Figure 4.10: Deadweight Losses with Bankruptcy Costs

The loading once again diminishes the dividend paid out to shareholders. Similar to E_λ in (4.17), the value of their shares as of the first date becomes

$$E_\lambda^M = E_0 + R_0^M - R_\lambda$$

Methodically, the task is still to examine the tradeoff between the two deadweight losses, as depicted in Figure 4.10. The firm insures if, and only if, $R_0^M - R_\lambda \geq 0$.
It is easy to see where this leads to. As the deadweight loss of not insuring is even greater with bankruptcy costs, insurance should be more attractive for firms in the sense that they will demand it for even higher levels of risky debt compared to the case without bankruptcy costs. Remember that we focus on the linear-uniform special case. From (4.23) and (4.37), it follows that

$$\begin{aligned} R_0^M &= (\delta - \gamma) g \left[S_c S_a - \frac{S_a^2}{2} \right] + g \int_0^{S_a} M dS \\ &= (\delta - \gamma) g \left[S_c S_a - \frac{S_a^2}{2} \right] + g M S_a. \end{aligned} \tag{4.38}$$

One can see nicely that the deadweight loss of not insuring increases with the level of bankruptcy costs. The derivative is $\frac{dR_0^M}{dM} = gS_a$, which is strictly positive for levels of debt above $V^* - I(0) = V^* - \gamma S_c$.[100] Thus, the higher the bankruptcy costs, the higher the deadweight

[100] We said that the present value of the costs is represented by parallelogram WXBA in Figure 4.10. The two short sides (line segment BX and AW) are M in length. This can be redrawn as a rectangle with width M and length S_a that has the same area. Now, if the width is to increase marginally, then the increase in the area of the rectangle is proportional to length S_a.

loss of not insuring. Graphically, the tetragon representing R_0^M increases, making it harder for triangle DEF to "catch up" as F increases. Insuring becomes more attractive for higher levels of debt. The derivative also tells us that the increase is larger for higher S_a or, equivalently, for higher F: an S_a that is graphically situated further to the right implies that there are more underinvestment states for each of which bankruptcy costs are incurred, increasing the present value of these costs. Thus, leverage affects their present value even though we assume M to be fixed.

Combining (4.38) and (4.24) yields

$$\begin{aligned} R_0^M - R_\lambda &= (\delta-\gamma)\, g\left[S_c S_a - \frac{S_a^2}{2}\right] - \lambda\gamma g\frac{S_a^2}{2} + gMS_a \\ &= g\frac{S_a}{2}\left[(\delta-\gamma)(2S_c - S_a) - \lambda\gamma S_a\right] + gMS_a. \end{aligned}$$

The first summand is equal to (4.25) such that $R_0^M - R_\lambda = R_0 - R_\lambda + gMS_a$. We know that (4.25) leads to (4.26). Therefore, we skip the math and state that

$$\begin{aligned} R_0^M - R_\lambda &= \frac{g}{2}\left(S_c - \frac{V^*-F}{\gamma}\right)\left[(\delta-\gamma-\lambda\gamma)\,S_c + (\delta-\gamma+\lambda\gamma)\frac{V^*-F}{\gamma}\right] \\ &\quad + gM\left(S_c - \frac{V^*-F}{\gamma}\right) \\ &= \frac{g}{2}\left(S_c - \frac{V^*-F}{\gamma}\right)\left[(\delta-\gamma-\lambda\gamma)\,S_c + (\delta-\gamma+\lambda\gamma)\frac{V^*-F}{\gamma} + 2M\right] \end{aligned} \tag{4.39}$$

The first line of the equation above shows that the new function is the old $(R_0 - R_\lambda)$ plus a non-negative term. This facilitates determining the derivative of $R_0^M - R_\lambda$ with respect to F. We already know the derivative of $R_0 - R_\lambda$ from (4.27). So, all we need to do is determine the second summand in the equation's first line such that

$$\begin{aligned} \frac{d\left(R_0^M - R_\lambda\right)}{dF} &= \frac{g}{\gamma}\left[(\delta-\gamma+\lambda\gamma)\frac{V^*-F}{\gamma} - \lambda\gamma S_c\right] + \frac{g}{\gamma}M \\ &= \frac{g}{\gamma}\left[(\delta-\gamma+\lambda\gamma)\frac{V^*-F}{\gamma} - \lambda\gamma S_c + M\right]. \end{aligned} \tag{4.40}$$

For every level of risky debt other than $F = V^* - \gamma S_c$, the curve depicting $R_0^M - R_\lambda$ is now positioned at a higher level than to $R_0 - R_\lambda$ in Figure 4.8.

As in the case without bankruptcy costs, for the lowest level of risky debt, i.e., $F = V^* - \gamma S_c$ and, consequently, $S_a = 0$, equation (4.39) becomes zero. From (4.37) and (4.16), we have $R_0^M = R_\lambda = 0$ because the underinvestment problem just commences. Examining the derivative for that level of debt, we once again find that is positive $\left(\frac{g}{\gamma}\left[(\delta-\gamma)\,S_c\right] + \frac{g}{\gamma}M\right)$ —

and even more so (by the second summand) than before. In other words, $R_0^M - R_\lambda$ rises to positive levels from $F = V^* - \gamma S_c$ in a steeper way than $R_0 - R_\lambda$, so that $R_0^M > R_\lambda$, and the firm buys insurance for low enough levels of risky debt. $R_0^M - R_\lambda$ is a strictly concave function, too. This implies the existence of a unique maximum such that $R_0^M - R_\lambda$ crosses, if ever, the F-axis just once. To find this maximum, we have to determine that level of F for which the expression in square brackets in (4.40) becomes zero. The solution is $F = V^* - \frac{\lambda\gamma^2 S_c}{\delta-\gamma+\lambda\gamma} + \frac{\gamma M}{\delta-\gamma+\lambda\gamma}$. A comparison with (4.28) reveals that the first two summands constitute the value of F for which the function $R_0 - R_\lambda$ takes on its maximum in the case without bankruptcy costs. The last summand is positive ($\delta - \gamma > 0$), which implies that $R_0^M - R_\lambda$ does not stop to rise until a larger F is reached.

One question we now have to ask ourselves is whether the new extremum is still within the feasible interval of risky debt levels? The old value is greater than $V^* - \gamma S_c$. Since the new F for which the function takes on its maximum is larger, it must be greater than $V^* - \gamma S_c$, too. The upper boundary V^* is more interesting. The question is whether $V^* - \frac{\lambda\gamma^2 S_c}{\delta-\gamma+\lambda\gamma} + \frac{\gamma M}{\delta-\gamma+\lambda\gamma} < V^*$. The old value, i.e., the first two summands, are smaller than V^*, but we are now adding a positive term such that there is a critical value of M for which the inequality is not fulfilled any longer. Solving for M, we have $M < \lambda\gamma S_c$. If we want the new extremum to be within the interval, this is what we have to assume. We will do so for the remainder of this section, i.e., $M < \lambda\gamma S_c$.[101]

So far, one result is the same qualitatively: the firm takes insurance for F small enough (where "small enough" is not the same in the two scenarios, as we will see). Let us go on to examine whether F_M^* exists (within the interval of feasible debt levels), i.e., whether the firm switches from insuring to not insuring in the presence of bankruptcy costs. Following the same logic as before, we inspect $R_0^M - R_\lambda$ for $F = V^*$ and check whether it terminates in a positive or a negative value. For $F = V^*$, (4.39) becomes

$$\begin{aligned} R_0^M - R_\lambda &= \frac{g}{2} S_c \left[(\delta - \gamma - \lambda\gamma) S_c + 2M \right] \\ &= \frac{g}{2} S_c^2 (\delta - \gamma - \lambda\gamma) + gMS_c. \end{aligned}$$

Figure 4.11 provides a graphical representation of the new situation in the fashion of Figure 4.8. The first summand in the equation above is the old, i.e., the value of $R_0 - R_\lambda$ for $F = V^*$.

[101] If $M \geq \lambda\gamma S_c$ (which does not contradict $0 < \gamma < \delta \leq \frac{V^*-M}{S_c}$ as long as we assume V^* large enough in that $V^* > S_c(\delta + \lambda\gamma)$), then the curve representing function $R_0^M - R_\lambda$ would start to decline only after it passes $F = V^*$, which is an unfeasible debt level. But note that this would by no means make our research question obsolete. It would rather provide an answer in itself. In that case, the firm would always insure irrespective of the magnitudes of the risky debt and, respectively, the safety loading because the high deadweight loss of not insuring (induced by high costs of bankruptcy) would make insuring attractive per se.

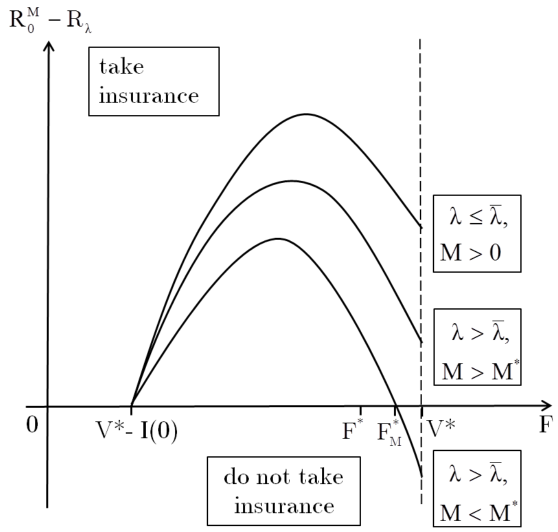

Figure 4.11: $R_0 - R_\lambda$ as a Function of F in the Presence of Bankruptcy Costs

It now increases by $gMS_c > 0$ for $R_0^M - R_\lambda$. That is,

$$R_0^M - R_{\lambda|_{F=V^*}} = R_0 - R_{\lambda|_{F=V^*}} + gMS_c.$$

Comparing the old and the new function value at $F = V^*$ tells us that the curve including bankruptcy costs always terminates in a higher value than its counterpart without these costs (irrespective of its mathematical sign). Whether this also precludes negative termination values still remains to be answered. Checking if the right-hand side of the previous equation is positive or negative comes down to

$$\underbrace{\frac{S_c}{2}}_{>0} \underbrace{(\delta - \gamma - \lambda\gamma)}_{\substack{\geq 0 \text{ for } \lambda \leq \bar{\lambda} \\ <0 \text{ for } \lambda > \bar{\lambda}}} + \underbrace{M}_{>0} \gtrless 0.$$

Obviously, the critical safety loading $\bar{\lambda} = \frac{\delta-\gamma}{\gamma}$ from (4.29), for which $R_0 = R_\lambda$ at $F = V^*$ in the case without bankruptcy costs, still makes the first summand zero. But not the entire term. $\lambda > \bar{\lambda}$ now is the necessary condition for the mathematical sign to be negative in the inequality above; but it is not sufficient. There are *three* possible scenarios, each of which corresponds to one of the curves depicted in Figure 4.11[102]. The scenarios are:

- $\lambda \leq \bar{\lambda}$: while the first summand in the inequality above is non-negative, the fact that

[102] Of course, we could compute a new critical value for the safety loading ($\bar{\lambda}^M = \frac{\delta-\gamma}{\gamma} + 2\frac{M}{\gamma S_c}$), but this would miss the point as it would only tell us that the critical value that makes $R_0^M - R_\lambda = 0$ for $F = V^*$ increases with M. We are interested in how the presence of bankruptcy costs changes the outcome relative to the case without these costs. That is why we keep considering $\bar{\lambda}$ — to be able to compute a critical level of M given $\bar{\lambda}$.

$M > 0$ makes the second summand and, thus, the entire term positive. This is the case where $R_0 - R_\lambda$ never becomes negative. $R_0^M - R_\lambda$ takes on even larger values, i.e., it is situated above the old curve for all levels of risky debt $F \in (V^* - \gamma S_c, V^*]$. The function terminates at a positive value and never crosses the F-axis. F_M^* does not exist within the interval of risky debt levels, just like F^* did not exist in the case without bankruptcy costs. This result is of the type of Mayers and Smith (1989). For low enough levels of the safety loading, the firm demands insurance for all levels of risky debt irrespective of the magnitude of the bankruptcy costs (as long as they are less than $\lambda\gamma S_c$ due to the assumption made above).

- $\lambda > \overline{\lambda}$ in conjunction with high enough costs of bankruptcy: even though the first summand turns out negative because of $\lambda > \overline{\lambda}$, the entire term may still be positive if M is large enough. The firm would decide not to insure at $F = V^*$ without bankruptcy costs (F^* exists), but in their presence it opts for insurance. $R_0^M - R_\lambda$ stays positive all along and does not pass through the F-axis in the interval. As for the critical level of bankruptcy costs for this to happen, we must solve $\frac{S_c}{2}(\delta - \gamma - \lambda\gamma) + M > 0$ for M, which yields $M > -\frac{S_c}{2}(\delta - \gamma - \lambda\gamma)$. Note that the right-hand side is positive as the expression in brackets is negative. We set $M^* = -\frac{S_c}{2}(\delta - \gamma - \lambda\gamma)$, *conditional* on $\lambda > \overline{\lambda}$ (otherwise we would have a contradiction to $M > 0$). This scenario relates to our statement that bankruptcy costs provide a greater incentive to insure. Under "normal" circumstances, the function would end up negative at $F = V^*$ such that the firm would switch to not insuring at F^*. Bankruptcy costs move the curve back into the first quadrant, and the firm always insures. Thus, what formerly kept the firm from insuring for high enough levels of debt ($F > F^*$) does not do so anymore now. Despite a high safety loading ($\lambda > \overline{\lambda}$), the firm will buy insurance regardless of its indebtedness if bankruptcy costs are high enough. The result is also of the Mayers and Smith (1989) type.

- $\lambda > \overline{\lambda}$ and $M < M^*$: this the case where the second summand is positive, but insufficiently so to compensate the negative value of the first. Therefore, the entire expression becomes negative. In other words, $R_0^M - R_\lambda < 0$ for $F = V^*$. This is the only constellation for which there exists a F_M^* ($< V^*$) such that the function crosses the F-axis. Graphically, the function ends in a higher, yet still negative value and is situated above its no-bankruptcy-cost equivalent for all $F \in (V^* - \gamma S_c, V^*]$. The firm switches from insuring to not insuring for $F_M^* < F \leq V^*$. The result is summarized in the following statement: what keeps the firm from demanding casualty insurance is the combination of high leverage, high safety loading *and* low costs of bankruptcy.

This outcome is still in such a manner that it is contrary to Schnabel and Roumi (1989). Given sufficiently high λ and sufficiently low M, the firm finds it optimal *not* to buy insurance for high levels of risky debt, as opposed to the authors' suggestion to seek coverage for high levels. Finally, coming back to our comment about the necessary versus sufficient condition, "low enough" bankruptcy costs, i.e., $M < M^*$, is the sufficient condition for $R_0^M - R_\lambda < 0$ at $F = V^*$.

Note that the function will end exactly at $R_0^M - R_\lambda = 0$ for $M = M^*$ (which implies $\lambda > \overline{\lambda}$). Without bankruptcy costs, $R_0 - R_\lambda$ is zero at $F = V^*$ for $\lambda = \overline{\lambda}$. Now, $R_0^M - R_\lambda$ is positive at $F = V^*$ for $\lambda = \overline{\lambda}$ because the costs of bankruptcy push the curve above the F-axis.

Mathematically, two tasks remain. First, we have to prove that, given $\lambda > \overline{\lambda}$, M^* is feasible. In case one should wonder why it should not be: We have to reconcile the assumption $M < \lambda\gamma S_c$ (that we established for the maximum of the function $R_0^M - R_\lambda$ to lie within the interval of risky debt levels) with $M > -\frac{S_c}{2}(\delta - \gamma - \lambda\gamma)$, i.e., $M > M^*$, since the second bullet point above is only valid for the latter inequality. We need to verify that

$$\lambda\gamma S_c > -\frac{S_c}{2}(\delta - \gamma - \lambda\gamma)$$

is a true statement such that M between the two is feasible. Simplifying leads to $\lambda\gamma > \gamma - \delta$. This is a true statement: the right-hand side is negative due to $\delta > \gamma$, while the left-hand side is positive.[103]

Second, we have not defined F_M^* so far. F_M^* is the debt level for which $R_0^M - R_\lambda$ becomes zero in the third bullet point above. The procedure is similar to the derivation of F^* in (4.30). From $R_0^M - R_\lambda$ in (4.39), the first factor becomes zero for $F = V^* - \gamma S_c$. We know this cannot be the F we are looking for. Therefore, the solution is once again the F which makes the second factor, i.e.,

$$(\delta - \gamma - \lambda\gamma) S_c + (\delta - \gamma + \lambda\gamma)\frac{V^* - F}{\gamma} + 2M,$$

[103] There is no problem for the third bullet point. $M^* < \lambda\gamma S_c$ implies that all bankruptcy costs for which $M < M^*$ are also less than $\lambda\gamma S_c$.

zero. Solving for F and using (4.30), we find F_M^* to be

$$\begin{aligned} F_M^* &= V^* + \gamma S_c \frac{\delta - \gamma - \lambda\gamma}{\delta - \gamma + \lambda\gamma} + \gamma \frac{2M}{\delta - \gamma + \lambda\gamma} \\ &= F^* + \gamma \frac{2M}{\delta - \gamma + \lambda\gamma}. \end{aligned} \tag{4.41}$$

Remember that $\delta - \gamma - \lambda\gamma$ in the numerator in the first line is negative as $\lambda > \overline{\lambda}$ in the case of the third bullet point. Let us conclude by showing that the value is within the interval $(V^* - \gamma S_c, V^*)$. The second summand in the second line in (4.41) is positive. Hence, $F_M^* > V^* - \gamma S_c$ as $F^* > V^* - \gamma S_c$. Concerning the upper boundary of the interval, we would like to show that

$$V^* + \gamma S_c \frac{\delta - \gamma - \lambda\gamma}{\delta - \gamma + \lambda\gamma} + \gamma \frac{2M}{\delta - \gamma + \lambda\gamma} < V^*.$$

The second summand is negative, while the third is positive. Dividing by $\frac{\gamma}{\delta - \gamma + \lambda\gamma}$ leaves us with $S_c (\delta - \gamma - \lambda\gamma) + 2M < 0$. Solving for M yields

$$M < -\frac{S_c}{2} (\delta - \gamma - \lambda\gamma).$$

The right-hand side should look familiar, for it is M^*, defined it in the second bullet point above. It follows that the inequality is fulfilled by assumption as we have $M < M^*$ in the third bullet point. This proves $F_M^* < V^*$.

Finally, note from (4.41) that F_M^* is strictly greater than F^*. This comes as no big surprise as we said that bankruptcy costs push the curves upwards graphically. Thus, if the former curve crossed the F-axis, and if the curve still crosses it (bullet point three) in the presence of bankruptcy costs, it does so at a higher level of risky debt.

This completes the examination of the impact of bankruptcy costs on the firm's decision to buy insurance. The innovation is that bankruptcy costs may lead a firm to insure for such (high) levels of debt for which it formerly decided not to seek insurance as the curve is pushed back up above the F-axis graphically. Insurance coverage is bought if the deadweight loss of insuring (R_λ) is less than that of not insuring (R_0^M). In sum, bankruptcy costs make the model outcome more complex. More parameters have to be dealt with, allowing for a broader range of possible results. Fair insurance will always be sought. In the presence of a positive safety loading, the firm generally demands insurance for sufficiently low levels of risky debt. If the safety loading is small enough, it even does so for all levels of risky debt. This outcome also arises when the safety loading is in fact above its (formerly) critical level, but large enough bankruptcy costs keep persuading the firm to buy insurance, for the loss in value would be greater if it did not do so. Insuring becomes unattractive if, and only if, bankruptcy costs are low enough while both the safety loading and the level of debt are sufficiently high. Bankruptcy costs do not constitute a sufficient deterrent to not insuring in this case.

4.11 The underinvestment problem with the financing condition

We come to cover the last big section in relation the underinvestment problem — and to this dissertation. We disregard costs of bankruptcy and return to the model as discussed before that. Garven and MacMinn (1993) do not consider the *cum* dividend interpretation of the underinvestment problem. As a matter of fact, they state that this approach to the problem is "... a somewhat artificial supplement to the Mayers and Smith model that confounds the dividend and financing decisions unnecessarily" (Garven and MacMinn, 1993, p. 640). The quote alludes to the circumstance that F is assumed fixed, which – with insurance – introduces a first-date cash flow to shareholders in the form of a dividend received on top of the residual claim on second-date payoffs. Their point is: why assume a fixed F in the first place? It is not economic (and, as we will show, not efficient once a safety loading is considered) to do so because, in the *cum* dividend case, the firm raises more money than it needs when it buys insurance. It also makes the interpretation somewhat cumbersome as one has to distinguish between first-date and second-date cash flows to shareholders. That is why the authors introduce a financing condition. In other words, they allow F to change along with the insurance/no-insurance decision.

The money (D_0) the firm raises in the uninsured case must be just enough for whatever it is intended for. It constitutes our benchmark in the sense that the firm still needs to have this money at its free disposal through the debt issue with a different promised repayment.[104] As insurance makes the debt safe, it generally allows a firm to promise a lower repayment at the second date for a given amount of money it needs to raise. Potential bondholders do not require compensation for the risk of default of the firm because there is no risk. Thus, what a rationally-acting firm will do in such a situation is to promise a repayment (less than the original F) that will allow it to raise the same amount that the uninsured issue raised *plus* enough to cover the insurance premium (with and without a safety loading, respectively) to make the debt safe. This is the financing condition. To ensure this promise

[104] This is also the reason why we consider the bankruptcy cost scenario only for the *cum* dividend interpretation. There, we care about F being fixed which imposes us to state that the firm needs the debt issue to finance a different activity than in the case without theses costs. Here, rather than fixing the repayment, we fix the amount of money the firm needs at its free disposal in order to finance the *same* activity as before.

is trustworthy, the firm incorporates the financing condition as a covenant into the bond's indenture, guaranteeing the purchase of the required level of insurance coverage (explained below) to make the debt free of risk. This should also tell us that we will need to consider two different debt levels in what follows. One is for the fair insurance premium ($\lambda = 0$). If, on the other hand, the insurance company charges a safety loading ($\lambda > 0$), the overall cost of the insurance package is raised, forcing the firm to raise more money on its part at the first date by promising a repayment to future bondholders that is higher than in the case without a safety loading (but still lower than the original F). We will label the former F'_0 and the latter simply F'. The corresponding boundary states are S'_{a0} and S'_a. We will be more concerned with F', for we will examine extensively the influence of changing debt levels on the decision to buy (unfair) insurance.[105]

This is how we proceed: first, we will show that the model has the same result in the sense that shareholders enjoy the same gains (just not in the form of a dividend) in the presence of a fair insurance premium. Furthermore, the underinvestment problem is removed entirely. Under this scenario, we will work with F'_0. After that, we will introduce a safety loading once again. The innovation we provide is that we show that our conclusion from the *cum* dividend model also holds for the most part under the financing condition. Admittedly, Garven and MacMinn's (1993) main focus is not on the safety loading, they merely sketch its implications in their paper. They do not go into depth in this regard. We try to close this gap. However, they do note one important thing. Once $\lambda > 0$ is considered, the "...financing-constrained model has different net value implications than a *cum* dividend interpretation of Schnabel and Roumi" (Garven and MacMinn, 1993, p. 644). More precisely, the net present value of the shareholders' claim is higher. Because the financing condition allows for an $F' < F$, it directly affects the deadweight loss that comes with insuring. Since this loss is proportional (by the factor λ) to the fair insurance premium (which in turn increases with the promised repayment), a lower F' causes a lower deadweight loss than in the *cum* dividend interpretation. Because of this, shareholders have an incentive to minimize the promised repayment rather than leaving it fixed. They gain by doing so. The deadweight loss comes out of their pockets. Therefore, shareholders themselves would prefer this interpretation of the model.

We focus on the linear-uniform special case once again. For now, this allows us to compare the areas in the graphs, while still keeping the formulas rather general. Once we get involved

[105] Some of the new insights presented below were contained in an earlier version of Arnold and Hartl (2011). They are not presented in the published version of the paper.

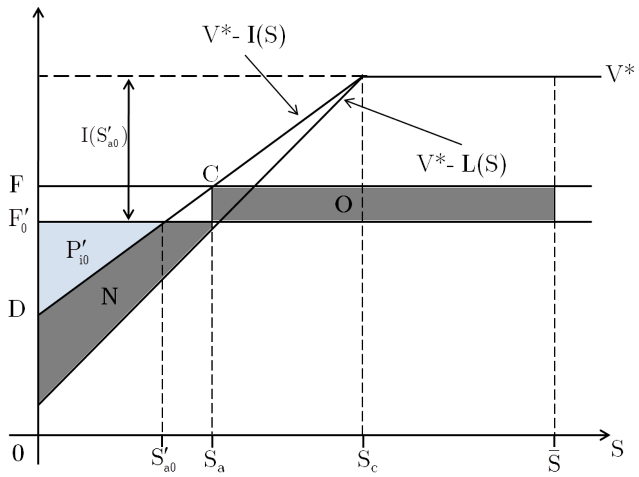

Figure 4.12: Financing Condition

with the mathematics later on, it will facilitate derivations, too. Have a look at Figure 4.12 to begin with. It sketches the new situation with fair insurance coverage, as considered by Garven and MacMinn (1993).

Fair insurance makes risky debt safe such that the firm can promise to repay F_0' ($< F$). This results in a boundary state S_{a_0}' that is further to the left in the figure. The state is implicitly defined by the equation $V^* - I\left(S_{a_0}'\right) = F_0'$. One can easily see that the maximum deductible consistent with solving the (new) underinvestment problem, $I(S_{a_0}')$, is greater than before $\left(I\left(S_a\right)\right)$ because the debt level has become lower. In other words, the minimum coverage needed is less than before. The exact amount of promised repayment necessary is implicitly defined by the (fair) *financing condition*

$$D_{i_0}' = D_0 + P_{i_0}'. \tag{4.42}$$

The condition states that the repayment promised in the insured debt issue, F_0', has to be selected such that its proceeds D_{i_0}' are just enough to raise the same amount D_0 that the uninsured issue raised plus enough to cover the expenditures for the actuarially fair insurance premium P_{i_0}' in order to make the debt safe. Since the insured debt is risk-free, we have

$$D_{i_0}' = \int_0^{\overline{S}} F_0' g(S) dS. \tag{4.43}$$

P_{i_0}' is the fair insurance premium provided we have F_0' as the second-date repayment to bondholders. Lowering the debt level from F to F_0' implies that there are fewer underinvestment states ($S_{a_0}' < S_a$). Therefore, the minimum fair insurance premium required to make the debt safe (and to be able to promise F_0' in the first place) is less than the fair premium P_i that we had before, i.e.,

$$P_{i_0}' = \int_0^{S_{a_0}'} \left[I(S) - I(S_{a_0}')\right] g(S)dS. \tag{4.44}$$

P_{i_0}' as the (risk adjusted) present value of the insurance payoff is proportional to the lightly shaded triangle in Figure 4.12. It is obviously smaller than triangle DCF, which represents P_i. As we know from the prior analysis, fair insurance completely removes the underinvestment problem. We want to find out, however, whether doing so under the financing condition has the same implications for shareholder value and, thus, for the decision to acquire insurance coverage. In other words, we want to prove that shareholders under this interpretation of the model gain the same R_0 in the presence of fair insurance as before. Let us start by rewriting the financing condition in (4.42). Breaking up the integral in D_{i_0}' in (4.43) and plugging in the other values using (4.4) and (4.44), we get

$$\begin{aligned} \int_0^{S_a} F_0' g(S)dS + \int_{S_a}^{\overline{S}} F_0' g(S)dS &= \int_0^{S_a} \left[V^* - L(S)\right] g(S)dS + \int_{S_a}^{\overline{S}} F g(s)dS \\ &\quad + \int_0^{S_{a_0}'} \left[I(S) - I(S_{a_0}')\right] g(S)dS. \end{aligned}$$

This equation can be simplified:

$$\begin{aligned} \int_{S_a}^{\overline{S}} \left(F - F_0'\right) g(S)dS &= \int_0^{S_{a_0}'} F_0' g(S)dS + \int_{S_{a_0}'}^{S_a} F_0' g(S)dS - \int_0^{S_a} \left[V^* - L(S)\right] g(S)dS \\ &\quad - \int_0^{S_{a_0}'} \left[I(S) - I(S_{a_0}')\right] g(S)dS. \end{aligned}$$

Using the equation that implicitly defines S_{a_0}', substitute F_0' in the first summand with $V^* - I\left(S_{a_0}'\right)$ or, equivalently, $V^* - I\left(S\right) + \left[I\left(S\right) - I(S_{a_0}')\right]$ and combine the first and the fourth summand on the right-hand side:

$$\int_{S_a}^{\overline{S}} \left(F - F_0'\right) g(S)dS = \int_0^{S_{a_0}'} \left[V^* - I\left(S\right)\right] g(S)dS + \int_{S_{a_0}'}^{S_a} F_0' g(S)dS - \int_0^{S_a} \left[V^* - L(S)\right] g(S)dS.$$

There is a clever way to merge the first two summands in the equation above. Have a look at Figure 4.12 again. We have $F_0' > V^* - I\left(S\right)$ in all underinvestment states $S \in [0, S_{a_0}')$, and $F_0' \leq V^* - I\left(S\right)$ in all remaining loss states $S \in [S_{a_0}', S_c]$. Note that the right-hand side of the two inequalities just stated appears in the first summand in the equation above, while the left-hand side is contained in the second. We can combine these two summands into one by stating them as $\int_0^{S_a} [\min \{V^* - I(S), F_0'\}] g(S)dS$. From the graph, the smaller term is $V^* - I(S)$ for the underinvestment states $S < S_{a_0}'$, while this assertion applies to F_0' for the states remaining until S_a is reached (as we move up the states). Now, both the new integral and the integral in the third summand in the equation above run from 0 to S_a. Combining them, the financing condition (4.42) is finally restated as

$$\int_{S_a}^{\overline{S}} \left(F - F_0'\right) g(S)dS = \int_0^{S_a} \left[\min \left\{V^* - I(S), F_0'\right\} - [V^* - L(S)]\right] g(S)dS. \tag{4.45}$$

Both sides of this equation have a graphical representation as areas in Figure 4.12. The right-hand side is proportional to the heavily shaded pentagon denoted by N. The left-hand side is represented by the heavily shaded rectangle labeled O. The financing condition states that areas N and O are equal. Why? Area O is defined over states S_a to $\overline{S}$, i.e., the states for which there is no underinvestment problem under the *cum* dividend interpretation (so that bondholders are paid back in full). The width of the rectangle is $F - F_0'$, which is the amount by which the promised repayment is less than before. Therefore, area O can be interpreted as the loss suffered by bondholders due to the fact that F is not assumed fixed anymore, but lowered to F_0' because it is chosen to raise just enough to cover what the uninsured issue covered plus the insurance premium. Area N represents the gain to debtholders from being promised a safe F_0' in repayment. In the uninsured case in the *cum* dividend interpretation, there is no investment to reconstitute damaged assets in states $S < S_a$, and the firm's payoff is $V^* - L(S)$ in these states. In the presence of the financing condition, debt becomes safe by lowering the promised repayment through purchasing insurance such that the firm is able to repay F_0' to its bondholders in all states; this includes $S < S_a$, where bondholders now also receive F_0' (as opposed to $V^* - L(S)$). That is, bondholders are better off. Because the firm now invests in every state (including $S < S_a$), the gain in value is proportional to the areas denoted by N and P_{i_0}'. But this cannot be the gain of bondholders entirely.[106] We know that the insurance company has to be paid off, so that we must subtract P_{i_0}'. We are left with area N as the net gain in debtholder value caused by lowering the face value of debt from a risky F to a safe F_0'.

That said, equation (4.45) simply states that the first-date value of debtholders' claims is left

[106] A word of caution. Do not get confused at this point with the cum dividend interpretation. Its downside is that we have to assume that the increase in value is distributed to shareholders via dividends. This forces us to make a distinction between first-date and second-date payoffs to shareholders. There is no such distinction with the financing condition. Neither N nor P_{i_0}' goes to shareholders. The increase in equity value is expressed through a higher present value of shareholders' residual claim caused by lowering the promised repayment to F_0'. There is no first-date component to shareholder value. Graphically, the area between the line specifying the firm's payoff (starting from state S_{a_0}', first $V^* - I(S)$ and then V^* from state S_c on) and the horizontal line indicating the promised repayment has become larger.

unchanged in the presence of a financing condition because their loss (O) equals their gain (N). Think about it this way: the new debt issue raises the same amount of disposable funds as the old issue, while face value is lower. Thus, debtholders are no worse off. They lose just as much as they gain by being promised a sure F_0' instead of a risky F. Therefore, they do not mind the new structure of the debt contract, but will accept the bond indenture that specifies the new level of debt and guarantees the purchase of insurance. The advantage of accepting the new debt structure is that the financing condition does not change debtholders' value position, while both raising P_{i_0}' more in funds than the uninsured issue and guaranteeing reconstitution in every state of the world at the same time, so that the underinvestment problem is solved.

We have shown that debtholders are no worse off than before. The crucial point for the decision to invest, however, is whether the same holds true for shareholders' gains that come with insuring. Managers will only decide to invest if shareholder value is not lowered by doing so. To answer the question whether the increase in equity value through insuring is the same R_0 as in the *cum* dividend interpretation, let us start by writing out the shareholder value in the presence of the financing condition:

$$E_{i_0}' = \int_{S_{a_0}'}^{S_c} \left[V^* - I(S) - F_0'\right] g(S)dS + \int_{S_c}^{\overline{S}} \left(V^* - F_0'\right) g(S)dS. \tag{4.46}$$

There is no more first-date component to shareholder value. It is determined exclusively as the present value of the second-date residual claim, which now is larger than in the case without a financing condition because the promised repayment to debtholders is lower. From the equation, shareholder value as of the first date is greater for two reasons. First, we now deduct a lower face value of debt in the two integrals. Second, the first integral now starts at $S_{a_0}' < S_a$, meaning that there are more states in which shareholders are entitled to a second-date residual claim. To compute the increase in value through insuring and, thus, solving the underinvestment problem, we need to compare shareholder value under the fair financing condition to that of risky uninsured debt in the firm's capital structure. In short, we have to compute $E_{i_0}' - E_0$. Using (4.46) and (4.5), we start off with

$$\begin{aligned} E_{i_0}' - E_0 \quad = \quad & \int_{S_{a_0}'}^{S_c} \left[V^* - I(S) - F_0'\right] g(S)dS + \int_{S_c}^{\overline{S}} \left(V^* - F_0'\right) g(S)dS \\ & - \int_{S_a}^{S_c} \left[V^* - I(S) - F\right] g(S)dS - \int_{S_c}^{\overline{S}} \left(V^* - F\right) g(S)dS. \end{aligned}$$

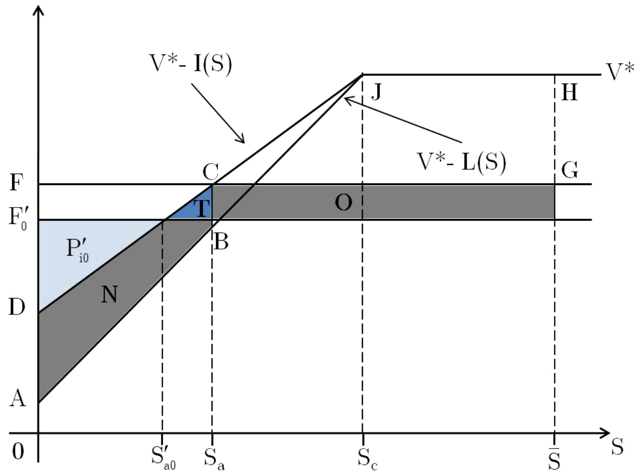

Figure 4.13: Gain in Shareholder Value

We can perform several modifications to simplify the equation above:

$$
\begin{aligned}
E'_{i_0} - E_0 &= \int_{S'_{a_0}}^{S_a} \left[V^* - I(S) - F'_0\right] g(S)dS + \int_{S_c}^{\overline{S}} \left[\left(V^* - F'_0\right) - \left(V^* - F\right)\right] g(S)dS \\
&\quad + \int_{S_a}^{S_c} \left[\left(V^* - I(S) - F'_0\right) - \left(V^* - I(S) - F\right)\right] g(S)dS \\
&= \int_{S'_{a_0}}^{S_a} \left[V^* - I(S) - F'_0\right] g(S)dS + \int_{S_a}^{\overline{S}} \left(F - F'_0\right) g(S)dS.
\end{aligned}
$$

The last summand, $\int_{S_a}^{\overline{S}} \left(F - F'_0\right) g(S)dS$, also appears in the fair financing condition (4.45), and we know that its graphical representation is the heavily shaded area O in Figure 4.12. Therefore, let us substitute the last summand with the right-hand side from (4.45) to get

$$
E'_{i_0} - E_0 = \int_{S'_{a_0}}^{S_a} \left[V^* - I(S) - F'_0\right] g(S)dS + \int_0^{S_a} \left[\min\left\{V^* - I\left(S\right), F'_0\right\} - \left[V^* - L(S)\right]\right] g(S)dS. \tag{4.47}
$$

The new term just substituted is proportional to area N. The first summand is represented by the newly shaded area denoted by T in Figure 4.13. The figure also contains the original capital letters we utilized to label the areas in the *cum* dividend interpretation for reasons of better comparison.

The increase in shareholder value that comes with insuring is thus represented graphically by areas N and T in the case of the financing condition. From Figure 4.13, however, these two areas should appear familiar to us. N plus T is exactly the tetragon ABCD, which represents the deadweight loss in firm value (R_0, cf. (4.7)) associated with the underinvestment problem in the *cum* dividend interpretation. Therefore, at this point we can conclude from the graphical inspection that the answer to the question posed whether shareholders gain the same amount under the financing condition is "yes". A closer look at Figure 4.13 also explains why. The new underinvestment boundary state is S'_{a_0}. Shareholders are entitled to a second-date residual claim only in higher states. The present value of these second-date gains is now higher than in the *cum* dividend interpretation as $S'_{a_0} < S_a$. One can verify from the figure that the rise in shareholder value under the financing condition (relative to not having insurance coverage) is proportional to areas T and O. The respective gain in the *cum* dividend case (R_0) is proportional to ABCD, which we now know to be N plus T. Finally, we understand from (4.45) that area N is of the same size as O. Thus, it is a true statement that N and T are equal to T and O. The gain in shareholder value is irrespective of the mode of interpretation.

Mathematically, $V^* - I\left(S'_{a_0}\right) = F'_0$ and the fact that $I(S)$ is strictly decreasing imply that $V^* - I(S) \leq F'_0$ for $0 \leq S \leq S'_{a_0}$ and that $V^* - I(S) > F'_0$ for $S'_{a_0} < S \leq S_c$. Therefore, restate the second integral containing the min operator in equation (4.47) above such that

$$\begin{aligned} E'_{i_0} - E_0 &= \int_{S'_{a_0}}^{S_a} \left[V^* - I(S) - F'_0\right] g(S)dS + \int_0^{S'_{a_0}} \{[V^* - I(S)] - [V^* - L(S)]\} g(S)dS \\ &\quad + \int_{S'_{a_0}}^{S_a} \left\{F'_0 - [V^* - L(S)]\right\} g(S)dS \\ &= \int_0^{S_a} [L(S) - I(S)]\, g(S)dS. \end{aligned}$$

Compare (4.7) to verify that the last equality is the deadweight loss of not insuring, i.e.,

$$E'_{i_0} - E_0 = R_0. \tag{4.48}$$

This proves that the gain to shareholders in the presence of actuarially fair insurance is the same regardless of whether we use the *cum* dividend interpretation or the financing condition setup; the agency cost of the underinvestment problem R_0 is the gain to shareholders that comes with buying fair insurance. In the former interpretation, shareholders receive it as a dividend at the first date. In the latter, shareholders receive it via a higher second-date residual claim. As long as the insurance premium is actuarially fair, either interpretation's value implications are the same for shareholders.

Before we go on to examine the value implications of an unfair insurance, there is one further point worth noting. In Figures 4.12 and 4.13, F'_0 intersects the line $V^* - L(S)$ at a state that is higher than S_a. But there may be a second case, as noted (but not displayed) by

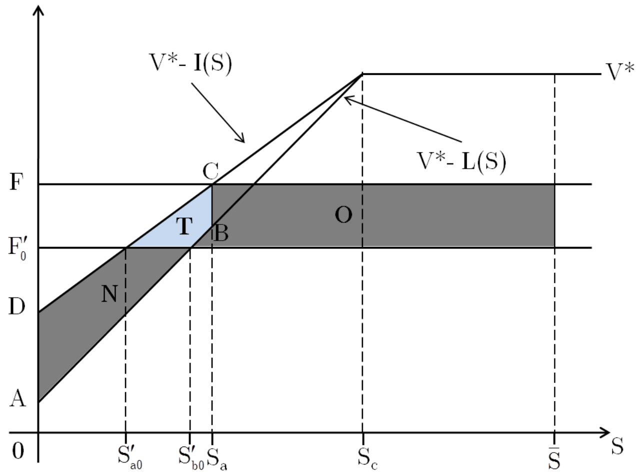

Figure 4.14: Financing Condition – Second Case

Garven and MacMinn (1993, p. 642, fn. 6). Depending on the parameters, one cannot rule out the possibility that buying insurance under the financing condition lowers the promised repayment to the point that that F_0' passes through $V^* - L(S)$ at a state equal to or lower than S_a. We will not go into detail here. The derivation is very similar and conclusions are the same ($E_{i_0}' - E_0 = R_0$). We merely provide a graphical representation in Figure 4.14. Note that we need to characterize a new state S_{b_0}' in this case, defined by $V^* - L(S_{b_0}') = F_0'$. The figure is drawn such that $S_{b_0}' < S_a$. The difference to the former two figures is that area O now is not a rectangle, but a pentagon. One can verify that the equivalent to the financing condition in (4.45) is

$$\begin{aligned}\int_0^{S_{b_0}'} \left[\min\left\{V^* - I\left(S\right), F_0'\right\} - \left[V^* - L(S)\right]\right] g(S)dS \quad &= \quad \int_{S_{b_0}'}^{S_a} \left[V^* - L\left(S\right) - F_0'\right] g(S)dS \\ &\quad + \int_{S_a}^{\overline{S}} \left(F - F_0'\right) g(S)dS,\end{aligned}$$

which states that areas N (left-hand side) and O (right-hand side) in Figure 4.14 are equal in size. Furthermore, the equivalent to (4.47), which makes use of the equation above, can be expressed as

$$\begin{aligned}E_{i_0}' - E_0 \quad &= \quad \int_{S_{a_0}'}^{S_a} \left[V^* - I(S) - \max\left\{V^* - L(S), F_0'\right\}\right] g(S)dS \\ &\quad + \int_0^{S_{b_0}'} \left[\min\left\{V^* - I\left(S\right), F_0'\right\} - \left[V^* - L(S)\right]\right] g(S)dS.\end{aligned}$$

The first summand is represented by the lightly shaded area T and the second by area N in

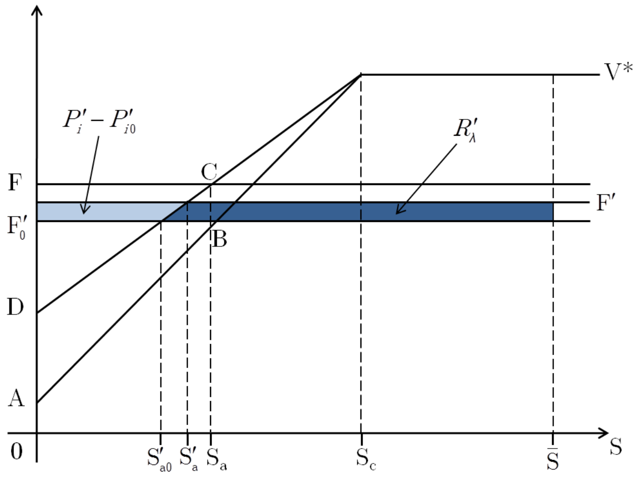

Figure 4.15: Loading Premium

Figure 4.14. The result in this setup is identical. The gain in shareholder value is proportional to N plus T, which equals ABCD (i.e., R_0). For the model conclusions it is irrelevant whether we have $S'_{b0} \leq S_a$ or $S'_{b0} > S_a$.

4.11.1 Safety loading

Before getting involved with the mathematics, the case should be clear from the start — at least graphically. If insurance companies want a piece of the pie by demanding a safety loading, they take it from shareholders. After all, they are the ones who enjoy the gains that come with insuring and, therefore, they also have to cover the costs accompanying it. Incorporating a positive loading makes the insurance premium more expensive. Since the financing condition is chosen such that the bond issue raises all that the uninsured issue raised plus enough to pay for the insurance premium, the firm obviously has to raise more money now in order to pay for the increased premium that makes the debt safe. Consequently, it does so by guaranteeing a higher second-date repayment than F_0' (which is still less than F). The firm now issues debt with a face value of F'. Compared to the financing condition figures above, the horizontal line indicating the promised repayment to bondholders must now be located above line F_0'. In other words, areas T and O in Figure 4.13, which constitute the gain in shareholder value given fair insurance, are diminished. The heavily shaded area in Figure 4.15 represents the profit to insurance companies which comes out of shareholders' pockets.

If we are correct in our assessment, then this area should reflect the equity value lost because it is transferred to insurance companies. Since the value lost by shareholders *is* the loading premium, we expect the heavily shaded area to be λ times the fair insurance premium prevailing at debt level F'. Thus, we expect that area to be the deadweight loss of insuring, i.e., the equivalent to R_λ. But since the promised repayment under the financing condition changes, so does the deadweight loss. Therefore, we will denote it by R'_λ. Assuming our conjecture is correct, we have the same gain R_0 to shareholders, but a different deadweight loss of insuring (R'_λ). This is what is meant by "different net value implications" in the quote above. Another implication is that the loading premium is no longer portrayed as a part of the triangle representing the fair insurance premium, like in the *cum* dividend case,[107] but directly as (the heavily shaded) part of the increase in shareholder value given fair insurance coverage, i.e., areas T and O in Figure 4.13. This graphical analysis leads to the conclusion that – since managers will only decide to invest if it is beneficial to the company's owners – the firm will opt for reconstitution as long as the heavily shaded area in Figure 4.15 is less than or equal to areas T and O (see Figure 4.13), i.e., as long as $R'_\lambda \leq R_0$.

Let us proceed by mathematically proving the statements just made on the basis of the figures. First, we have to address the issue of increasing the promised repayment due to the inclusion of a safety loading by adjusting the financing condition in (4.42) such that

$$\begin{aligned} D'_\lambda &= D_0 + P'_\lambda \\ &= D_0 + (1+\lambda)\, P'_i. \end{aligned} \tag{4.49}$$

The difference to the case without a loading is that the firm needs to raise $D'_\lambda > D'_{i_0}$ because it now has to finance the unfair insurance premium. In order to do so, the firm has to promise $F' > F'_0$ in repayment due at the second date. The loading premium is – as before – λ times the fair premium *at* the relevant debt level. Here, we have F' such that the loading premium is $\lambda P'_i$, where

$$P'_i = \int_0^{S'_a} \left[I(S) - I(S'_a)\right] g(S) dS. \tag{4.50}$$

and $S'_a \left(> S'_{a_0}\right)$ is implicitly defined by $V^* - I\left(S'_a\right) = F'$, following the same logic as for S_a and S'_{a_0}. Given P'_i, we can now formally define R'_λ, the deadweight loss of insuring under the financing condition, which we know to be $\lambda P'_i$:

$$R'_\lambda = \lambda \int_0^{S'_a} \left[I(S) - I(S'_a)\right] g(S) dS.$$

[107] There, we had triangle DEF as the loading premium within triangle DCF as the fair insurance premium. Compare, e.g., Figure 4.5. Of course, we could still illustrate the loading premium in that manner, but then we would not have the nice direct comparison of the deadweight loss R'_λ as a part of shareholders' gain R_0 in the figures.

Comparing this equation to the original R_λ defined in (4.16), it is apparent that one merely needs to replace S_a with S'_a in the equation to obtain R'_λ.
The unfair insurance purchased makes the debt safe such that

$$D'_\lambda = \int_0^{\overline{S}} F' g(S) dS. \tag{4.51}$$

Since $F' > F'_0$, the insurance contract's deductible $I(S'_a)$ is lower relative to $I\left(S'_{a_0}\right)$ of the fair insurance premium or, equivalently, the minimum coverage to solve the underinvestment problem is higher in the presence of a safety loading. Obviously, the difference in debt values for unfair and fair insurance is $D'_\lambda - D'_{i_0} = \int_0^{\overline{S}} \left(F' - F'_0\right) g(S) dS$, and its graphical representation is the sum of the lightly and heavily shaded area in Figure 4.15. From the financing conditions (4.42) and (4.49), we can express the increase in debt value as $D'_\lambda - D'_{i_0} = P'_i + \lambda P'_i - P'_{i_0}$. $P'_i - P'_{i_0}$ is the increase in the *fair* insurance premium induced by the need to promise a higher repayment and corresponds to the lightly shaded area: beginning with $P'_i - P'_{i_0} = \int_0^{S'_a} \left[I(S) - I(S'_a)\right] g(S) dS - \int_0^{S'_{a_0}} \left[I(S) - I(S'_{a_0})\right] g(S) dS$ from (4.50) and (4.44), one first has to split up the integral in (4.50) into two, one running from 0 to S'_{a_0} and the other from S'_{a_0} to S'_a. Then we merge the former with (4.44) and, finally, substitute the formulas implicitly defining states S'_{a_0} and S'_a (i.e., $V^* - I\left(S'_{a_0}\right) = F'_0$ and $V^* - I\left(S'_a\right) = F'$) to receive $P'_i - P'_{i_0} = \int_0^{S'_{a_0}} \left(F' - F'_0\right) g(S) dS + \int_{S'_{a_0}}^{S'_a} \left\{F' - \left[V^* - I(S)\right]\right\} g(S) dS$. A comparison with Figure 4.15 reveals that the right-hand side indeed corresponds to the lightly shaded area. It is implied by $D'_\lambda - D'_{i_0} = P'_i + \lambda P'_i - P'_{i_0}$ that the heavily shaded area in fact represents $\lambda P'_i$, i.e., the deadweight loss of insuring R'_λ — our conjecture from the graphical analysis above holds true.

We also stated before that the gain in shareholder value given a fair insurance premium shrinks by the heavily shaded area (i.e., the very area we just identified as R'_λ) once we start to consider a safety loading. Thus, shareholder value given $\lambda > 0$ (E'_λ) should be lower than E'_{i_0} by the deadweight loss R'_λ. We now prove this claim, i.e., $E'_{i_0} - E'_\lambda = R'_\lambda$, formally.
The owners of the firm are entitled to a residual claim worth $E'_\lambda = \int_{S'_a}^{S_c} \left[V^* - I(S) - F'\right] g(S) dS + \int_{S_c}^{\overline{S}} \left(V^* - F'\right) g(S) dS$. It follows from (4.46) that

$$\begin{aligned} E'_{i_0} - E'_\lambda &= \int_{S'_{a_0}}^{S_c} \left[V^* - I(S) - F'_0\right] g(S) dS + \int_{S_c}^{\overline{S}} \left(V^* - F'_0\right) g(S) dS \\ &\quad - \int_{S'_a}^{S_c} \left[V^* - I(S) - F'\right] g(S) dS - \int_{S_c}^{\overline{S}} \left(V^* - F'\right) g(S) dS, \end{aligned}$$

which can be simplified to

$$\begin{aligned} E'_{i_0} - E'_\lambda &= \int_{S'_{a_0}}^{S'_a} \left[V^* - I(S) - F'_0\right] g(S)dS + \int_{S'_a}^{S_c} \left(F' - F'_0\right) g(S)dS + \int_{S_c}^{\overline{S}} \left(F' - F'_0\right) g(S)dS \\ &= \int_{S'_{a_0}}^{S'_a} \left[V^* - I(S) - F'_0\right] g(S)dS + \int_{S'_a}^{\overline{S}} \left(F' - F'_0\right) g(S)dS. \end{aligned}$$

Substituting the fair financing condition $D_0 = D'_{i_0} - P'_{i_0}$ from (4.42) into its unfair counterpart (4.49) yields $D'_\lambda = D'_{i_0} - P'_{i_0} + (1+\lambda) P'_i$ or, equivalently, $\int_0^{\overline{S}} F'g(S)dS = \int_0^{\overline{S}} F'_0 g(S)dS - P'_{i_0} + (1+\lambda) P'_i$ with the help of (4.43) and (4.51). This in turn may be expressed as $\int_0^{\overline{S}} (F' - F'_0) g(S)dS = (1+\lambda) P'_i - P'_{i_0}$, which is identical to $\int_{S'_a}^{\overline{S}} (F' - F'_0) g(S)dS = (1+\lambda) P'_i - P'_{i_0} - \int_0^{S'_a} (F' - F'_0) g(S)dS$. Additionally, by use of the equations specifying the boundary states under the financing conditions, i.e., $V^* - I(S'_a) = F'$ and $V^* - I\left(S'_{a_0}\right) = F'_0$, restate $F' - F'_0$ as $I\left(S'_{a_0}\right) - I(S'_a)$ in the last summand on the right-hand side of the equation just established. Plugging this back into $E'_{i_0} - E'_\lambda$, we have

$$\begin{aligned} E'_{i_0} - E'_\lambda &= \int_{S'_{a_0}}^{S'_a} \left[V^* - I\left(S'_{a_0}\right) - F'_0 + I\left(S'_{a_0}\right) - I(S)\right] g(S)dS + (1+\lambda) P'_i - P'_{i_0} \\ &\quad - \int_0^{S'_a} \left[I\left(S'_{a_0}\right) - I\left(S'_a\right)\right] g(S)dS. \end{aligned}$$

Since we added $I\left(S'_{a_0}\right) - I\left(S'_{a_0}\right)$ in the first integral, $V^* - I\left(S'_{a_0}\right) - F'_0$ cancels out. Further modifications yield

$$\begin{aligned} E'_{i_0} - E'_\lambda &= \int_{S'_{a_0}}^{S'_a} \left[I\left(S'_{a_0}\right) - I(S)\right] g(S)dS + (1+\lambda) P'_i - P'_{i_0} \\ &\quad - \int_0^{S'_{a_0}} \left[I\left(S'_{a_0}\right) - I\left(S'_a\right)\right] g(S)dS - \int_{S'_{a_0}}^{S'_a} \left[I\left(S'_{a_0}\right) - I\left(S'_a\right)\right] g(S)dS \\ &= \int_{S'_{a_0}}^{S'_a} \left[I\left(S'_a\right) - I(S)\right] g(S)dS + (1+\lambda) P'_i - P'_{i_0} \\ &\quad + \int_0^{S'_{a_0}} \left[I(S) - I\left(S'_{a_0}\right)\right] g(S)dS - \int_0^{S'_{a_0}} \left[I(S) - I\left(S'_a\right)\right] g(S)dS. \end{aligned}$$

The first and the last integral merge to $-\int_0^{S'_a} \left[I(S) - I\left(S'_a\right)\right] g(S)dS$, which is equal to $-P'_i$ by (4.50). From (4.44), at last we are left with $E'_{i_0} - E'_\lambda = -P'_i + (1+\lambda) P'_i - P'_{i_0} + P'_{i_0}$ and, thus,

$$E'_{i_0} - E'_\lambda = \lambda P'_i. \tag{4.52}$$

This completes the proof. Graphically, shareholders will decide to invest as long as the heavily shaded area in Figure 4.15 is smaller than or equally large as areas T and O in Figure

4.13. Mathematically, we can easily infer $E'_{\lambda} - E_0$ from (4.48) and (4.52). It follows that $E'_{\lambda} - E_0 = \left(E'_{i_0} - E_0\right) - \left(E'_{i_0} - E'_{\lambda}\right) = R_0 - \lambda P'_i$. Because $R'_{\lambda} = \lambda P'_i$, it follows that

$$E'_{\lambda} - E_0 = R_0 - R'_{\lambda}.$$

As long as the gain through insuring is greater than the loss associated with insuring, the firm will opt for coverage. This is qualitatively the same result as in the *cum* dividend interpretation, but value implications are somewhat different because $R'_{\lambda} < R_{\lambda}$ as long as $F' < F$. Shareholders are better off under the financing condition because debtholders are promised a lower repayment, and the deadweight loss of insuring is proportional to the fair insurance premium (which increases with the level of debt). Hence, a smaller deadweight loss is subtracted from the value gains that come with insuring. Economically, it makes more sense to use the financing condition interpretation of the model.

4.11.2 Changing debt levels and the decision to insure

After having explained the model as reconsidered by Garven and MacMinn (1993), we now show that our main result derived above also holds under the financing condition. We focus on the linear-uniform special case and show that – having the same $\overline{\lambda} = \frac{\delta - \gamma}{\gamma}$ and F^*, cf. equation (4.30), as in the *cum* dividend case – *for $\lambda \leq \overline{\lambda}$, it is optimal to buy insurance, while for $\lambda > \overline{\lambda}$, the firm takes out insurance if, and only if, $F \leq F^*$. Only for large enough debt values, $F > F^*$, the firm decides not to insure.*

A simplifying assumption we make is that the upper bound of the support of S is unity ($\overline{S} = 1$), so that state prices are uniform ($g(S) = g$) on $[0, 1]$. This facilitates derivations. As is the case with F under the *cum* dividend interpretation, we are solely interested in risky debt levels under the financing condition interpretation. There is no underinvestment problem for safe levels of debt. Therefore, we merely consider $F' \in [V^* - I(0), V^*]$ or, equivalently for the linear-uniform special case, $F' \in [V^* - \gamma S_c, V^*]$, cf. (4.21). It was mentioned before that one simply has to replace S_a with S'_a in the definition of R_{λ} to get R'_{λ}. Hence, it follows from (4.24) that $R'_{\lambda} = \lambda \gamma g \frac{(S'_a)^2}{2}$. We will need to work with the derivatives $\frac{dR_0}{dF}$ and $\frac{dR'_{\lambda}}{dF}$ shortly. S'_a in the specification of R'_{λ} thus needs to be substituted such that we have a function of F'. Using (4.21), we solve the equation $V^* - I(S'_a) = F'$, which implicitly defines the boundary state S'_a, for $S'_a = S_c - \frac{V^* - F'}{\gamma}$ in the linear-uniform special case, cf. (4.22). The reduction in firm value given unfair insurance coverage compared to pure equity financing is consequently given by

$$R'_\lambda = \frac{\lambda\gamma g}{2}\left(S_c - \frac{V^* - F'}{\gamma}\right)^2. \tag{4.53}$$

Before we go on, let us pause here for a moment to understand the bigger picture. What are we trying to do? It should be clear that F' changes when F changes due to the financing condition. From (4.49), altering F affects the uninsured debt value D_0 on the equation's right-hand side. To maintain the equality sign, the funds raised in debt under the financing condition have to be adjusted accordingly. This happens through changing the promised repayment F' such that the money raised is enough to cover the uninsured issue plus the insurance premium needed to make the debt safe. Generally, increasing F should lead to a rise in F' to make economic sense. If the firm wants to raise more money in the uninsured case, it must promise to repay more at the second date (and will repay more if it finds itself in the position, i.e., in a non-underinvestment state, to actually make the payment).[108] Increasing F implies a higher insurance premium necessary to make the debt safe. Thus, in order to obey the financing condition, the firm needs more fresh money in the insured case, too. It accomplishes so by promising the face value of debt F'. The higher the face value, the higher the proceeds with insurance. Accordingly, R'_λ changes when R_0 changes with F. In the *cum* dividend case, we were interested in finding the unique debt level F^* for which the firm switches from insuring to not insuring, i.e., for which $R_0 = R_\lambda$. But we are dealing with R'_λ in the presence of the financing condition. And for different levels of F there must exist different (lower) levels of F' for which $R_0 = R'_\lambda$ such that the two deadweight losses are commensurate. In a first step, what we will do is to figure out all these combinations of F and F' within the interval of feasible debt levels $[V^* - \gamma S_c, V^*]$ for which the firm is just indifferent between taking out and not taking out insurance. By doing so, the locus of points (F, F') such that $R_0 = R'_\lambda$ will partition the area spanning the feasible debt levels into two subareas in an (F, F')-diagram, one for which the firm demands insurance and the other for which it decides not to insure any losses, respectively.

However, this graphical partition of space will not tell us anything per se. Note that the debt levels F' for which $R_0 = R'_\lambda$ just mentioned need not be the repayment that the firm actually promises to pay back for different F. The effective promised repayment for a given F is determined by the financing condition. Thus, think of the two subareas in terms of an auxiliary means for partitioning space to find that F' which *would* make $R_0 = R'_\lambda$. Therefore, in a second step, what we need to establish is a another locus of points which, in combination

[108] We will take on this point more specifically shortly. Unfortunately, this interdependency is not readily provided by the model setup.

with the first, provides us with instructions in that it tells us whether to insure or not. This is where the financing condition comes into play, which evidently needs to be satisfied: we will draw a second curve into the (F, F')-diagram that stands for all combinations of feasible debt levels F and F' for which the condition is fulfilled. We are interested in its path through the two subareas just mentioned, so that we can determine for which combinations the firm decides to insure, and for which it does not. This will allow for the validation of the claim made in the beginning of this section, namely that the results derived in the *cum* dividend case also hold under the financing condition interpretation of the model.

By plugging S_a into (4.22) into (4.23), the agency cost of the underinvestment problem may be stated as $R_0 = (\delta - \gamma)\, g \left[S_c \left(S_c - \frac{V^* - F}{\gamma} \right) - \frac{1}{2} \left(S_c - \frac{V^* - F}{\gamma} \right)^2 \right]$. Furthermore, this expression can be simplified. Factoring out and rearranging lead to R_0 as a function of F:

$$
\begin{aligned}
R_0 &= (\delta - \gamma)\, g \left(S_c - \frac{V^* - F}{\gamma} \right) \left[S_c - \frac{1}{2} \left(S_c - \frac{V^* - F}{\gamma} \right) \right] \\
&= \frac{(\delta - \gamma)\, g}{2} \left(S_c - \frac{V^* - F}{\gamma} \right) \left(S_c + \frac{V^* - F}{\gamma} \right) \\
&= \frac{(\delta - \gamma)\, g}{2} \left[S_c^2 - \left(\frac{V^* - F}{\gamma} \right)^2 \right].
\end{aligned}
$$

With the help of this equation and (4.53), $R_0 = R'_\lambda$ if, and only if,

$$
\frac{(\delta - \gamma)\, g}{2} \left[S_c^2 - \left(\frac{V^* - F}{\gamma} \right)^2 \right] = \frac{\lambda \gamma g}{2} \left(S_c - \frac{V^* - F'}{\gamma} \right)^2. \tag{4.54}
$$

Before we go on to explicitly analyze the effects of changing F and, consequently, F' to keep the equation above valid, we can already make some important statements by considering the pair of equations (4.54) and $F = F'$.[109] If the *cum* dividend and the financing condition debt levels are one and the same, i.e., $F = F'$, then $R_0 = R'_\lambda$ must obviously become $R_0 = R_\lambda$. In that case, we are back to our analysis of the linear-uniform special case under the *cum* dividend interpretation established initially. And from there we know that the lowest possible risky debt level $F = F' = V^* - \gamma S_c$ solves the pair of equations (the underinvestment problem just commences at that level of debt such that we have $R_0 = R_\lambda = 0$). The curve representing the locus of points (F, F') such that $R_0 = R'_\lambda$ commences at point $F = F' = V^* - \gamma S_c$.

We can make yet another inference. Remember that in the *cum* dividend case we said that

[109] $F = F'$ may arise for two reasons economically. First, they are the same when there is no safety loading, i.e., $\lambda = 0$. Second, increasing λ increases F' relative to F'_0 for a given F because a bigger safety loading needs to be financed with the issue. Thus, the loading may be so high that it pushes F' back to level F, so that there would be no gain in applying the financing condition. Graphically, it simply is the 45-degree line in an (F, F') diagram.

$(F' =)$ $F = V^* - \gamma S_c$ cannot be the solution we are looking for, i.e., it cannot be the promised repayment for which the firm starts to switch to not taking out insurance precisely because the problem just commences at that level of debt. The correct answer is/was $F = F' = F^*$, cf. (4.30). Therefore, it should not come as surprise that the locus of points for which $R_0 = R'_\lambda$ passes through $(F = F' =)F^*$, for that is the level of debt above which the firm no longer takes out insurance in the *cum* dividend case, i.e., for which $R_0 = R_\lambda$. Importantly, recall further that F^* only exists provided that the safety loading is high enough. In other words, we know that there is no solution to the pair of equations in the interval $(V^* - \gamma S_c, V^*)$ if $\lambda \leq \frac{\delta - \gamma}{\gamma}$. By contrast, $F = F' = F^*$ on the 45-degree line in an (F, F')-diagram is the unique solution given that $\lambda > \frac{\delta - \gamma}{\gamma}$. The fact that the solution is unique implies graphically that the locus of points (F, F') such that $R_0 = R'_\lambda$ intersects the 45-degree line only once.

What we need to establish in order to describe the entire shape of the curve is the derivative $\frac{dF'}{dF}$ such that $R_0 = R'_\lambda$ is preserved. In order to do so, one has to construct the differential of $R_0 = R'_\lambda$ such that

$$\frac{dR_0}{dF} dF = \frac{dR'_\lambda}{dF'} dF',$$

and then rearrange it for

$$\frac{dF'}{dF} = \frac{\frac{dR_0}{dF}}{\frac{dR'_\lambda}{dF'}}.$$

This derivative tells us by how much F' must vary in order to maintain $R_0 = R'_\lambda$ given a marginal increase in F. From the left-hand side of (4.54), the derivative of R_0 with respect to F is

$$\frac{dR_0}{dF} = \frac{(\delta - \gamma)\, g}{\gamma} \frac{V^* - F}{\gamma},$$

and for R'_λ it follows by the right-hand side that

$$\frac{dR'_\lambda}{dF'} = \lambda g \left(S_c - \frac{V^* - F'}{\gamma} \right).$$

Dividing the two above equations finally allows us to express the derivative $\frac{dF'}{dF}$ as

$$\frac{dF'}{dF} = \frac{(\delta - \gamma) \frac{V^* - F}{\gamma}}{\lambda \gamma \left(S_c - \frac{V^* - F'}{\gamma} \right)}. \tag{4.55}$$

This allows us to illustrate the curve representing the locus of points (F, F') such that $R_0 = R'_\lambda$, as can be seen in Figure 4.16 for both cases $\lambda \leq \overline{\lambda}$ and $\lambda > \overline{\lambda}$.

Evaluating (4.55) at the lowest feasible debt level reveals that $\frac{dF'}{dF}$ is infinity for $F = F' = V^* - \gamma S_c$. This means that, in either case, the curve starts to ascend from its starting

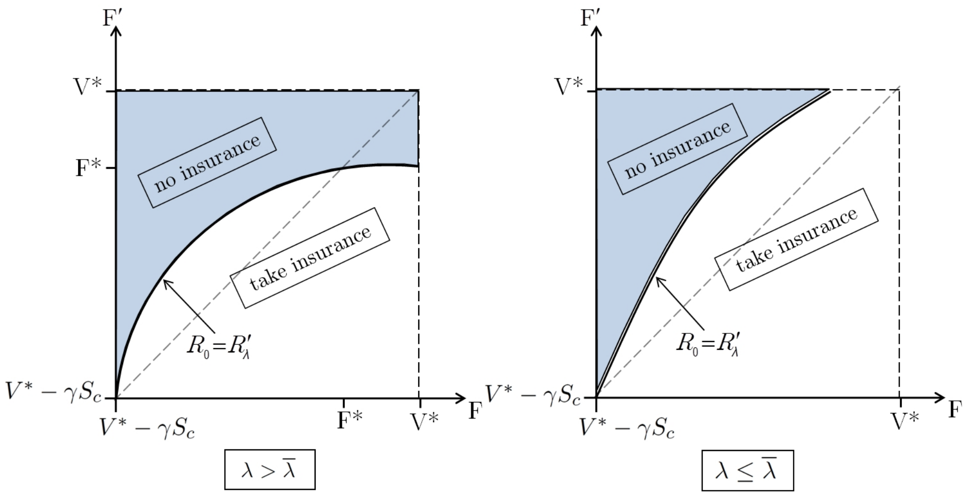

Figure 4.16: Insurance Versus No Insurance (left panel: $\lambda > \overline{\lambda}$, right panel $\lambda \leq \overline{\lambda}$)

point $(V^* - \gamma S_c, V^* - \gamma S_c)$, so that it is initially situated above the 45-degree line (on which $F = F'$). Whether it ever crosses that line depends on the safety loading. For $\lambda \leq \overline{\lambda}$ (right panel in Figure 4.16), the curve never falls below the 45-degree line over the interval $[V^* - \gamma S_c, V^*]$.[110] For $\lambda > \overline{\lambda}$, it intersects the 45-degree line at $F = F' = F^*$; and because it does so only once, the curve must hence terminate ($F = V^*$) at a point below the 45-degree line, as can be seen in Figure 4.16 in the left panel.

Now, there remains only one question. The curve parts space into two subareas in both panels in Figure 4.16. But which of the two areas represents the insurance and the non-insurance part, respectively? Compare equation (4.54), which represents $R_0 = R'_\lambda$. Obviously, an (F, F') combination that satisfies the equation stands for a point *on* the line (regardless of the magnitude of the safety loading). Now, if we were to increase F' from that point on while keeping F unchanged, we would graphically move upwards into the shaded area in Figure 4.16. Mathematically, R'_λ on the equation's right-hand side increases with F' (while $\frac{dR_0}{dF'} = 0$) such that we would no longer have an equality, but an inequality stating $R_0 < R'_\lambda$. In other words, the deadweight loss from insuring outweighs the one from not buying insurance in the shaded area. The firm decides not to purchase insurance coverage in that area. Hence, the firm takes insurance if, and only if, (F, F') is on or below the curve.

We may utilize this insight to check more precisely for the shape of the curve in Figure 4.16, too. Let us calculate the values of R_0 and R'_λ for the highest possible level of debt $F = F' = V^*$. Recall that states S_a and S_c coincide for this level of debt, cf. (4.22). The same holds true for S'_a $\left(= S_c - \frac{V^* - F'}{\gamma}\right)$. Thus, from (4.23) and (4.53), it follows that

[110] For $\lambda = \overline{\lambda}$, the curve intersects the 45-degree line exactly at $F = F' = F^* = V^*$, cf. equation (4.30).

$R_0 = \frac{(\delta-\gamma)g}{2} S_c^2$ and $R'_\lambda = \frac{\lambda\gamma g}{2} S_c^2$ for $F = F' = V^*$. Which deadweight loss is bigger? The answer is: it depends — on the safety loading in the equation for R'_λ. The firm will decide not to buy insurance, i.e., $R_0 < R'_\lambda$, at $F = F' = V^*$ if, and only if, $\lambda > \frac{\delta-\gamma}{\gamma}$ or, equivalently, $\lambda > \overline{\lambda}$. In other words, if the safety loading is sufficiently high in that $\lambda > \overline{\lambda}$, then $R_0 < R'_\lambda$ on the 45-degree line at $F = F' = V^*$. But we know that $R_0 < R'_\lambda$ only holds above the curve representing $R_0 = R'_\lambda$ in Figure 4.16 (left panel). It follows that the curve must terminate at a point below the 45-degree line at $F = V^*$ for $\lambda > \overline{\lambda}$. This also implies that it crosses the 45-degree line at a lower value, which we know to be $F = F' = F^*$.[111] Following the same logic, we have $R_0 > R'_\lambda \iff \lambda < \overline{\lambda}$ at $F = F' = V^*$. Accordingly, the curve indicating $R_0 = R'_\lambda$ never crosses the 45-degree line because the firm only decides to insure ($R_0 > R'_\lambda$) below the curve. See the right panel in Figure 4.16 for an illustration.
This completes the derivation of the first curve. But remember that we said that we need a second one — one that depicts the financing condition.

The financing condition says that the amount of money the insured debt issue raises (D'_λ) is just enough to cover the proceeds from the uninsured issue (D_0) plus the (unfair) insurance premium ($(1+\lambda)\, P'_i$) to make the debt safe. We know from (4.4) that the amount of money raised with the uninsured debt issue is $D_0 = \int_0^{S_a} [V^* - L(S)]\, g(S)dS + \int_{S_a}^{\overline{S}} Fg(s)dS$. This expression still appears in its general form. So far, we have not "adapted" it to our linear-uniform special case which will facilitate calculations later on. Therefore, using $g(S) = g$, $\overline{S} = 1$ and the function $L(S)$ from (4.20), D_0 presents itself as

$$D_0 = g \int_0^{S_a} (V^* - \delta S_c + \delta S)\, dS + g \int_{S_a}^{1} F dS.$$

Next, the equation is simplified such that

$$D_0 = g\left[(V^* - \delta S_c)\, S\right]_0^{S_a} + g\delta \left[\frac{S^2}{2}\right]_0^{S_a} + gF\,[S]_{S_a}^1 .$$

The value of the uninsured debt issue is thus given by

$$D_0 = g\left[(V^* - \delta S_c)\, S_a + \frac{\delta}{2} S_a^2 + F\,(1 - S_a)\right].$$

We will need to work with the derivative with respect to F. Hence, we need a function of F.

[111] Uniqueness is also proved by the fact that $\frac{dF'}{dF}$ does not become negative. From (4.55), the numerator would be negative for $F > V^*$ only, which is not included in the interval of feasible debt levels. Similarly, the denominator is less than zero only for $F' < V^* - \gamma S_c$, which is also inadmissible. Additionally, from (4.55), $\frac{dF'}{dF} < 1$ for $F > V^* - \frac{\lambda\gamma^2 S_c}{\delta-\gamma+\lambda\gamma}$. This is the level of debt for which $R_0 - R_\lambda$ takes on its maximum value in the linear-uniform special case.

Once again, let us replace S_a with $S_c - \frac{V^*-F}{\gamma}$, cf. (4.22), yielding

$$D_0 = g\left[(V^* - \delta S_c)\left(S_c - \frac{V^*-F}{\gamma}\right) + \frac{\delta}{2}\left(S_c - \frac{V^*-F}{\gamma}\right)^2 + F\left(1 - S_c + \frac{V^*-F}{\gamma}\right)\right]. \tag{4.56}$$

The derivative is given by

$$\frac{dD_0}{dF} = g\left[(V^* - \delta S_c)\frac{1}{\gamma} + \frac{\delta}{\gamma}\left(S_c - \frac{V^*-F}{\gamma}\right) + \left(1 - S_c + \frac{V^*-F}{\gamma}\right) - \frac{F}{\gamma}\right].$$

$\frac{\delta}{\gamma}S_c$ in the first and second summand cancel out. Furthermore, $\frac{V^*}{\gamma}$ in the first and $\frac{F}{\gamma}$ in the last summand can be merged to $\frac{V^*-F}{\gamma}$, resulting in $2\frac{V^*-F}{\gamma}$ when combined with the term in the third summand. Factoring out this term then leads to the expression

$$\frac{dD_0}{dF} = g\left[\frac{V^*-F}{\gamma}\left(2 - \frac{\delta}{\gamma}\right) + 1 - S_c\right].$$

Some more minor "cosmetics" provide us with the final form of the derivative, namely

$$\frac{dD_0}{dF} = g\left(\frac{2\gamma - \delta}{\gamma}\frac{V^*-F}{\gamma} + 1 - S_c\right). \tag{4.57}$$

So, we have got the derivative, but what do we need it for exactly? The answer is twofold: first, it is part of the derivation of the curve representing all (F, F')-combinations satisfying the financing condition to be established later on. Second, and more importantly, the interrelation between promised repayment F and the value of uninsured debt D_0 in the model is not as clear and simple as one might hope, unfortunately. Evidently, if – as a firm – you promise to pay back more to bondholders at the second date, you do so because you want to raise more money at the first date because you are in need of a bigger amount of cash to, say, make an investment. If promising a higher repayment would result in a lower or equal debt value, one would not do so as it would be inefficient. Before we go into mathematical details, check out Figure 4.17, which depicts the situation we face from the derivative.

Initially, the figure needs some explanation (additionally, see Remark 1 at the end of this chapter for an explanation of why Figure 4.17 is illustrated "for a given combination of γ and S_c", as stated in its caption. For now, take it as granted). First, note that in the graph, unlike in Figure 4.16, the function does not start at the lowest level of risky debt, $F = V^* - \gamma S_c$, but rather at the lowest overall-level $F = 0$. In other words, it explicitly depicts all riskless levels of debt (i.e., $0 \leq F < V^* - \gamma S_c$) in addition to the risky ones. Second, the function

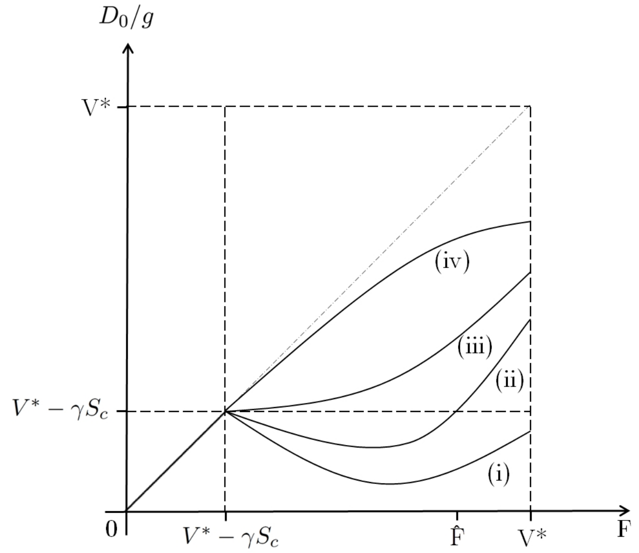

Figure 4.17: Possible Shapes of $\frac{D_0}{g}$ for a Given Combination of γ and S_c.

$\frac{D_0}{g}$ is represented by the 45-degree line for the risk-free levels of promised repayment. It may not be clear right away why there should be a one-to-one relationship between the two. Equation (4.4) defines the value of risky uninsured debt only. How can we reconcile $D_0 = \int_0^{S_a} [V^* - L(S)]\, g(S)dS + \int_{S_a}^{\overline{S}} Fg(s)dS$ with the value of safe debt? Provided a safe promised repayment $F < V^* - \gamma S_c$, the value of debt becomes $\int_0^{\overline{S}} Fg(S)dS$, cf. (4.2). The latter equation is the former without its first summand, but with the integral running from 0 to $\overline{S}$. This is due to the fact that the first summand in D_0 reflects the depressed debt value in all underinvestment states. But there is no underinvestment when debt is safe. The repayment promised at the first date equals the amount actually paid back to debtholders at the second date in each state. In other words, with safe (uninsured) debt, there exists no underinvestment boundary state S_a (the lowest value S_a can take on is zero, which happens for $F = V^* - \gamma S_c$). Therefore, there is no first summand and, consequently, the second comprises all states.[112]

Concerning its functional form in this linear-uniform special case, D_0 becomes $gF \int_0^{\overline{S}} dS$ $\left(= gF\overline{S}\right)$ for levels of debt $F < V^* - \gamma S_c$. Taking the antiderivative yields gF for $F \in (0, V^* - \gamma S_c)$. Economically, since you are repaid F at the second date as a bondholder in

[112] The picky reader might still raise an objection. At the beginning of the model, we defined D_0 in (4.4) as the first-date value of *risky* debt explicitly, i.e., for debt levels $F \geq V^* - \gamma S_c$. Debt value for the firm financed with *safe* debt ($F < V^* - \gamma S_c$), as corresponding to the straight line leading up to point $(V^* - \gamma S_c, V^* - \gamma S_c)$ in Figure 4.17, is defined as D_u, cf. equation (4.2). Hence, strictly speaking, is denoting the ordinate $\frac{D_0}{g}$ over *all* levels of debt not wrong? The answer is: it depends on the point of view. If one finds that D_0 and D_u are two different functions corresponding to two different intervals of debt levels, then yes. If, on the other hand, one argues, as we did, that D_u becomes D_0 as debt becomes risky, then one might pull through with labelling the ordinate $\frac{D_0}{g}$. Either way, the appearance is neater the way we chose it in Figure 4.17.

any case, all there is to do is to discount the safe payment to get the (time) value as of the first date, which is done via multiplying by g. Hence, we have $\frac{D_0}{g} = F$, which justifies the appearance as the 45-degree line for all safe debt levels in Figure 4.17.[113]

The figure indicates that, once we cross into "underinvestment space", the function $\frac{D_0}{g}$ may follow one of four different paths (labeled by (i)-(iv)). As we will see shortly, it depends on the constellation of parameters which one it actually takes on. What we can state already, however, is that every single path pictured must be situated entirely below the 45-degree line. For a given promised repayment, debt as of the first date is most valuable when it is safe because there is no risk of default that investors require to be compensated for. And we have just learned that safe debt is represented by the the 45-degree line in Figure 4.17. Debt becomes risky for levels of debt in excess of $V^* - \gamma S_c$. Hence, $\frac{D_0}{g}$ must be located below the dashed line in Figure 4.17 once debt becomes risky.

To figure out exactly why the function may take on these different shapes starting from the level of debt of $V^* - \gamma S_c$, the obvious thing to do is to examine the derivative of D_0 with respect to F at that (initial) level of risky debt. For $F = V^* - \gamma S_c$, (4.57) becomes

$$\begin{aligned} \frac{dD_0}{dF} &= g\left(\frac{2\gamma - \delta}{\gamma} S_c + 1 - S_c\right) \\ &= g\left(1 - S_c \frac{\delta - \gamma}{\gamma}\right). \end{aligned} \tag{4.58}$$

Whether the derivative is positive or negative, i.e., whether the function D_0 (and thus $\frac{D_0}{g}$) starts to ascend or descend from $F = V^* - \gamma S_c$, apparently depends on whether $S_c \frac{\delta-\gamma}{\gamma}$ is less than or greater than one.

4.11.2.1 (Partly) inefficient debt levels First, suppose that $S_c \frac{\delta-\gamma}{\gamma} > 1$, which implies $\delta > 2\gamma$.[114] Then $\frac{dD_0}{dF} < 0$ (or, equivalently, $\frac{d(D_0/g)}{dF} < 0$) for $F = V^* - \gamma S_c$, and the function starts to descend once debt becomes risky. What about the curvature? From (4.57), the second derivative is $\frac{d^2(D_0/g)}{dF^2} = -\frac{2\gamma-\delta}{\gamma^2}$ for $F > V^* - \gamma S_c$. The expression is positive because the numerator is negative due to the implied $\delta > 2\gamma$. The function is convex.

Before we go on, however, there is one important point. Even though $\frac{dD_0}{dF} < 0$ for $F =$

[113] Of course, we could have made the ordinate depict D_0 instead of $\frac{D_0}{g}$. Then, however, we would not have had the neat appearance as the 45-degree line, but a line that runs slightly flatter up until $F = V^* - \gamma S_c$. It might help to still think in terms of debt value. When D_0 starts to drop, so does $\frac{D_0}{g}$ as g is always positive. That is, results remain unchanged qualitatively. Technically, $\frac{D_0}{g}$ is the first-date debt value compounded for one period such that it may be compared to second-date cash flows in this linear-uniform special case. This means that $\frac{D_0}{g}$ is actually given by area $0\overline{S}$GCBA in Figure 4.3, as opposed to being proportional to it.

[114] We have $\overline{S} = 1$ and $0 < S_c < \overline{S}$. Thus, $S_c < 1$. Therefore, it must be that $\frac{\delta-\gamma}{\gamma} > 1$ and, thus, $\delta > 2\gamma$ in order for $S_c \frac{\delta-\gamma}{\gamma} > 1$ to be true.

$V^* - \gamma S_c$ is possible from a mathematical point of view (which is the reason why we examine it here), note that it is not rational from an economic standpoint. Why? The fact that the function starts to descend from $F = V^* - \gamma S_c$ implies that there exist levels of risky debt – at least for F slightly above $V^* - \gamma S_c$ – such that $\frac{D_0}{g} < V^* - \gamma S_c$ for $F > V^* - \gamma S_c$. This is inefficient. Inefficient in that there exists a level of debt below $V^* - \gamma S_c$ that generates the same debt value without ever facing the prospects of the underinvestment problem (as debt is safe). Graphically speaking, for both shapes of the function (i) and (ii) in Figure 4.17, there is a lower level of (safe) debt which yields the same value $\frac{D_0}{g}$ (as long as (i) and (ii) are located below the horizontal line $\frac{D_0}{g} = V^* - \gamma S_c$) that is situated on the 45-degree line. Rational individuals would always opt for the safe level of debt — why promise more when you can have the same amount for less?

Convexity of (i) and (ii) in Figure 4.17 – given our assumption $S_c \frac{\delta - \gamma}{\gamma} > 1$ – gives rise to two possible scenarios. The function $\frac{D_0}{g}$ may never reach $V^* - \gamma S_c$ over the entire range of risky debt levels, or it may at some point rebound and take on values greater than $V^* - \gamma S_c$.

(i) $\frac{D_0}{g} \leq V^* - \gamma S_c$ for all risky F up to V^*. This is the case where it is always irrational to promise a repayment greater than $V^* - \gamma S_c$. In other words, there is no point in issuing debt beyond the point where its repayment becomes uncertain. Due to its inefficiency, we rule out this case in the current setup.

(ii) This scenario is more interesting. Debt is merely partly inefficient. The function first dips into the "inefficient area", but later takes on values in excess of $V^* - \gamma S_c$ such that rationally acting managers could indeed choose such a level of (relatively high) promised repayment if they are in need of fresh capital amounting to more than what is achievable with safe debt. In other words, there exists $\widehat{F} \in (V^* - \gamma S_c, V^*)$ such that $\frac{D_0}{g} \leq V^* - \gamma S_c$ for risky debt F in $(V^* - \gamma S_c, \widehat{F}]$ and $\frac{D_0}{g} > V^* - \gamma S_c$ for F in $\left(\widehat{F}, V^*\right]$. Again, we rule out F in the former interval (while allowing for the ones in the latter) due to their inefficiency: there are safe levels of debt for which the outcome is the same without having to face the discomfort of underinvestment.

To formally show that both (i) and (ii) are possible, we need to evaluate $\frac{D_0}{g}$ at $F = V^*$ (where $S_a = S_c$, cf. (4.22)) and find two solutions — one below, and one above $V^* - \gamma S_c$. All $\frac{V^* - F}{\gamma}$ terms in (4.56) cancel out such that uninsured debt value because

$$D_0 = g\left[\left(V^* - \delta S_c\right) S_c + \frac{\delta}{2} S_c^2 + V^* \left(1 - S_c\right)\right]$$

for $F = V^*$. This ultimately leads to

$$\frac{D_0}{g} = V^* - \frac{\delta S_c^2}{2}, \tag{4.59}$$

which is obviously less than V^* as the second term on the right-hand side is positive. For case (i), we need a solution $\frac{D_0}{g}$ that satisfies $V^* - \frac{\delta S_c^2}{2} \leq V^* - \gamma S_c$ or, equivalently, $S_c \geq \frac{2\gamma}{\delta}$. Conversely, the condition is $S_c < \frac{2\gamma}{\delta}$ for (ii) to arise.

This tells us one thing right away. Parameters matter. Their constellation matters in that – even though it is exogenous – the magnitude of S_c decides over whether the function follows shape (i) or (ii). A high enough S_c leads to (i), and all risky debt levels are inefficient — and whether a given S_c actually surpasses the threshold $\frac{2\gamma}{\delta}$ depends on parameters δ and γ. We have to make sure, however, that the constraint that this new threshold imposes on state S_c does not contradict any other restriction on S_c that we have in place already: $S_c\frac{\delta-\gamma}{\gamma} > 1$ implies for both (i) and (ii) that $S_c > \frac{\gamma}{\delta-\gamma}$ must be satisfied. Accordingly, the constraints one is faced with for the respective shape of the function in Figure 4.17 are:

(i) $S_c \geq \frac{2\gamma}{\delta}$ and $S_c > \frac{\gamma}{\delta-\gamma}$. To find the lower of the two thresholds, try $\frac{2\gamma}{\delta} > \frac{\gamma}{\delta-\gamma}$. Rearranging yields $2\delta\gamma - 2\gamma^2 > \delta\gamma$, which leads to $\delta > 2\gamma$. This is a true statement because, as mentioned before, $S_c\frac{\delta-\gamma}{\gamma} > 1$ implies $\delta > 2\gamma$. Hence, $\frac{\gamma}{\delta-\gamma}$ is the minimum value such that S_c must be equal to or greater than $\frac{2\gamma}{\delta}$ in order for both inequalities to be satisfied. However, is this also reconcilable with the upper limit? We know that $0 < S_c < \overline{S}$ and $\overline{S} = 1$. The highest value S_c can take on is (slightly below) one. To verify that shape (i) may arise, we must have $\frac{2\gamma}{\delta} < 1$ or, equivalently, $\delta > 2\gamma$. Since this is a true statement, scenario (i) is feasible for $S_c \in \left[\frac{2\gamma}{\delta}, 1\right)$.

(ii) $S_c < \frac{2\gamma}{\delta}$ and $S_c > \frac{\gamma}{\delta-\gamma}$. We know from (i) that $\frac{\gamma}{\delta-\gamma}$ is the lower of the two thresholds. Hence, S_c must thus lie in the interval $\left(\frac{\gamma}{\delta-\gamma}, \frac{2\gamma}{\delta}\right)$. Feasibility is accounted for because $\frac{2\gamma}{\delta} < \overline{S}$ still holds. $\frac{D_0}{g}$ becomes greater than $V^* - \gamma S_c$ at some unique – we have shown that the function is convex in cases (i) and (ii) – level of debt $\widehat{F}$ which is less than V^*, cf. (4.59).[115]

[115] The derivation of $\widehat{F}$ is cumbersome. For the interested reader, we sketch the procedure here. $\widehat{F}$ is the level of debt in $(V^* - \gamma S_c, V^*)$ for which $\frac{D_0}{g} = V^* - \gamma S_c$. Therefore, dividing by g and replacing the resulting $\frac{D_0}{g}$ with $V^* - \gamma S_c$ on the right-hand side in (4.56) yields $V^* - \gamma S_c = (V^* - \delta S_c)\left(S_c - \frac{V^*-F}{\gamma}\right) + \frac{\delta}{2}\left(S_c - \frac{V^*-F}{\gamma}\right)^2 + F\left(1 - S_c + \frac{V^*-F}{\gamma}\right)$. We are obviously dealing with a quadratic function in F. Quite a bit of rearranging yields $0 = \frac{\delta-2\gamma}{2\gamma^2}V^* + F\left(\frac{2\gamma-\delta}{\gamma^2}V^* + 1 - S_c\right) + F^2\frac{\delta-2\gamma}{2\gamma^2}$. The discriminant turns out to be $\frac{[S_c(\gamma-\delta)+\gamma]^2}{\gamma^2} > 0$. Hence, there are two real solutions, i.e., there are two real levels of debt for which $\frac{D_0}{g} = V^* - \gamma S_c$. This should not come as a surprise. The quadratic function does not discriminate between feasible and infeasible debt levels. Hence, one of the solutions should be $F = V^* - \gamma S_c$ because this is the level of debt for which the function starts to descend at $\frac{D_0}{g} = V^* - \gamma S_c$, cf. Figure 4.17. Some calculations reveal that this is indeed the case. We, however, exclude this debt level precisely because the function here passes through $V^* - \gamma S_c$ with negative slope. We are looking for that level for which the function *returns* to the efficient area (so that it

From this level of debt on, F is efficient in that it leads to a first-date debt value D_0 in excess of $g\,(V^* - \gamma S_c)$. The proceeds further increase with F, and the firm is now able to finance an investment that is more expensive than the utmost amount issuable in safe debt.

In sum, whether all risky debt levels or just some (lower ones) are inefficient, depends on state S_c. More precisely, if the exogenously given S_c is sufficiently large in that it is greater than a given $\frac{2\gamma}{\delta}$, then the function $\frac{D_0}{g}$ never rises above $V^* - \gamma S_c$ as F increases, but ends at a value below that at $F = V^*$ because the term $V^* - \frac{\delta S_c^2}{2}$ in (4.59) takes on a value lower than $V^* - \gamma S_c$ for $F = V^*$ in case (i).

Before turning to efficient levels of risky debt, let us dig a little deeper here. The new insights just presented have implications for the way the graph is depicted in the original underinvestment problem. Regarding (i), we know from (4.59) that we must have $\frac{D_0}{g} = V^* - \frac{\delta S_c^2}{2} < V^* - \gamma S_c$ at $F = V^*$, implying that all risky debt levels are inefficient and, accordingly, the first-date value of safe debt at $F = V^* - \gamma S_c$ is higher than the value of risky debt for *any* (uncertain) promised repayment. But under what circumstances does this case occur graphically? We figured out that it is for sufficiently high S_c. On top of that, compare the two sides of the inequality just put forward. In order for the right-hand side to be large, γ should be small (relative to δ) on the left side. And for the left-hand side to be small, we require δ to take on a large value.[116] However, cases (i) and (ii) both impose the condition $\delta > 2\gamma$, i.e., $L\,(S)$ must at least be twice as steep as $I\,(S)$ to begin with. Therefore, loosely speaking, for case (i) to arise, it is best to picture a δ that is considerably larger than 2γ, as illustrated in Figure 4.18.

The left panel depicts the original graph for some δ which is significantly greater than 2γ, where $F = V^* - \gamma S_c$ such that $S_a = 0$, and debt is only just safe. Accordingly, debt value as of the first date is proportional to the area of the tetragon $0\overline{S}$GF, cf. equation (4.2). The right panel in Figure 4.18 illustrates the situation for the same δ and γ, but for $F = V^*$, i.e., debt is most risky. Since debt is also uninsured, the firm's managers will decide not to invest in any underinvestment state. And because $F = V^*$ implies $S_a = S_c$, this is equivalent to asserting that the firm will not invest to reconstitute its damaged assets in any state $S < S_c$. Therefore, as we know, for example, from equation (4.4) for $S_a = S_c$, the value of the uninsured debt

crosses with positive slope). Thus, the second solution is the level of debt we are looking for. One can verify that this level is given by $\widehat{F} = \frac{V^*(2\gamma-\delta)+\gamma(2\gamma-\delta S_c)}{2\gamma-\delta}$. To prove that $\widehat{F}$ lies within the interval of admissible debt levels, first set $\frac{V^*(2\gamma-\delta)+\gamma(2\gamma-\delta S_c)}{2\gamma-\delta} > V^* - \gamma S_c$. This ultimately leads to $\frac{\delta-\gamma}{\gamma} S_c > 1$. This is a true statement per assumption. Then, let $\frac{V^*(2\gamma-\delta)+\gamma(2\gamma-\delta S_c)}{2\gamma-\delta} < V^*$. This yields $S_c < \frac{2\gamma}{\delta}$, a true statement in case (ii).

[116] Alternatively, recall that $S_c \geq \frac{2\gamma}{\delta}$ for (i). In order to make sure that this condition is fulfilled, γ must be small, and δ large.

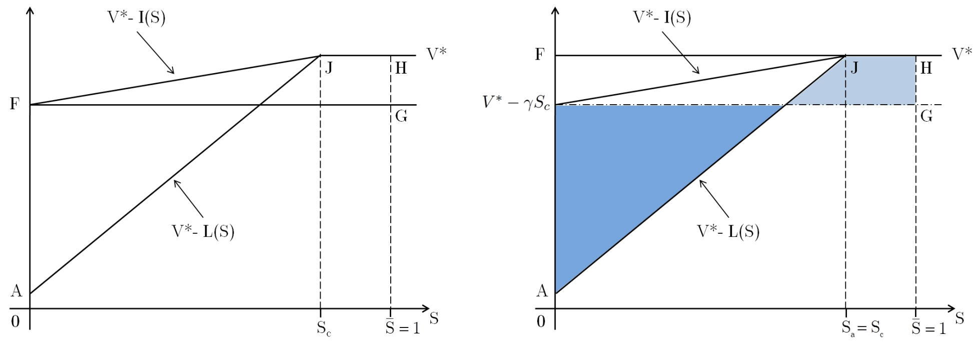

Figure 4.18: Scenario (i) (left panel: $F = V^* - \gamma S_c$, right panel $F = V^*$)

upon issue graphically is proportional to the area of the pentagon $0\overline{S}$HJA.[117]

As can be seen in Figure 4.18, scenario (i) is characterized by the fact that the area $0\overline{S}$GF in the left panel is larger than $0\overline{S}$HJA in the right due to δ being significantly greater than 2γ, i.e., line $V^* - L(S)$ is significantly steeper than $V^* - I(S)$. In such a scenario, there is no point in promising a risky F because even if the firm pushes it to the limit by offering $F = V^*$, it could still raise more funds at the first date by promising to repay a safe $F = V^* - \gamma S_c$ at the second date.[118] This is because the gain in debt value by switching from a safe repayment amounting to $V^* - \gamma S_c$ to a risky one of V^*, as represented by the lightly shaded area in the right panel of Figure 4.18, is less than the loss in debt value accompanying such an action, as depicted by the heavily shaded area. You gain less than you lose.

When characterizing the underinvestment problem, one should *not* draw the graph the way we did in Figure 4.18 as this implies inefficient risky debt levels altogether, and we stated before that we rule out such values of F. This concludes scenario (i).

Conversely, case (ii) requires that $(\frac{D_0}{g} =)\ V^* - \frac{\delta S_c^2}{2} \geq V^* - \gamma S_c$ at $F = V^*$. Remember that (ii) allows for some efficient risky debt levels (it is the higher ones, i.e., above $\widehat{F}$, that are efficient). For the left-hand side to be large and the right to be small, this time we require δ, the slope of $L(S)$, to be relatively small and γ, the slope of $I(S)$, to be large, respectively. However, δ may not be arbitrarily small as we have to take into account the fact that $\delta > 2\gamma$. Hence, in order to reconcile these requirements, it is best to assume a δ that is only marginally

[117] Do not get confused with Figure 4.18 (and 4.19) because it does not show F' as in, say, Figure 4.12, for example. We are still interested in the relationship between F and F'. Our objective is to examine the underinvestment problem under the financing condition. However, the value of uninsured debt D_0 that we are currently analyzing is part of that condition, cf. (4.49). And we are in the process of explaining that some initial levels of risky debt F may be inefficient in the first place (before being concerned with F'), depending on the constellation of parameters. Thus, in order to exclude such levels, one has to make sure from the beginning that the model and, hence, the graphs depicting it are designed accordingly (such that they do not appear as in Figures 4.18). Once this is taken care of, *then* we can proceed to give thought to F'.

[118] This is true for any level of risky debt, cf. Figure 4.17.

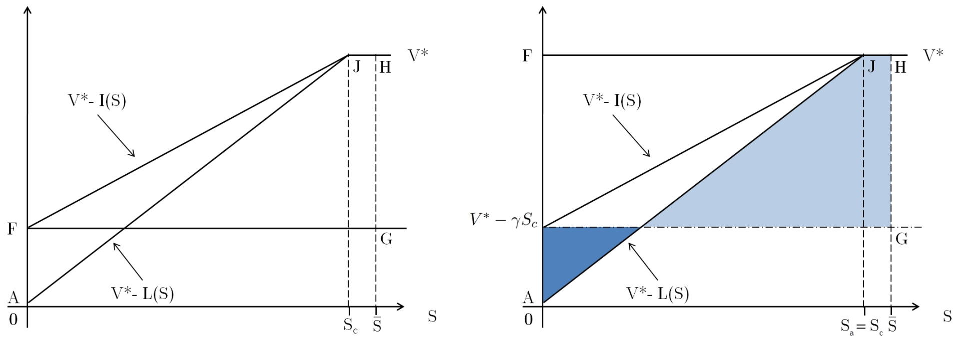

Figure 4.19: Scenario (ii) (left panel: $F = V^* - \gamma S_c$, right panel $F = V^*$)

greater than 2γ. Graphically, this means that lines $V^* - L(S)$ and $V^* - I(S)$ are situated as closely together as admissible. See Figure 4.19 for a visualization.

Note that the figure is generally constructed in the same manner as Figure 4.18. That is, the left-hand panel depicts the original underinvestment graph for $F = V^* - \gamma S_c$. The panel on the right side shows the same graph, except that the maximum level of promised repayment $F = V^*$ is illustrated. The major difference is that the two lines $V^* - L(S)$ and $V^* - I(S)$ are much closer together (compared to Figure 4.18) in that we have some δ which is merely about twice the size of γ. The first-date value of safe debt is once again represented by the area $0\overline{S}$GF in the left panel, while the value of risky debt is proportional to area $0\overline{S}$HJA in the right panel in Figure 4.19. The decisive qualitative distinction is that, as opposed to Figure 4.18, the heavily shaded area now is smaller in size compared to the lightly shaded area in the right panel such that, this time, $0\overline{S}$GF on the left is smaller than $0\overline{S}$HJA on the right. In other words, the loss in first-date debt value due to switching from a sure $F = V^* - \gamma S_c$ to a risky $F = V^*$ is more than offset. This time, you gain more than you lose. The firm thus is able to issue more than $g(V^* - \gamma S_c)$ in funds, so that bigger investments may be undertaken.

One last point regarding case (ii): remember that it is the lower levels of risky debt that are not efficient. Graphically, imagine an F-line that is situated only slightly above the dashed line representing $V^* - \gamma S_c$ in the right panel. In that case, the heavily shaded area would remain unchanged, while the lightly shaded area would shrink to become only a narrow strip. The latter would be smaller than the heavily shaded area, i.e., F is inefficient. From that level of debt on, consider an increase in F such that the lightly shaded area becomes bigger and bigger. At some point, both shaded areas would be of the same size. That happens at debt level $\widehat{F}$ (illustrated in Figure 4.17). All $\widehat{F} < F \leq V^*$ are efficient as they allow the firm to raise more funds compared to a safe issue. This concludes scenario (ii).

Summing up cases (i) and (ii), we have touched on an important issue. The way the standard underinvestment figure is depicted *does* matter. Simply drawing the lines such that $L(S) > I(S)$ in all loss states is typically not enough. Provided that $S_c \frac{\delta-\gamma}{\gamma} > 1$, whether $V^* - L(S)$ and $V^* - I(S)$ stay closely together or drift apart rather quickly matters for the (inefficient) shape that the function $\frac{D_0}{g}$ will take on in Figure 4.17. We have therefore provided specific graphical representations for both cases (i) and (ii) in the form of Figures 4.18 and 4.19 in order to stress the significance of the far-reaching implications a “simple” graph may have. Both of them lead to inefficient risky debt levels (at least partly). Hence, one is generally advised to exercise caution when depicting the figures. Even though the model at first sight appears fairly simple, it is the details that matter and that make it challenging.

4.11.2.2 Efficient debt levels To analyze paths (iii) and (iv) in Figure 4.17, let us return to the derivative of D_0 with respect to F at $F = V^* - \gamma S_c$ in equation (4.58). Unlike for (i) and (ii), now let $S_c \frac{\delta-\gamma}{\gamma} \leq 1$, which implies that the expression $\frac{d(D_0/g)}{dF} = 1 - S_c \frac{\delta-\gamma}{\gamma}$ is non-negative: this time, function $\frac{D_0}{g}$ starts to ascend (or at least not descend) when debt becomes risky. Contrary to the case with inefficient debt levels, not only $\delta > 2\gamma$, but also $\delta \leq 2\gamma$ is now reconcilable with $S_c \frac{\delta-\gamma}{\gamma} \leq 1$: we know that $S_c < 1$ and $\frac{\delta-\gamma}{\gamma} > 0$. However, in addition to being positive, $\frac{\delta-\gamma}{\gamma}$ may be either greater or less than one (and still fulfill the inequality). It follows from $\frac{\delta-\gamma}{\gamma} > 1$ that $\delta > 2\gamma$, while $\frac{\delta-\gamma}{\gamma} \leq 1$ implies $\delta \leq 2\gamma$. Either way, the assumption $S_c \frac{\delta-\gamma}{\gamma} \leq 1$ is sufficient for monotonicity of the relationship between D_0 and F and, thus, ensures that $\frac{D_0}{g} > V^* - \gamma S_c$ for $F > V^* - \gamma S_c$. That is, inefficient debt levels do not exist. Generally, we prove monotonicity by showing that the derivative $\frac{dD_0}{dF}$, cf. (4.57), is positive over the entire interval of risky debt levels. When the function starts to ascend from $F = V^* - \gamma S_c$ and keeps a positive slope through its shape altogether, it cannot terminate at a value lower than the one it started to increase from (i.e., $\frac{D_0}{g} = V^* - \gamma S_c$). Let us validate case by case that $\frac{dD_0}{dF} > 0$:

(iii) $\delta > 2\gamma$. From (4.57), a little rearranging yields $(2\gamma - \delta)\frac{V^*-F}{\gamma} > (S_c - 1)\gamma$. When dividing by $(2\gamma - \delta)$ in the next step, one has to pay attention to changing the inequality sign because $2\gamma - \delta < 0$ per assumption. Thereafter, all that is left to do is solving for F such that we have

$$\frac{d(D_0/g)}{dF} > 0 \text{ for } F > V^* - \gamma^2 \frac{(1 - S_c)}{(\delta - 2\gamma)}.$$

Luckily, the condition $S_c \frac{\delta-\gamma}{\gamma} \leq 1$ ensures that the right-hand side of this inequality is no greater than $V^* - \gamma S_c$, which guarantees monotonicity: set $V^* - \gamma^2 \frac{(1-S_c)}{(\delta-2\gamma)} \leq V^* - \gamma S_c$. This leads via $S_c \leq \frac{\gamma(1-S_c)}{\delta-2\gamma}$ to $(\delta - 2\gamma)\, S_c \leq \gamma(1 - S_c)$. After combining the S_c-terms, the result is $S_c\frac{\delta-\gamma}{\gamma} \leq 1$ — a true statement by assumption. Hence, we have $\frac{d(D_0/g)}{dF} > 0$ for $F > V^* - \gamma^2\frac{(1-S_c)}{(\delta-2\gamma)}$, which is itself less than $V^* - \gamma S_c$ such that $\frac{d(D_0/g)}{dF} > 0$ for $F > V^* - \gamma S_c$. This proves monotonicity.

What about the curvature? As before, from (4.57), the second derivative is given by $\frac{d^2(D_0/g)}{dF^2} = -\frac{2\gamma-\delta}{\gamma^2}$. Since the numerator is (once again) negative, the whole term is positive for risky debt levels. The function is convex. This is illustrated by (iii) in Figure 4.17.

(iv) $\delta \leq 2\gamma$. Monotonicity of the relation between D_0 (and thus $\frac{D_0}{g}$) and F is evident for $\delta \leq 2\gamma$. From (4.57), the derivative is given by $\frac{d(D_0/g)}{dF} = \frac{2\gamma-\delta}{\gamma}\frac{V^*-F}{\gamma} + 1 - S_c$. The term $1 - S_c$ is obviously positive. The first of the two factors in brackets is non-negative due to $\delta \leq 2\gamma$. As is the second because the maximum value F can take on is V^*. Therefore, the entire term is positive for all levels of risky debt, i.e., $\frac{D_0}{g} > V^* - \gamma S_c$ for $F > V^* - \gamma S_c$.

Regarding the curvature, due to $\delta \leq 2\gamma$ the second derivative, $-\frac{2\gamma-\delta}{\gamma^2}$, is negative for levels of debt above $V^* - \gamma S_c$. Pictured as path (iv) in Figure 4.17, this is the only constellation that leads to a concave function $\frac{D_0}{g}$.

Once again, parameters matter. Here, however, they only matter in that δ and γ determine whether the function is convex or concave. Debt levels are efficient in either case.

The above conclusion implies that, for both (iii) and (iv), the function $\frac{D_0}{g}$ ends at a value greater than $V^* - \gamma S_c$ at $F = V^*$ — and from (4.59) we know that this value is less than V^*. This is a situation that makes economic sense. Promising an extreme $F = V^*$ leads to a high debt value, but one that is less than gV^*. This accounts for the risk of default. If there are states in which the firm cannot deliver on its promise, potential debtholders will factor this into the price formation. Upon issue, they will only be willing to pay an amount that is less than gV^*.

Finally, as in cases (i) and (ii), let us perform a quick compatibility check on the restrictions imposed on state S_c. First, $S_c \leq \frac{\gamma}{\delta-\gamma}$, which follows from $S_c\frac{\delta-\gamma}{\gamma} \leq 1$. Second, we have just explained that, in either case, the function $\frac{D_0}{g}$ terminates at a value between $V^* - \gamma S_c$ and V^*.[119] In other words, the termination value, cf. (4.59), satisfies $V^* - \frac{\delta S_c^2}{2} > V^* - \gamma S_c$. This implies the second restriction, namely $S_c < \frac{2\gamma}{\delta}$ (as in (ii)). All we have to do now is to check for each scenario which of the thresholds is the lower one.

(iii) $\delta > 2\gamma$. $\frac{\gamma}{\delta-\gamma} < \frac{2\gamma}{\delta}$ implies $\delta > 2\gamma$, which is a true statement. Thus, S_c must not be greater than $\frac{\gamma}{\delta-\gamma}$ (< 1) in this case. The higher the critical value $\frac{\gamma}{\delta-\gamma}$, the more easily the restriction is satisfied. For $\frac{\gamma}{\delta-\gamma}$ to be high, γ needs to be rather large, and δ must be relatively

[119] Unlike with inefficient debt levels. There, the same holds true only for (ii). The function terminates below $V^* - \gamma S_c$ in case (i).

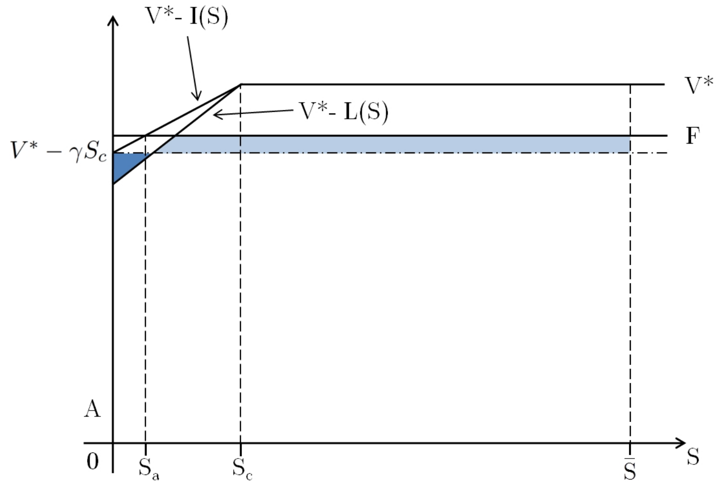

Figure 4.20: Scenario (iii) for Some Low Level of Risky Debt

small. As in cases (i) and (ii), it must also be assured that the condition $\delta > 2\gamma$ is satisfied. This is accomplished, similar to case for (ii) (the one with partly efficient debt levels), by assuming that functions $V^* - L(S)$ and $V^* - I(S)$ are as closely together graphically as possible: picture a δ that is once again only slightly above 2γ.

The comparison of the two cases (ii) and (iii) is insightful because they share the same "boundary" level $\frac{\gamma}{\delta-\gamma}$.[120] The difference between the two is that state S_c must be located above that boundary in (ii), while it must be on or below it in (iii). Apparently, when S_c becomes sufficiently small in this scenario, all risky debt levels turn out efficient. Going back to the graphical illustration of the original underinvestment problem, if we were to move state S_c – keeping the slopes of the functions $L(S)$ and $I(S)$ constant – sufficiently far to the left in Figure 4.19 (which implies case (ii)), then debt would become efficient altogether. Figure 4.20 visualizes just that. One can nicely make out the effect of choosing a low enough S_c. The figure shows, for an arbitrarily chosen low level of risky debt, that the lightly shaded area representing the gain in debt value accompanied by making the issue risky (relative to safe debt $F = V^* - \gamma S_c$, as indicated by the horizontal dashed line) is now larger in size than the heavily shaded area.[121] Unlike in (ii), even low levels of risky debt are efficient in (iii).

(iv) $\delta \leq 2\gamma$. Remember that this is the only scenario for which $\frac{D_0}{g}$ is concave. It is also

[120] Note that this circumstance does not need to be significant per se, as we know that different scenarios, i.e., (i)-(iv), go hand in hand with different parameter constellations. True, for (i)-(iii) there is $\delta > 2\gamma$ as a joint element. But there is more to it. $\delta > 2\gamma$ leaves open a whole lot of possibilities for the values of δ and γ and, thus, $\frac{\gamma}{\delta-\gamma}$ (for example, δ may be slightly, modestly or a lot bigger than 2γ). Cases (ii) and (iii), however, have δ close to 2γ in common. Thus, assuming that both parameters take on the same values in cases (ii) and (iii), they are nicely comparable.

[121] As it is for even lower levels of risky debt than the one pictured. Obviously, the statement continues to be valid for higher levels of F.

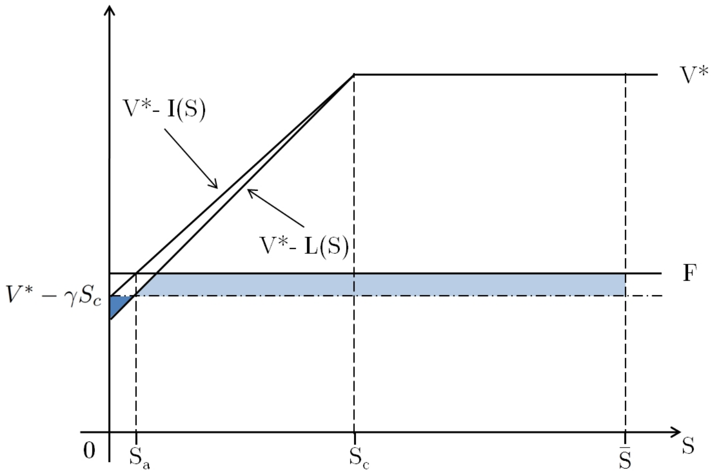

Figure 4.21: Scenario (iv) for Some Low Level of Risky Debt

the only opportunity for $V^* - L(S)$ and $V^* - I(S)$ to be "truly" close together graphically as the distance between them may be arbitrarily small (of course, $V^* - I(S)$ must still be located above $V^* - L(S)$ in all underinvestment states). Regarding the two restrictions on S_c, this time try $\frac{\gamma}{\delta-\gamma} \geq \frac{2\gamma}{\delta}$. Rearranging leads to $\delta \leq 2\gamma$, which is true by assumption. Now, unlike in (iii), $\frac{2\gamma}{\delta}$ is the boundary that S_c must stay below. However, there is one problem — a problem for which we need to invoke the third constraint imposed on S_c, namely $S_c < 1$. The condition $\delta \leq 2\gamma$ implies that $\frac{2\gamma}{\delta}$ (and, thus, $\frac{\gamma}{\delta-\gamma}$) is itself greater than (or equal to) one. Since we limited the highest state to $\overline{S} = 1$, we must confine our analysis to states $S_c < 1$: given that $\delta \leq 2\gamma$, S_c may take on any state (except for $\overline{S} = 1$), and all levels of risky debt remain efficient. Speaking graphically, for efficiency it does not matter how far to the left or to the right state S_c is located. As long as the distance between the two functions is close enough, F will always be efficient. Unlike in scenario (ii), the heavily shaded area is smaller than the lightly shaded area even for levels of debt only slightly above $V^* - \gamma S_c$. Figure 4.21 provides a graphical representation for some random S_c, where functions $V^* - L(S)$ and $V^* - I(S)$ are located very closely together. Put differently, the net gain in first-date debt value from switching from the highest level of safe debt, $F = V^* - \gamma S_c$, to a risky one is always positive. As F increases further, the imbalance becomes even greater in favor of the gain in value. The lightly shaded area is always bigger.

Finally, a short reminder may be useful: in cases (i)-(iv), when we speak of the distance between $V^* - L(S)$ and $V^* - I(S)$ in the underinvestment figures, we are really talking about the investment project's NPV, as defined by $L(S) - I(S)$. Interestingly, there never arises a problem concerning efficiency when NPV from rebuilding is sufficiently small, see case (iv). On the other hand, for very large NPVs – see case (i) – debt may become inefficient (depending on whether state S_c is large enough, which in turn depends on the parameter setting). This may come as a surprise at first sight because one would suspect that this situation is especially desirable. It tells us that, while a large NPV generally is preferable, there are more issues to take into consideration in this linear-uniform special case of the model. As pictured in Figure 4.18, a large NPV may lead to a loss in debt value that is not compensated by the gain that comes with making the debt risky by promising an F that surpasses $V^* - \gamma S_c$.

Monotonicity of (iii) and (iv) makes sure that all risky debt levels are efficient. Given both efficiency and no insurance, firms find themselves in the position to raise more funds at the first date by promising a repayment that may not be honored.[122]

No underinvestment problem arises for inefficient risky debt levels (which is why we exclude them). Managers of the firm would always stick to riskless financing, implying that firm value is always enough to pay off debtholders. Hence, if one wants to focus on underinvestment, efficient debt levels are a necessary assumption to begin with. That way, it is guaranteed that $\frac{D_0}{g} > V^* - \gamma S_c$ for $F > V^* - \gamma S_c$.

This completes the rather extensive (but necessary) detour to the relationship between D_0 and F in the model. Once again, inefficient debt levels are ruled out in the following. Let us now return to Figure 4.16 and construct the second curve, which represents all feasible combinations of F and F' for which the financing condition is fulfilled. As it makes its ways through the two subareas it tells us for which combinations of debt levels the firm decides to insure (and vice versa). Establishing its shape through the (F, F')-space will thus be the first task in what follows.

Remark 1: By now, it might be clear why Figure 4.17 is depicted for given γ and S_c. We have worked out that it depends on several restrictions imposed on state S_c which one of the paths (i)-(iv) the function follows. For each scenario, there is a threshold that S_c must be above or below (or an interval that it must lie in) for a given restriction on the slopes of the functions $L(S)$ and $I(S)$ (either $\delta > 2\gamma$ or $\delta \leq 2\gamma$). The threshold itself is dependent on δ and γ, however. Thus, for different (feasible) combinations of the two, some given S_c may be either below or above it. The point is that changes in the values of δ and/or γ are responsible for a possible switch from one path to another for a given S_c. We would therefore actually have to provide four figures, each one corresponding to one of the four cases (i)-(iv), i.e., with a different constellation of parameters feasible for the respective path — unless we fix γ and

[122] This also applies to efficient levels $F > \widehat{F}$ in (ii).

S_c. For if we did not, we would also have to start out by drawing a different straight line through the origin (representing safe debt) that leads up to the point $(V^* - \gamma S_c, V^* - \gamma S_c)$ in Figure 4.17 for each case. This would be required by the different values of γ and S_c (and thus $V^* - \gamma S_c$) in every respective scenario (i)-(iv) if these parameters were not fixed. Since we postulated that they are, however, different values of δ are responsible for the path of the function as F rises in Figure 4.17.

An example might help: Consider paths (iii) and (iv) in Figure 4.17. At first sight, one might be tempted to think that the convex and the concave function must end in the same terminal value, since for both paths we have $\frac{D_0}{g} = V^* - \frac{\delta S_c^2}{2}$ for $F = V^*$ by (4.59).[123] This is not the case, however. Remember that the restriction on the functions' slopes is given by $\delta > 2\gamma$ for (iii) and $\delta \leq 2\gamma$ for (iv), respectively. Since we fixed γ and S_c, we have a higher δ for (iii), implying that $V^* - \frac{\delta S_c^2}{2}$ terminates at a lower value in (iii). The convex function terminates at a lower value than the concave function, as pictured in Figure 4.17.

4.11.3 Insuring versus not insuring

The approach to establishing the curve that represents the financing condition is similar to that of finding the curve depicted in Figure 4.16 (for which $R_0 = R'_\lambda$). We have to determine the derivative $\frac{dF'}{dF}$ such that the financing condition is fulfilled. As with the first curve, we are only interested in debt levels F and F' within the interval of feasible debt levels $[V^* - \gamma S_c, V^*]$. From (4.49), the financing condition in its general form is given by $D'_\lambda = D_0 + (1+\lambda) P'_i$. Insured debt is chosen such that it raises the combined amount of the uninsured issue and the (unfair) insurance premium. To establish the derivative, we have to convert the general condition to the linear-uniform case first. Luckily, the great majority of the mathematical work involved has been done already. D_0 is given by equation (4.56). Remember that $\lambda P'_i$ equals R'_λ, the deadweight loss of insuring. R'_λ is given by $\frac{\lambda\gamma g}{2}\left(S_c - \frac{V^*-F'}{\gamma}\right)^2$ in (4.53), where $S'_a = S_c - \frac{V^*-F'}{\gamma}$ has already been inserted. Consequently, P'_i equals $\frac{\gamma g}{2}\left(S_c - \frac{V^*-F'}{\gamma}\right)^2$. It follows that $(1+\lambda) P'_i = (1+\lambda)\frac{\gamma g}{2}\left(S_c - \frac{V^*-F'}{\gamma}\right)^2$. The only term remaining is the value of the insured debt D'_λ, cf. (4.51). Debt becomes safe by buying (unfair) insurance. Hence, the firm is able to pay off debtholders in whichever state materializes. For them, there is no more risk involved. Therefore, the first-date value D'_λ is simply the time value of the second-date repayment F'. Discounting is achieved by multiplying the payment by the uniform state price $g\left(= \int_0^1 g dS\right)$. Mathematically, taking the antiderivative of D'_λ in (4.51) yields gF'.

[123] Such as in scenarios (i) and (ii) as well, by the way.

Accordingly, the financing condition in the linear-uniform special case is given by

$$\begin{aligned} gF' &= g\left[(V^*-\delta S_c)\left(S_c-\frac{V^*-F}{\gamma}\right)+\frac{\delta}{2}\left(S_c-\frac{V^*-F}{\gamma}\right)^2+F\left(1-S_c+\frac{V^*-F}{\gamma}\right)\right] \\ &\quad +g\,(1+\lambda)\,\frac{\gamma}{2}\left(S_c-\frac{V^*-F'}{\gamma}\right)^2. \end{aligned} \tag{4.60}$$

Deriving $\frac{dF'}{dF}$ is the final major mathematical task of this chapter — and of this dissertation, too. In a first step, a little rearranging (and dividing by g) leaves us with

$$F'-F=(V^*-\delta S_c-F)\left(S_c-\frac{V^*-F}{\gamma}\right)+\frac{\delta}{2}\left(S_c-\frac{V^*-F}{\gamma}\right)^2+(1+\lambda)\,\frac{\gamma}{2}\left(S_c-\frac{V^*-F'}{\gamma}\right)^2.$$

Using this equation, we establish the derivative $\frac{dF'}{dF}$. Below, some important steps in the derivation are provided:

$$\begin{aligned} dF'-dF &= -\left(S_c-\frac{V^*-F}{\gamma}\right)dF+\frac{1}{\gamma}\,(V^*-\delta S_c-F)\,dF+\frac{\delta}{\gamma}\left(S_c-\frac{V^*-F}{\gamma}\right)dF \\ &\quad +(1+\lambda)\left(S_c-\frac{V^*-F'}{\gamma}\right)dF' \\ &= \left[\frac{\delta-\gamma}{\gamma}\left(S_c-\frac{V^*-F}{\gamma}\right)+\frac{V^*-F}{\gamma}-\frac{\delta S_c}{\gamma}\right]dF+(1+\lambda)\left(S_c-\frac{V^*-F'}{\gamma}\right)dF' \\ &= \left(\frac{2\gamma-\delta}{\gamma}\frac{V^*-F}{\gamma}-S_c\right)dF+(1+\lambda)\left(S_c-\frac{V^*-F'}{\gamma}\right)dF'. \end{aligned}$$

In a next step, dividing by dF yields

$$\frac{dF'}{dF}=1+\frac{2\gamma-\delta}{\gamma}\frac{V^*-F}{\gamma}-S_c+(1+\lambda)\left(S_c-\frac{V^*-F'}{\gamma}\right)\frac{dF'}{dF}.$$

All that is left to do is factoring out $\frac{dF'}{dF}$ and rearranging. The derivative that tells us by how much F' must change in response to a marginal increase in F in order for the financing condition to remain valid is given by

$$\frac{dF'}{dF}=\frac{1+\frac{2\gamma-\delta}{\gamma}\frac{V^*-F}{\gamma}-S_c}{1-(1+\lambda)\left(S_c-\frac{V^*-F'}{\gamma}\right)}.$$

First, it is easily verified that plugging in $F=F'=V^*-\gamma S_c$ into (4.60) leads the financing condition to being satisfied as all the $\left(S_c-\frac{V^*-F}{\gamma}\right)$-terms cancel out. In other words, the curve representing the condition has its origin at the point $(V^*-\gamma S_c, V^*-\gamma S_c)$, just like the curve splitting up space into an insurance and a non-insurance area in Figure 4.16. This, too, should not come as a surprise: uninsured debt D_0 is only just safe at $F=V^*-\gamma S_c$

as $S_a = 0$. There is no underinvestment problem to insure against yet.[124] Thus, there is just no need to acquire insurance to make the debt safe because there is no threat of default. Hence, the firm in this case does not find itself in the situation to raise D_0 plus the insurance premium P'_λ by promising a lower repayment F' simply because the repayment cannot be reduced. Consequently, F' must equal F, i.e., $F = F' = V^* - \gamma S_c$ and, thus, $S_a = S'_a = 0$. The insurance premium P'_λ, which is defined over the underinvestment states 0 to S'_a, is zero accordingly, cf. (4.49) and (4.50). Put differently, there is no difference between the two promised repayments as long as there is no need to purchase insurance, i.e., $F = F'$ as long as $F \leq V^* - \gamma S_c$. In an (F, F')-diagram with both axes ranging from 0 to V^*, this would mean that the relationship between F and F' coincides with the 45-degree line up to point $(V^* - \gamma S_c, V^* - \gamma S_c)$. From there on, we now establish the subsequent shape of the curve and depict it in the diagram as shown by Figure 4.16, where $(V^* - \gamma S_c, V^* - \gamma S_c)$ is illustrated as the origin.

To find the curve's shape, we invoke the derivative and evaluate it at $F = F' = V^* - \gamma S_c$, which gives us $\frac{dF'}{dF} = 1 - \frac{(\delta-\gamma)S_c}{\gamma}$ (< 1). This expression is well known. A comparison with (4.58) reveals that this is exactly the slope of the function $\frac{D_0}{g}$ at $F = V^* - \gamma S_c$, and we have already dealt with the shape of that function extensively in the previous section. As we know from there, the derivative may be negative or positive, depending on whether $S_c\frac{\delta-\gamma}{\gamma}$ is greater or non-greater than one. As before, this requires a case distinction. In short, when $\frac{D_0}{g}$ starts to descend from its point of origin, so does the curve representing the financing condition, and vice versa:

$$\left.\frac{d\left(\frac{D_0}{g}\right)}{dF}\right|_{F=V^*-\gamma S_c} < 0 \quad \Longleftrightarrow \quad \left.\frac{dF'}{dF}\right|_{F=F'=V^*-\gamma S_c} < 0, \text{ and}$$

$$\left.\frac{d\left(\frac{D_0}{g}\right)}{dF}\right|_{F=V^*-\gamma S_c} > 0 \quad \Longleftrightarrow \quad \left.\frac{dF'}{dF}\right|_{F=F'=V^*-\gamma S_c} > 0.$$

Let us start with $S_c\frac{\delta-\gamma}{\gamma} > 1$. This is the case we do not prefer economically (at least for its inefficient debt levels). Here, as F rises above $V^* - \gamma S_c$, the promised repayment with insurance, F', starts to descend. Graphically, if one were to imagine a second curve in Figure 4.16, having the same point of origin as the one pictured, it would first start to decline below the F-axis such that F' would fall below $V^* - \gamma S_c$. However, we cannot allow $F' < V^* - \gamma S_c$ for $F > V^* - \gamma Sc$. If the financing condition results in a risk-free

[124] Put differently, the insurance is free at the considered level of debt.

$F' < V^* - \gamma S_c$, then the firm could have issued uninsured debt with the same safe promised repayment $F\,(= F' < V^* - \gamma S_c)$ in the first place and achieved the same outcome. All debt levels F for which this holds true are inefficient.
Given $S_c \frac{\delta-\gamma}{\gamma} > 1$, inefficiency need not be the case necessarily. If $S_c \frac{\delta-\gamma}{\gamma} > 1$, then it holds true that $F' > V^* - \gamma S_c$ for all F above a unique level of debt. And that unique level turns out to be $\widehat{F}$, i.e., that F from the discussion of (partly) inefficient debt levels above which $\frac{D_0}{g}$ becomes efficient, cf. path (ii) in Figure 4.17. From the earlier discussion of $\widehat{F}$, we know that it lies within the interval of feasible levels of risky debt $(V^* - \gamma S_c, V^*)$, cf. fn. 115. Remember that we do not consider promised repayments $V^* - \gamma S_c < F \leq \widehat{F}$ because we stated in the previous section that we rule out such inefficient debt levels. Uniqueness follows from the fact that when we set F' equal to $V^* - \gamma S_c$ in the financing condition (4.60) and solve the ensuing quadratic function for F, the two solutions are $V^* - \gamma S_c$ and $\widehat{F} = \frac{V^*(2\gamma-\delta)+\gamma(2\gamma-\delta S_c)}{2\gamma-\delta}$.[125] The former cannot be the level of debt we are looking for, since the curve representing the financing condition only starts to descend at $F = V^* - \gamma S_c$ (cf. fn. 115). This solely leaves $\widehat{F}$. Graphically, since the function descends from its origin first, it follows that it must cross the F-axis at $F = \widehat{F}$ with positive slope, which implies that $F' > V^* - \gamma S_c$ for all admissible debt levels $F > \widehat{F}$.

Finally, we now come to the consideration of $S_c \frac{\delta-\gamma}{\gamma} \leq 1$, the case for which monotonicity of D_0 in F is guaranteed. An illustration is provided in Figure 4.22, where the second curve representing the financing condition is drawn into the setup of Figure 4.16. The function now starts to ascend from the origin (with a slope of less than one). For the reasons mentioned, this is the case to be preferred from an economic standpoint. Fortunately, it is straightforward to handle mathematically. Recall the financing condition in (4.60):

$$\begin{aligned} gF' \;&=\; g\left[(V^* - \delta S_c)\left(S_c - \frac{V^*-F}{\gamma}\right) + \frac{\delta}{2}\left(S_c - \frac{V^*-F}{\gamma}\right)^2 + F\left(1 - S_c + \frac{V^*-F}{\gamma}\right)\right] \\ &\quad + g\,(1+\lambda)\,\frac{\gamma}{2}\left(S_c - \frac{V^*-F'}{\gamma}\right)^2 . \end{aligned}$$

The first summand on the right-hand side is simply D_0, cf. (4.56). And since $S_c \frac{\delta-\gamma}{\gamma} \leq 1$ holds, we know from the discussion of efficient debt levels in the last chapter that we have $\frac{D_0}{g} > V^* - \gamma S_c$ for $F > V^* - \gamma S_c$ (see paths (iii) and (iv) in Figure 4.17). Therefore, after dividing the whole equation by g, the first term on the right-hand side exceeds $V^* - \gamma S_c$ for all debt levels $F > V^* - \gamma S_c$. Concerning the insurance premium in the second summand,

[125] The derivation follows fn. 115.

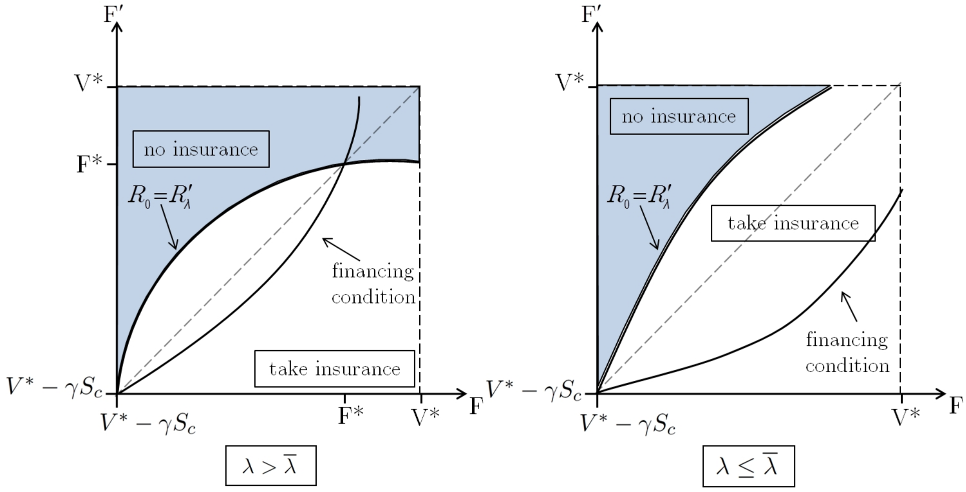

Figure 4.22: The Decision to Insure (left panel: $\lambda > \overline{\lambda}$; right panel: $\lambda \leq \overline{\lambda}$)

recall that the quadratic expression is simply $(S_a')^2$. The lowest value the boundary state can take on is $S_a' = 0$ (for $F' = V^* - \gamma S_c$). By implication, the lowest value the entire term can take on is zero, too. Hence, it holds true for F' on the left-hand side of the equation that $F' > V^* - \gamma S_c$ for all $F > V^* - \gamma S_c$ when $S_c \frac{\delta - \gamma}{\gamma} \leq 1$.

Let us go on to check whether the new curve crosses the 45-degree line, i.e., whether there is a solution to the pair of equations (4.60) and $F = F'$. We do so by plugging the latter into the former. In a first step, this yields $F = V^* - \delta S_c + \frac{\delta}{2}\left(S_c - \frac{V^* - F}{\gamma}\right) + (1+\lambda)\frac{\gamma}{2}\left(S_c - \frac{V^* - F}{\gamma}\right)$. Rearranging and solving for F then gives us the result:

$$F = F' = V^* + \gamma S_c \frac{\delta - \gamma - \lambda\gamma}{\delta - \gamma + \lambda\gamma}.$$

In case this does not look familiar, compare equation (4.30) to see that the value equals F^* — the debt level for which the firm starts to switch to not buying insurance in the *cum* dividend case, and for which the curve in Figure 4.16 crosses the 45-degree line. Thus, the curve representing the financing condition also goes through point (F^*, F^*). However, one has to exercise caution in making that statement. Remember that it only holds given that the safety loading is high enough. We already made it clear in previous sections that F^* only exists for $\lambda > \overline{\lambda}\left(= \frac{\delta - \gamma}{\gamma}\right)$ within the interval of feasible debt levels.[126] Therefore, we once again need

[126] Our explanation allows for a neat side effect: Garven and MacMinn (1993, p. 642) state that "the promised payment B^c must satisfy equation (10) but such a $B^c < B^u$ always exists". Their equation (10) is our fair financing condition (4.42), while B^c corresponds to our F_0' and B^u equals the uninsured F. The authors do not prove their claim explicitly. As they do not consider safety loadings either, consider $\lambda = 0$ (such that $F' = F_0'$), so that the right panel in Figure 4.22 is relevant to us. The level of debt $F = F_0' = F^*$ turns into $V^* + \gamma S_c$, which is clearly not in the interval of feasible debt levels. Graphically, the two curves would not cross the 45-degree line in the same point until some debt level $F = F_0' > V^*$ is reached. Hence, it follows that $F_0' < F$ for all feasible debt levels because the lower curve in Figure 4.22 stays below the 45-degree line.

a case distinction, as accommodated graphically by the left and the right panel in Figure 4.22: for $\lambda \leq \overline{\lambda}$, there is no solution to (4.60) and $F = F'$ in the interval $(V^* - \gamma S_c, V^*)$, i.e., the curve representing solutions to (4.60) does not rise above the 45-degree line over the interval $[V^* - \gamma S_c, V^*]$. For $\lambda > \overline{\lambda}$, the unique positive solution in the interval $(V^* - \gamma S_c, V^*)$ is $F = F' = F^*$: the curve intersects the 45-degree line at F^*, as shown in the left panel of Figure 4.22.[127] Both curves cross the 45-degree line at $F = F' = F^*$ (the level of debt above which the firm switches to not purchasing insurance in the *cum* dividend case if $\lambda > \overline{\lambda}$).

Finally, we have reached the point where we are in the position to check on our objective set out originally. That is, we can now verify whether the theorem established in the *cum* dividend case also holds under the financing condition. We can infer the validity of our assertion that the *cum* dividend conclusion also holds under the current scenario from an inspection of Figure 4.22. The two curves in the respective panels provide the answer. Recall that the curve representing (F, F')-combinations for which $R_0 = R'_\lambda$ merely divides space into a "buy insurance" and a "do not buy insurance" area (the latter being represented by the heavily shaded surface). The actual guidance on which action to take comes from the curve representing the financing condition as it passes through these two areas. Since we obviously require the financing condition to be satisfied, we simply have to check if and how the curve passes through the respective areas in order to provide the following concluding statement:

For $\lambda \leq \overline{\lambda}$, it is optimal for the firm to buy insurance in the presence of a financing condition, while for $\lambda > \overline{\lambda}$, the firm takes out insurance if $F \leq F^*$, but not otherwise. This is exactly the same result as in the *cum* dividend case: only the combination of a high safety loading and high leverage will lead the firm's managers not to purchase insurance.[128]

From the left panel in Figure 4.22, it is apparent that the firm stops demanding insurance at the same level of debt (F^*) at which it also does so in the *cum* dividend case. At $F = F' = F^*$, the lower curve enters the no-insurance-area. This is also justified from an economic standpoint: if the firm were to follow the financing condition even above the 45-degree line, then F' would become greater than F. In other words, buying insurance would lead to an *increase* in promised repayment, as opposed to a decline. As a consequence, the deadweight loss of insuring would be larger than in the *cum* dividend scenario, i.e., $R'_\lambda > R_\lambda$. This would render taking out insurance useless. Shareholders cannot have an interest in this.

[127] It can be checked that for large values of $\lambda \left(> \overline{\lambda}\right)$ there is no solution F' to (4.60) for large enough debt levels F (in that F' would exceed V^*, the maximum admissible level of debt). We omit the (cumbersome) derivation.

[128] For $\lambda = \overline{\lambda}$, it follows that $F = F' = F^* = V^*$, cf. (4.30). That is, the two curves in Figure 4.22 both cross the 45-degree line at the maximum level of risky debt.

The explanations given above also confirm Garven and MacMinn's (1993, p. 644-45) finding that, whenever the firm opts for insurance (see above), "the net value of the current shareholders' claim in the presence of loading is higher under our financing-constrained model compared to a *cum* dividend interpretation of Schnabel and Roumi". In other words, it *does* affect shareholder value which interpretation of the model is selected — even though the firm stops to demand loss insurance at the same level F^* (provided $\lambda > \overline{\lambda}$). This follows from the observation that $F' < F$ and, hence, $R'_\lambda < R_\lambda$ for each point on the curve representing the financing condition that lies below the $R_0 = R'_\lambda$-curve (for $\lambda > 0$) in Figure 4.22. Our analysis applies generally to (F, F') on *and* above the financing condition curve: in principle, the firm could choose a higher repayment than F' and still generate all the funds necessary (and more).[129] However, as pointed out by Garven and MacMinn (1993, p. 645), the firm has an incentive to minimize the insurance purchase by minimizing the face value of debt, i.e., to satisfy the financing condition. This is because (F, F') *on* the financing condition lead to the lowest possible repayment F' for a given risky $F\,(< F^*)$. This in turn leads to the highest possible deductible[130] and, hence, the lowest possible loading premium/deadweight loss of insuring $\lambda P'_i = R'_\lambda$. Regardless of whether considering the *cum* dividend interpretation or the financing condition, shareholders generally trade off the deadweight loss of insuring (R_λ and R'_λ, respectively) against the loss of not insuring (R_0) in determining whether equity value is higher with or without insurance. As long as the deadweight loss caused by insuring is lower, shareholders will acquire coverage because their claims' value will be higher. Thus, the lower R'_λ compared to R_λ, the better for shareholders. This concludes the proof.

This also concludes the analysis of the underinvestment problem in the reconstitution of damaged assets. We have presented considerable new insights that hopefully extend our understanding of the problem and, importantly, solutions to it. Most importantly, we have proved Schnabel and Roumi (1989) wrong in that it is not the high levels of risky debt for which the firm generally decides to insure, but rather the low levels. Furthermore, given a sufficiently high safety loading, the firm will not take out insurance for high levels of debt. Again, this result makes more sense from an economic point of view: roughly speaking, if the firm basically belongs to bondholders anyway, due to its high leverage, and if the insurance company asks for a high safety loading along with its insurance service, there is no point in

[129] Going lower than F' is not an option as it would result in less money than necessary to raise all that the uninsured issue raised plus enough to cover the insurance premium.

[130] Note, parenthetically, that Garven and MacMinn (1993, p. 645) accidentally state that "...loading creates an incentive to reduce the deductible...", as opposed to correctly explicating that there exists an incentive to *maximize* the deductible. Given their clear and thorough understanding of the model, this unquestionably is merely a typo.

trying to save the company from a shareholder point of view.

Part IV

Conclusion

5 Summary

We have come to the end of this dissertation. Hopefully, its readers have acquired a thorough understanding of corporate underinvestment and the real-life relevance of the theory involved. We have addressed in depth the circumstances under which firms decide to pass up profitable investment opportunities, both in the presence of asymmetric and symmetric information.

One commonality under both informational setups is that management's behavior is subject to certain requirements that induce underinvestment in the first place. In Myers and Majluf (1984), managers defend the interests of existing shareholders against potential new claimholders (be it debt or equity), while management represents the interests of stockholders in their conflict with bondholders in Mayers and Smith (1987). By implication, new investment is undertaken only if it does not decrease the value of the existing equity. The second feature that both setups have in common is that *risky* debt is a prerequisite for the underinvestment problem. In the case of asymmetric information, we have come to know that risk-free debt is as good as financial slack (cash) in that it leads the firm to invest in every positive-NPV project; there is no dilution of shareholders' equity claim because there is no scope for mispricing due to the fact that the new security is not subject to the risk of default. For this reason, the firm first exhausts its capacity to issue risk-free debt before it issues risky bonds. Given symmetric information, risk-free liabilities ensure that firm payoffs (with investment) are sufficient to cover the promised repayment to debtholders in every state of nature. Consequently, the firm always decides to rebuild (without needing insurance) as the NPV to shareholders is non-negative.

One difference between the two is that, with asymmetric information, the *issue* of risky debt may lead to underinvestment, whereas it is *preexisting* risky debt that prompts firms to pass up a worthwhile investment opportunity in the presence of symmetric information.

Concerning underinvestment and asymmetric information, Myers and Majluf's (1984) model does very well in explaining observed security issue announcement effects. By contrast, it fails

to explain actual corporate financing behavior in the sense that real-world corporations do not follow the pecking order for the most part. As to Myers' (1977) debt overhang, we have provided an extensive overview regarding the multitude of areas in which debt overhang is found (the corporate sector, the banking sector, development economics, etc.). It is safe to say that debt overhang matters in reality. Unfortunately, there is only little empirical evidence in relation to the influence of the underinvestment problem on the corporate demand for insurance. This is due to data availability; firms in most developed countries are generally not required to report insurance purchases. If data availability should change in the future, this is certainly an interesting area of future research, for it would enable the empirical validation of the conclusions of Mayers and Smith (1987) — as well as our own.
Both models clearly represent a deviation from the famous MM theorem stating the irrelevance of corporate financing. Capital structure matters. It is relevant because it alters the firm's investment scheme in that risky debt induces firms to invest suboptimally. As a consequence, firm value departs from its status quo benchmark.

Lastly, with respect to the underinvestment problem in the reconstitution of damaged assets, we have contributed to the existing literature in that we have identified a longstanding error in connection with corporate casualty insurance that comes with a safety loading. The rectification of this error is important because it significantly changes the conclusions of the model it builds on, namely Schnabel and Roumi (1989) — actually, it turns them upside down (for a high enough safety loading). By doing so, we provide theoretical results that have economic meaning. In the correct outcome of the model, shareholders prefer not to insure if the company is highly levered and has to pay dearly for insurance coverage. That is, if a firm is deeply underwater such that its shareholders hardly have a claim in it, they have no incentive to save it, since it basically does not belong to them. Finally, we have further contributed to a better understanding of the underinvestment problem by proving that the results by and large persist both in the presence of bankruptcy costs and in a financing condition environment (that is favored from a shareholder point of view): faced with the risk of incurring a loss to its assets, "the firm generally takes insurance for low levels of risky debt" (Arnold and Hartl, 2011, p. 1).

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