Information Asymmetry in the *M*-Curve Model

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Abstract

This paper adapts the Myers-Majluf and Seog-Lee asymmetric information methodologies to the Major-Froot *M*-curve model in order to calculate the probability of success, and effective cost, of raising capital via seasoned equity offering. The core assumption is that while both management and investors know the relationship between wealth (financial slack) and market value – the *M*-curve – only management knows current wealth. In the context of insurance companies, this can be interpreted as asymmetric information about reserve adequacy. Based on a plausible *M*-curve and parameters representing the US property and casualty insurance industry as a whole as if it were a single firm, effective costs peaking in the range of 100% to 400% were obtained as well as probabilities in excess of 10% that issue will not succeed. In states of high surplus, information effects drive the probability of successful issue to nearly zero; in states of covert insolvency, however, there is a significant probability – 30% to 50% – of a successful issue that transfers wealth from new to existing shareholders.

Keywords. Information asymmetry; costly capital; reserve uncertainty; *M*-curve.

1. INTRODUCTION

1.1 Previous Work

Akerlof (1970), in one of the earliest papers on asymmetric information, showed how the "lemons problem" – uncertainty about whether a to-be purchased good will turn out to be defective – induces economic loss. The literature that followed, examining the rôle of asymmetric information in other areas, is quite extensive.

Myers & Majluf (1984) focused on the problem of asymmetric information in the context of seasoned equity offerings. They consider the case of a firm with assets in place and an investment opportunity requiring funding. Both are are known to management but not known perfectly by investors who have only a probability distribution to guide them. Management acts in the interests of existing shareholders, maximizing the "intrinsic" value of old shares in their decisions to issue stock and invest in the new opportunity. Existing shareholders are assumed not to participate in any new issue. The authors show, first by a two-state example and then by a continuous lognormal model, how signaling affects the issue price and how it is possible for the firm to decide to pass up a positive NPV opportunity.

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Seog & Lee (2008) relate the Myers-Majluf results to the insurance underwriting cycle, via capital shock theory (Harrington & Niehaus 2000). "When a large capital shock such as a catastrophic event hits an insurer, the insurer will need to raise capital in order to, for example, preserve its franchise value. If external financing is costly, the insurer may opt not to raise capital from the capital market. Instead, it may finance internally by increasing prices, which will lead to a hard market." They find that the Myers-Majluf model, as presented, cannot explain financing difficulties after a large capital shock, but with a modification it can. Their model is also based on a two-state outcome, but they consider changes in liability as well as asset values, and allow for the possibility of bankruptcy.

1.2 Background on the *M*-curve model

The *M*-curve models of Major (2008) and Froot (2008) posit a relation between wealth (surplus, financial slack) W and shareholder market value M. In Major (2008) the *M*-curve is derived as the solution to a problem of maximizing the expected present value of capital flows to and from shareholders. There, a parameter κ represents the effective cost of raising external capital, and includes at least the transaction costs, e.g., payments to underwriters, attorneys, etc. When $M>W$, franchise value exists and actuarially "expensive" risk management can be justified.

Certain assumptions can be made about the *M*-curve. It is continuous; its value for $W \leq 0$ is zero; it is nondecreasing. Finally, as a result of diminishing returns to scale, there is a point W_0 at which additions of capital no longer increase franchise value, i.e. for $x>0$, $M(W_0+x) \leq M(W_0)+x$. Since the *M*-curve represents maximization of shareholder value, dividending the excess x in such a situation would be called for, making the inequality an equality. Similarly, for all $W>0$ and $\Delta W>0$, $M(W+\Delta W)$ must be no less than $M(W)+\Delta W$.

1.3 Objective

Major (2008) and Froot (2008), following Froot, Scharfstein, & Stein (1993) and Froot & Stein (1998), *assume* costly external capital as a necessary condition to avoid Modigliani-Miller (1958) irrelevancy. (M&M irrelevancy is elaborated upon in section 2.3.) Here, the aim is to replace a free parameter cost of capital with something more fundamental. Specifically, this paper derives estimates of the κ parameter for use in the *M*-curve model of Major (2008) based on a plausible set of parameters representing the US P&C industry as a whole. Following in the footsteps of Myers & Majluf (1984) and Seog & Lee (2008), it explores the

consequences of information asymmetry on the possibility and cost of raising external capital through seasoned equity offering.

In this paper, the assumption is that there is an exogenously given, fixed, M-curve. Both investors and management are assumed to know the M-curve, but only management knows the true current value of wealth (surplus, financial slack) W. Investors instead have an estimate of W with known probability distribution for error. This can be interpreted in the context of an insurance firm as uncertainty about the insurer's reserve adequacy. A numerical example is worked out to derive, for each level of wealth, the probability of successful issue, the expected share price given successful issue, and the effective cost to existing shareholders.

1.4 Outline

The remainder of the paper proceeds as follows. Section 2 reviews the basic (static) conditions under which a firm will choose to issue equity, in terms of the investors' error in estimating current wealth. The numerical example is introduced. Critical values for the estimation error, defining when issue will or will not proceed, are derived. Section 3 derives the equilibrium pricing that arises because the announcement of a stock issue is new information to investors regarding their estimation error. The probability of a successful issue and the conditional expected issue price, based on the probability distribution of investor error, are developed. Section 4 calculates the cost of information asymmetry, and expresses it as an equivalent to transaction cost. Section 5 explores the consequences of varying the (1) amount of capital to be raised, (2) the uncertainty in the surplus amount, and (3) the franchise value embedded in the M-curve. Section 6 concludes. A list of symbols follows the text.

2. SEASONED EQUITY OFFERINGS WITH NO INFORMATION EFFECTS

We take as given a relationship between the *ultimate*[2] economic equity value M and the current level of wealth (capital, surplus, financial slack) W of the firm. By "ultimate" we mean that the market cap of the firm can be construed as a mean-reverting stochastic

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[2] Myers & Majluf (1984) used the term "intrinsic."

process that tends towards *M* as an attractor. This relationship *M(W)* we call the "*M*-curve." This particular curve does not contemplate the possibility of external recapitalization. The goal of the analysis is to see how market valuation changes the *M*-curve when that possibility is considered, and to translate that into an "effective" cost of raising external capital.

We also assume that all parties – management and investors – know that relationship. However, while management knows the true current value of wealth (*W*), investors have only an estimate. This can be interpreted in the context of an insurance company as management having superior understanding of their reserve adequacy as compared to the investors.

For purposes of this analysis, we will assume that the market cap of the firm is strictly a function of the market's estimate of *W* (and the possibility of additional capital when an issue is announced). Uncertainty in the level of the *M*-curve and other influences on actual stock price (trading noise, supply and demand, liquidity, etc.) are assumed away here.

Moreover, we assume that the objective of management is the maximization of *M* for the ("ultimate") benefit of its current shareholders. This has precedent in Myers & Majluf (1984) and can be justified as follows. If a new equity issue proceeds, it is not certain – arguably not even likely – that a large majority of current shareholders will choose to participate to the full extent of keeping a proportional share in the company. To the extent that they experience dilution effects and a transfer of their wealth (or currently unrealized potential wealth) to new shareholders, they will express their unhappiness to the detriment of management. As this paper will show (following in the footsteps of the previous papers that also showed), information asymmetry can lead to just such dilution and wealth transfer effects. While a capital infusion might help the firm as a whole, in the sense of the aggregate wealth of old and new shareholders in total, we cannot expect management to fall on their swords in the pursuit of the greater good.

Thus, we will assume that current – a.k.a. "old" – investors do not participate in the new equity issue at all, and that management's concern is to maximize their benefit.

We also allow for the possibility that the firm is covertly insolvent, $W<0$, and desires a capital infusion $\Delta W > -W$ before this situation is recognized and acted upon by regulatory authorities. Note $M(W)=0$ for any $W<0$.

2.1 Decision to Issue Based on Current Market Sentiment Only

Say management finds the firm at the point (W, M) on the *M*-curve with an opportunity to go to $(W+\Delta W, M(W+\Delta W))=(W+\Delta W, M +\Delta M)$ if it can acquire outside capital ΔW.

Let's say the current market value of the entire outstanding stock (that is, share price times number of shares outstanding) is $P_0 Q$, which could be less than or greater than M, due to the market's incomplete knowledge of W.

Without loss of generality, we may take Q=1. The firm will want to issue stock if it is advantageous to the existing shareholders. Assume for this section that the new equity will be N shares issued at the price P per share.

There is also a transaction cost of raising capital: Assume $(1+\kappa)\Delta W$ comes out of new investors' pockets, ΔW goes into the firm's surplus account, and $\kappa\Delta W$ goes outside to service providers (lawyers, investment bankers, etc.). Old investors do not pay or receive cash in the transaction.

In that case, we have NP $= (1+\kappa)\Delta W$ so the share Q/(Q+N) of "ultimate" firm value $M+\Delta M$ going to the existing shareholders, i.e. the diluted value, is

$$\frac{Q}{Q+N}\cdot(M+\Delta M)=\frac{P}{P+N\cdot P}\cdot(M+\Delta M)=\frac{P}{P+(1+\kappa)\cdot\Delta W}\cdot(M+\Delta M)\equiv M_{dil}(P,W) \qquad (2.1)$$

and the firm will want to issue stock if this is greater than the existing shareholder value M. If we define the "opportunity" $\Theta = \Delta M/\Delta W$, we may rewrite this "will-issue" condition as:

$$P>\Psi(W)\equiv\frac{(1+\kappa)\cdot M}{\Theta} \qquad (2.2)$$

The firm will want to issue the stock at a price that is greater than the underlying value times a ratio whose numerator reflects the transaction cost and whose denominator reflects the slope of the *M*-curve. If the issue announcement does nothing to change the stock price, then the above statements hold with P replaced by P_0. In the sequel we will treat unsubscripted variables as generic and use the zero subscript to refer to values corresponding to the pre-announcement situation.

2.2 The New Investor Perspective

At a market price of P, potential new investors see the deal as this: buy N shares for a total outlay of NP $= (1+\kappa)\Delta W$ and get value $(N/(1+N))M(W+\Delta W)$. This is acceptable as

long as the value received is not less than the total outlay, or P ≤ (M +ΔM) - (1+κ)ΔW.

Investors do not know W, however. They estimate W as $\Lambda_0 = W + X_0$. Here, we assume X_0 is a random variable with zero mean and finite variance, and assume the investors know this fact and know the distribution of X. (Later in the numerical example we will specify it as normal.) We take their valuation to be the Bayesian posterior mean estimate of M:

$$P_0 = E_M(\Lambda_0) \equiv E[M(W - X) | W = \Lambda_0] = \int_{-\infty}^{\infty} M(\Lambda_0 - x) \cdot \phi(x) dx \qquad (2.3)$$

where ϕ is the p.d.f. of X. (This is a posterior expectation of the present-time value, not to be confused with the expectation of a future value of M, which has been labeled "EM" in other papers.) To investors, the fair pricing condition is

$$P \le P_1 \equiv E_M(\Lambda_0 + \Delta W) - (1 + \kappa) \cdot \Delta W \qquad (2.4)$$

We will use the term "uninformed" to refer to the situation where the announcement of a stock issue does *not* provide information about W. If uninformed, new investors will bid the price up from P_0 to P_1. Combining equations (2.2) and (2.4), we have the uninformed will-issue condition in terms of estimation error:

$$E_M(\Lambda_0 + \Delta W) - (1 + \kappa) \cdot \Delta W > \Psi(W) \qquad (2.5)$$

2.3 Introduction to the Numerical Example

For our example M-curve, we take a model of the US Property & Casualty industry as reflected in Highline Data's "PCOMP" aggregate. Details of this model are presented in Appendix A. Figure 1 shows the M-curve as a solid curve, with the locus M = W as a dashed line. Units are USD 100,000,000,000. For point of reference, the yearend 2008 book value of the industry is $W_0 = 4.625$, and its corresponding theoretical market value is M = 13.13. This is not particularly relevant to the discussion, however, as the focus is to examine the prospects for raising capital at all W points along the curve.

In what follows, we make these additional assumptions:

- The transaction cost of raising new capital is $\kappa = 0.05$.
- The amount of capital to be raised is $\Delta W = 1.5$.
- The estimation error X is distributed as a normal with mean zero and standard deviation $\sigma_X = 1$. Note this represents approximately 13% coefficient of variation on current reserves.

Recall the *M*-curve is known by all parties, but only management knows W accurately. Investors price based on Λ, their estimate of W. Figure 2 shows the $E_M(\Lambda)$ curve (equation 2.3). Note that the horizontal axis in this case represents the estimate of W, Λ, rather than the actual, unknown W. The actual *M*-curve, in the case $W=\Lambda$, is overlaid for comparison.
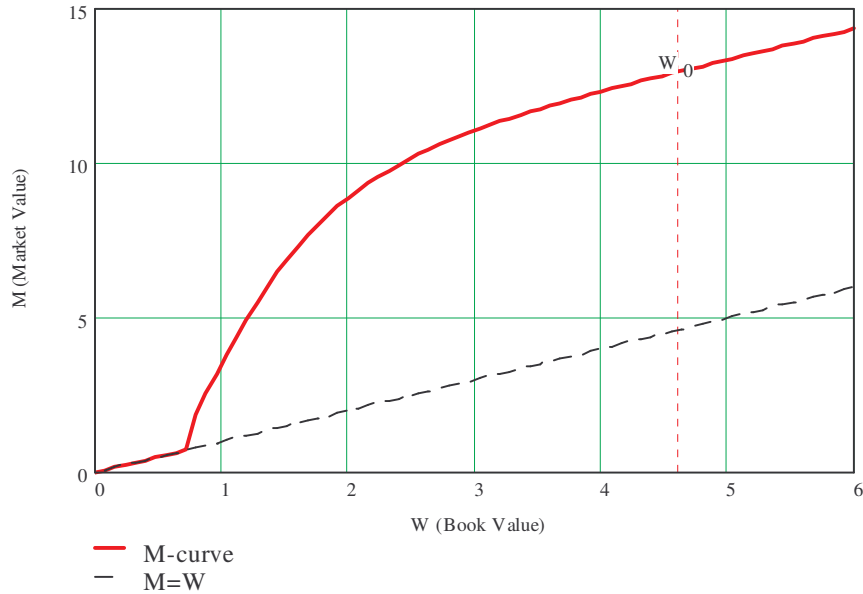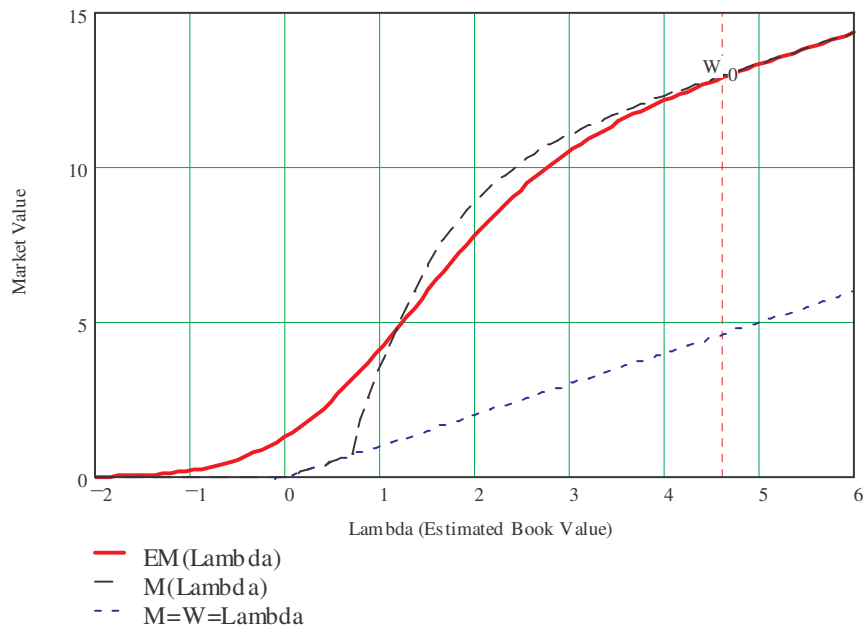

Figure 1: Example *M*-curve

Figure 2: Investor Estimate of Market Value

Note that even if investors' best estimate of book value is negative, their uncertainty may cause them to put a positive market value on the firm. On the other hand, there is a broad region where $E_M < M$. These are due to Jensen's Inequality applying to the convex and concave regions of the *M*-curve.

The opportunity function $\Theta(W) = \Delta M / \Delta W$, representing the multiple by which market value grows over the book value, is shown in figure 3.
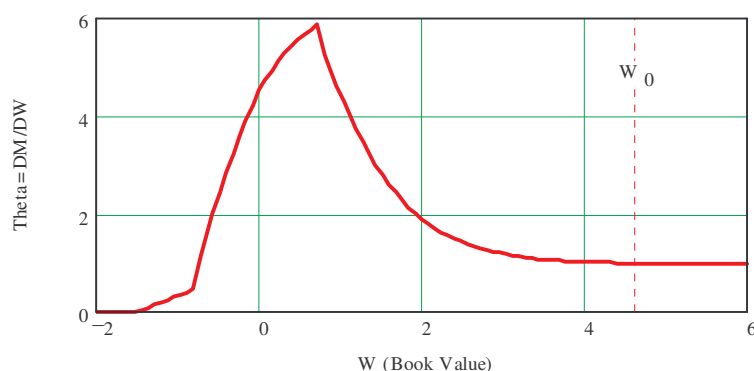

Figure 3: Opportunity Function (Theta)

If investors had perfect information about W, i.e. $\Lambda = W$ and they knew it, then pricing for a new issue would be given by equation 2.4 with $E_M = M(W + \Delta M)$. The opportunity to "move up the *M*-curve" would be capitalized, effectively shifting the curve left by ΔW and down by the outlay $(1+\kappa)\Delta W$. (The exception is in some bankruptcy states $W \leq 0$ where a negative issue price is required, obviating the stock issue.) Shifted *M*-curves are shown in figure 4 for $\Delta W = 1.5$ and 3. The ability to recapitalize arbitrary ΔW at a cost of κ results in an *M*-curve with minimum slope of 1 and maximum slope of $1+\kappa$. As $\kappa \rightarrow 0$, a linear *M*-curve means that Modigliani-Miller irrelevancy of risk management ensues and optimal W is determined by the balance between profitability (as a function of W) and the opportunity cost of holding W rather than giving it back to shareholders, as was shown in Major (2008).

With uncertainty, on the other hand, pricing depends on the extent and sign of the estimation error X_0 that happens to exist at the time of announcement.
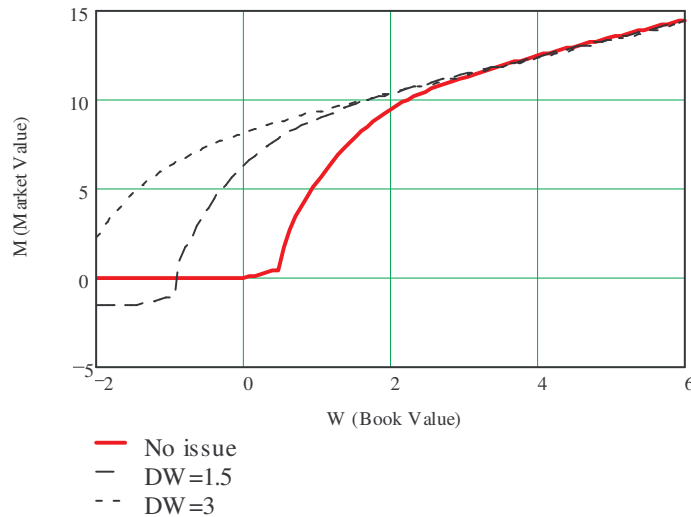
Figure 4: Fully-Informed *M*-Curves Anticipating Issue

2.4 Critical Estimation Error for Will-Issue

The uninformed will-issue condition (2.5) is satisfied for values of Λ_0 greater than a certain critical threshold $\Lambda_{crit}^u = W + X_{crit}^u$ (for nondecreasing *M,* a reasonable assumption in general and true in the case of this numerical example). X_{crit}^u is shown in figure 5.

For higher (more optimistic) values of X the will-issue condition will be satisfied. In the high opportunity zone $0<W<1$, an estimate can be quite pessimistic and still suffice. In the high linear zone $W>4$, the estimate has to be optimistic enough to cover the transaction cost. In the insolvency zone $W<0$, the estimate has to be at least optimistic enough to assume that post-issue, the firm will be solvent.
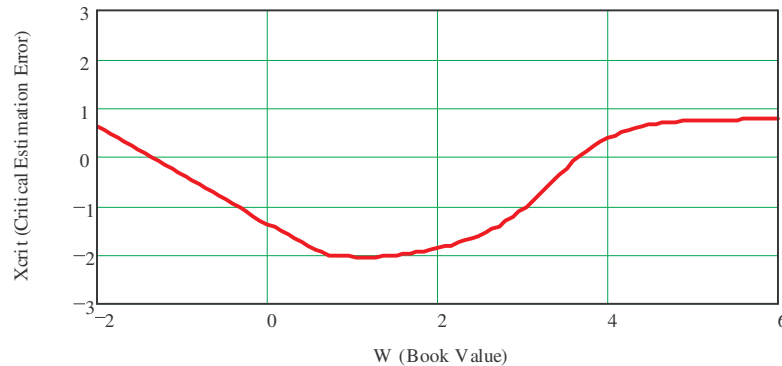

Figure 5: Critical Estimation Error for Will-Issue (Uninformed Case)

Given the distribution for X, we can determine the long-run probability that market pricing will be such that issue can be successful. In other words, in contemplating a date sufficiently far in the future so that current market conditions are irrelevant, if the firm will find itself at W, what is the probability that the corresponding market estimate of W is sufficiently high as to support issue? For our example, those probabilities are given in figure 6. This figure makes intuitive sense relative to figure 5. However, it is not all that meaningful, because it does not take into account the market reaction to the issue announcement.
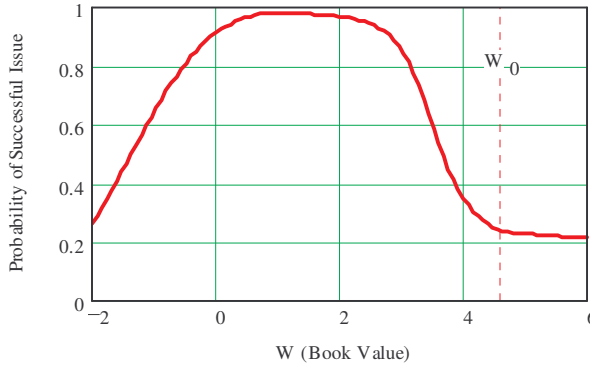

Figure 6: Probability of Successful Issue (Uninformed)

3. THE REACTION TO THE ISSUE ANNOUNCEMENT

We now assume investors know about the will-issue condition. Upon hearing of the forthcoming issue, they will immediately adjust their bid price to take this information about their estimation error X into account. In contrast to the uninformed case discussed in section 2, we will refer to this as the "equilibrium" case. Appendix B derives the equilibrium condition, which is stated here without proof.

Recall the will-issue condition $P > \Psi(W)$ of equation 2.2. This is a condition on price from management's perspective. From the investor perspective, it is a condition on W and therefore a condition on $X_0 = \Lambda_0 - W$. For investors to use the issue announcement as information that their pricing error is acceptable to management, and to update their pricing, and for management to anticipate this updating and still to accept the pricing, equilibrium pricing must satisfy the following:

$$P_{equil} = E\big[M(\Lambda_0 - X + \Delta W)\,\big|\, P_{equil} > \Psi(\Lambda_0 - X)\big] - (1 + \kappa) \cdot \Delta W \qquad (3.1)$$

where expectation is taken with respect to the distribution of X. Note that equilibrium pricing is a function only of the initial investor estimate Λ_0 (and the other parameters of the model), not the true W, under the assumption that the firm finds the equilibrium price acceptable; we may write it as $P_{equil}(\Lambda_0)$. Figure 7 compares equilibrium pricing with uninformed pricing.
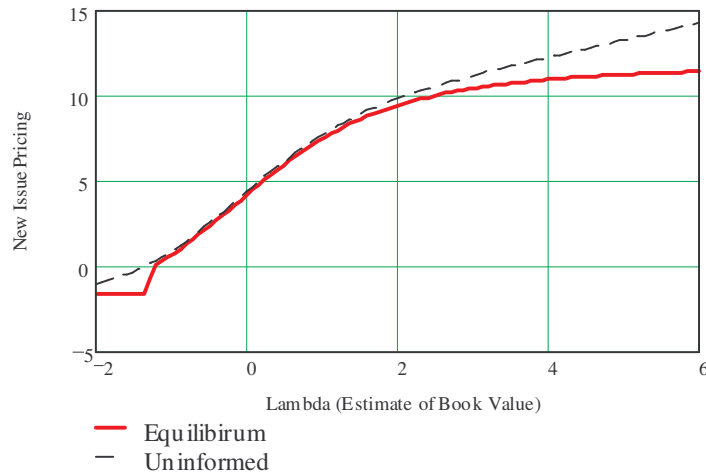

Figure 7: Post-Announcement Issue Pricing With and Without Using Announcement as Information About Book Value Estimate

Notice that at no value of Λ is the equilibrium price higher than the uninformed price. Since M ultimately increases linearly with W, $\Psi(W)$ ultimately increases (without bound). The $P > \Psi(\Lambda_0\text{-}X)$ condition therefore serves to eliminate a left-unbounded interval of X values. For this particular M-curve, Ψ is nondecreasing throughout its range and the new information *only* serves to eliminate a left-unbounded interval of X values, causing investors to decrease their estimate of W and hence of M. Around $\Lambda = 0$, high opportunity means that large negative estimation errors can still be tolerated, therefore the announcement comes as no surprise. At very high Λ, announcement strongly suggests that investors have overestimated W and need to readjust downwards.

With equilibrium pricing, the probability of successful issue is also different (and lower) than that calculated by uninformed pricing. With equilibrium pricing, successful issue depends on a sufficiently high price ($P_{equil} > \Psi(W)$) after the adjustment given by equation 3.1, which is not higher than the price given by the uninformed equation 2.4. It appears that over most of its range, equation 3.1 is invertible, therefore a critical price $\Psi(W)$ implies a

critical pre-announcement value for the investor W estimate

$$\Lambda^e_{crit} \equiv P^{-1}_{equil}\left(\Psi(W)\right) \tag{3.2}$$

and, equivalently, a critical estimation error X^e_{crit}, and therefore a probability that sufficiently high Λ_0 obtains. This will be no greater than the uninformed successful issue probability computed in section 2.4. This is shown in figure 8. Equilibrium adjustment most dramatically affects the high end where there is no genuine opportunity and investors will punish the firm for a new issue announcement.
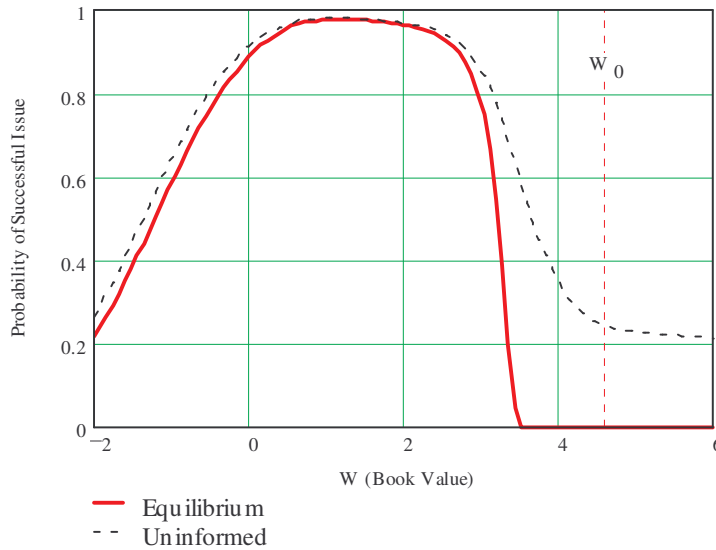

Figure 8: Long-Run Probability of Successful Issue as a Function of Book Value

If issue is successful, its price will be given by $P_{equil}(\Lambda_0)$. What is the expected price, conditional on successful issue? The key random variable is again X_0, and the expectation is taken with respect to the condition that $X_0 > X^e_{crit}$. The result is depicted in figure 9. The solid line represents the conditional expected issue price. The dashed line represents the minimum price that management would accept, that is, the price that equates the existing shareholders' no-issue and post-issue wealth. The cross-hatched line represents the post-issue *M*-curve, as given by equation 2.4 with $\sigma_X=0$; this is the highest price that fully-informed investors would be willing to pay. The expected issue price in this graph only extends to W=3.5 due to numerical difficulties in computing the conditional expectation when the required mispricing is greater than 10 standard deviations out. Note that for $W<-0.1$, the conditional expected issue price is *higher* than post-issue *M*, with a material probability of success. That is, there is a material probability (as high as 90%) that investors

will be sufficiently optimistic that they are willing to pay more than the new issue is actually worth to them.
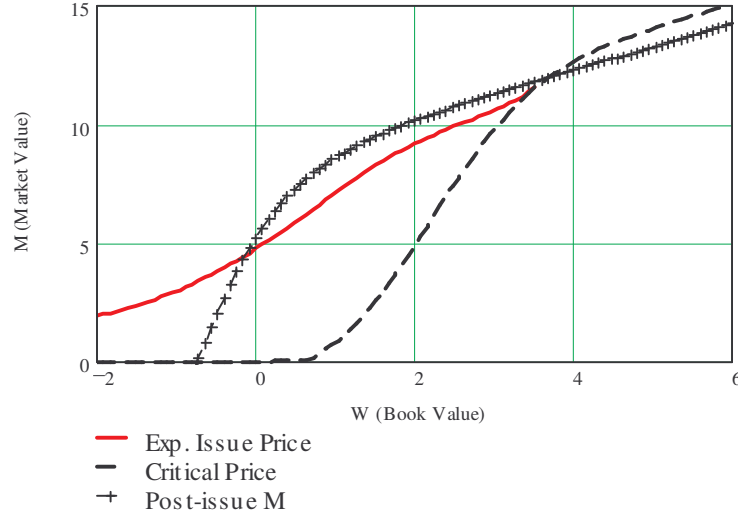

Figure 9: Expected Issue Price, Conditional on Successful Issue

4. THE COST OF INFORMATION ASYMMETRY

We define the effective cost of information asymmetry, as measured by management on behalf of existing shareholders, as the difference between (1) the value of their shares if they were to fund the issue themselves and (2) the (unconditional) expected value of their (possibly diluted) shares with the possibility of issue under the above model.

The value of the firm with surplus W, if an issue is to be funded proportionally by existing shareholders (i.e., no dilution of their ownership), is given by the maximum of $M(W)$ and $M(W+\Delta W)-(1+\kappa)\Delta W$. If it is to be funded by new investors at a particular issue price P, the diluted value of the old shares is given by $M_{dil}(P)$, defined in equation 2.1, if the issue succeeds at price P. (Note that if there is genuine opportunity ($\Theta>1+\kappa$) and investors are fully informed, then M_{dil} is equal to the self-funded value.) If the issue does not succeed, the value is still $M(W)$. The expected value is therefore given by

$$EM_{dil}(W) \equiv p_s(W) \cdot E\big[M_{dil}\big(P_{equil}(\Lambda_0)\big)\big|\ P_{equil}(\Lambda_0) > \Psi(W)\big] + (1 - p_s(W)) \cdot M(W) \qquad (4.1)$$

where p_s signifies the probability of the condition $P_{equil}(\Lambda_0) > \Psi(W)$. Here, expectations and probabilities are computed based on the marginal distribution of $\Lambda_0 = W+X_0$.

The results are shown in figure 10. The solid curve is EM_{dil}, the unconditional expected value of the existing shareholder's shares, taking into account the possibility of raising ΔW through new investor equity. The dashed curve is existing shareholders' wealth as it would be if the existing shareholders could fund the new issue themselves.
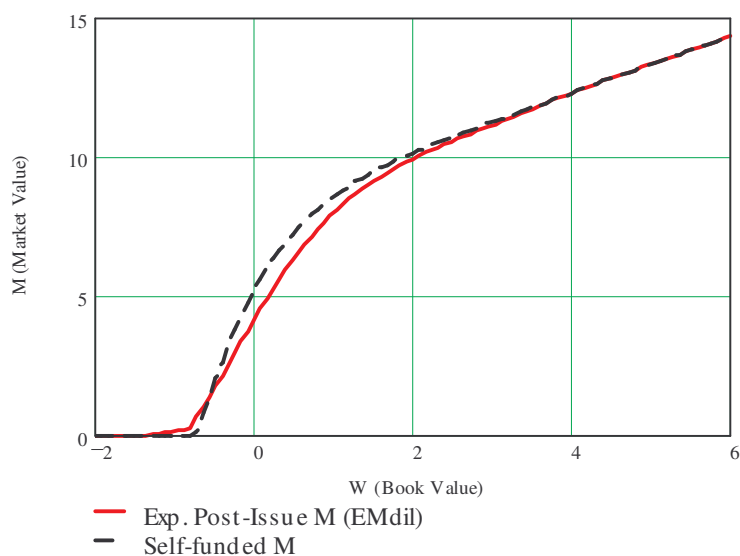

Figure 10: Expected Post-Issue Value of Pre-Issue Shares

The difference between these two curves, which we interpret as the cost of information asymmetry, is shown in figure 11. In this graph, the cost is represented by the solid curve, with vertical axis measuring dollars. Represented by a dashed curve is the opportunity $\Theta = \Delta M/\Delta W$, which is scaled to fit the graph (cf. figure 3). This shows that most of the opportunity zone (W<4) is adversely affected by the information asymmetry, and the cost closely tracks the opportunity.
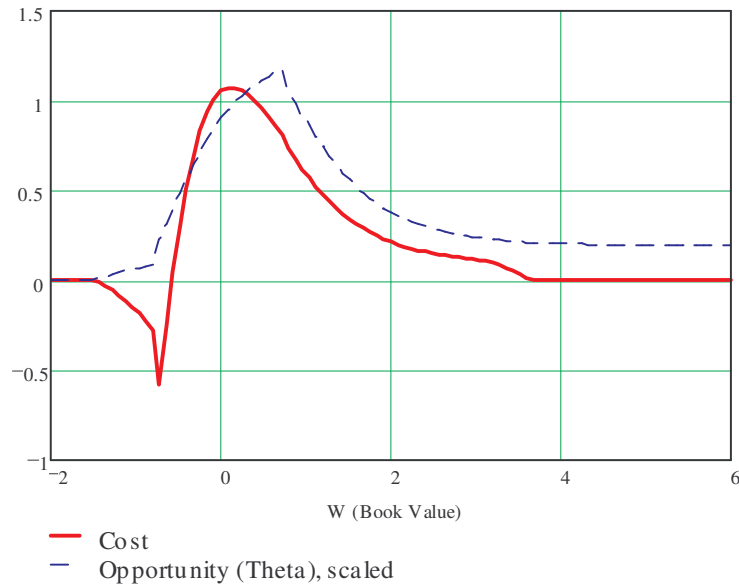
Figure 11: Cost of Information Asymmetry Compared to Investment Opportunity

The dollar cost can be translated into an "effective κ" of information asymmetry by solving the following:

$$EM_{dil} = M(W + \Delta W) - (1 + \kappa_{eff}) \cdot \Delta W \tag{4.2}$$

$$\kappa_{eff} = \frac{M(W + \Delta W) - EM_{dil}}{\Delta W} - 1 \tag{4.3}$$

This is graphed in figure 12. The solid curve is the effective cost of external capital as given by equation 4.3. The dashed curve is the long-run probability of successful issue. In contrast, the dotted horizontal line shows the transaction cost of external capital, which is assumed at 5% for this example. The effective cost factor peaks at 0.77 for $W = 0.1$, just above insolvency. It declines as W increases. For very high W, it is zero because (1) success has probability zero and therefore EM_{dil} equals $M(W)$, and (2) $M(W+\Delta W) = M(W) + \Delta W$ in the linear range. As might be expected from figure 11, for $W < -0.6$, the effective cost is negative.
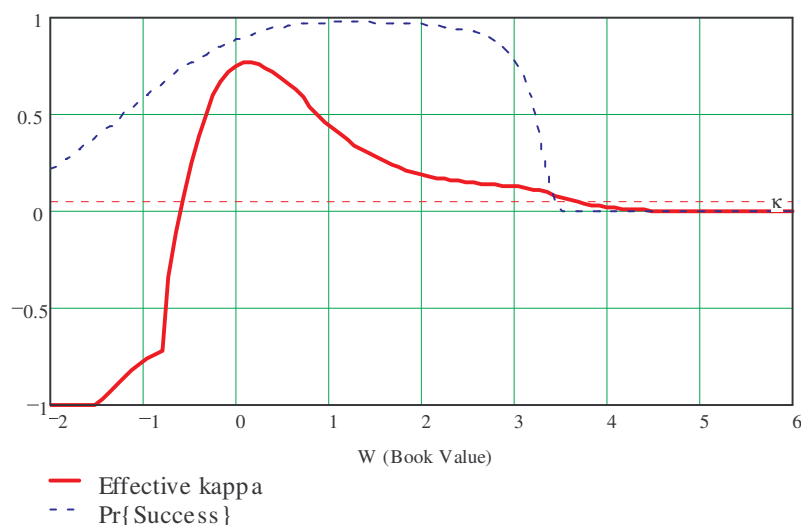
Figure 12: Effective Cost of External Capital Due to Information Asymmetry

5. VARYING THE ASSUMPTIONS

In this section, we explore the different κ_{eff} and p_s curves that result from varying some of the assumptions in the numerical example.

In the Major (2008) model, κ is intended to apply to infinitesimal values of ΔW, whereas in this example, we used a fairly large value of 1.5. Figure 13 shows the effective κ for some smaller values of ΔW. As ΔW is made smaller, the κ_{eff} profile becomes sharper and with a higher maximum. This is consistent with the shape of the *M*-curve (figure 1) with smaller ΔW more accurately "reading" the steep slope of the curve around $W = 0.7$.

Probability of successful issue also suffers when ΔW is decreased, as shown in figure 14.

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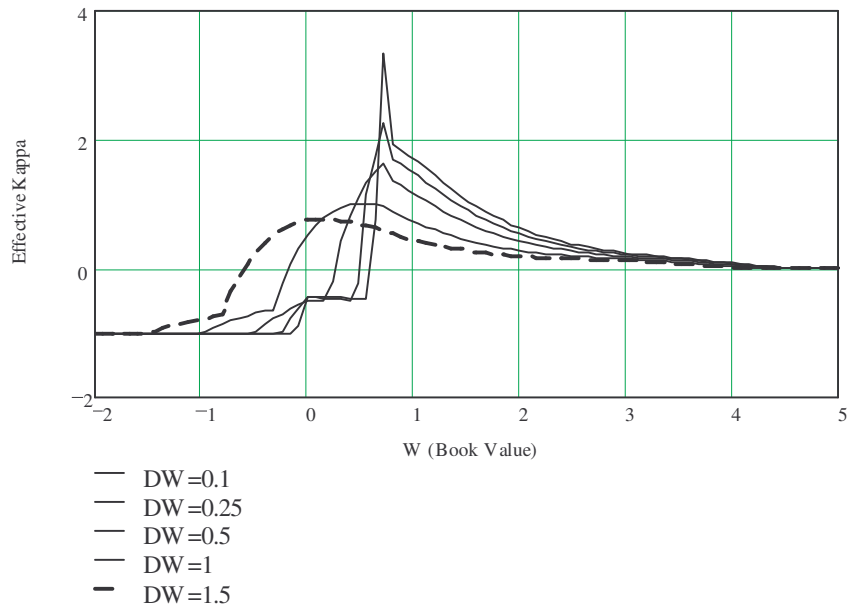
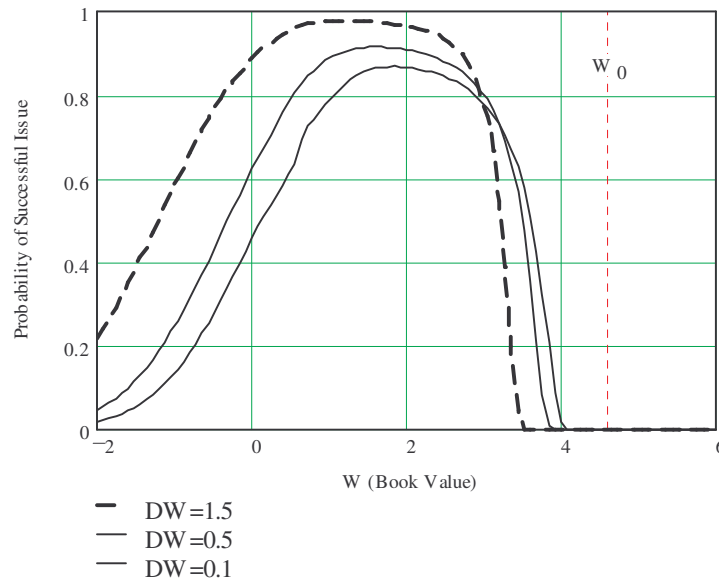**Figure 13: Effective κ for Various Values of ΔW**

Figure 14: Probability of Successful Issue for Various Values of ΔW

The magnitude of uncertainty assumed here corresponds to approximately 13% coefficient of variation on liabilities. This might be regarded as "normal" in some lines of business. After a catastrophe, however – a situation likely to call for raising capital – the uncertainty in liabilities is magnified. The results of doubling the standard deviation of X are

shown in figures 15 (κ_{eff}) and 16 (p_s). Unsurprisingly, both suffer. The maximum κ_{eff} nearly doubles, and its location shifts to a higher W value. Likewise, the probability of successful issue decreases materially, except in the deep insolvency region $W<-1.2$ where the prospects of taking advantage of investor mispricing increase.
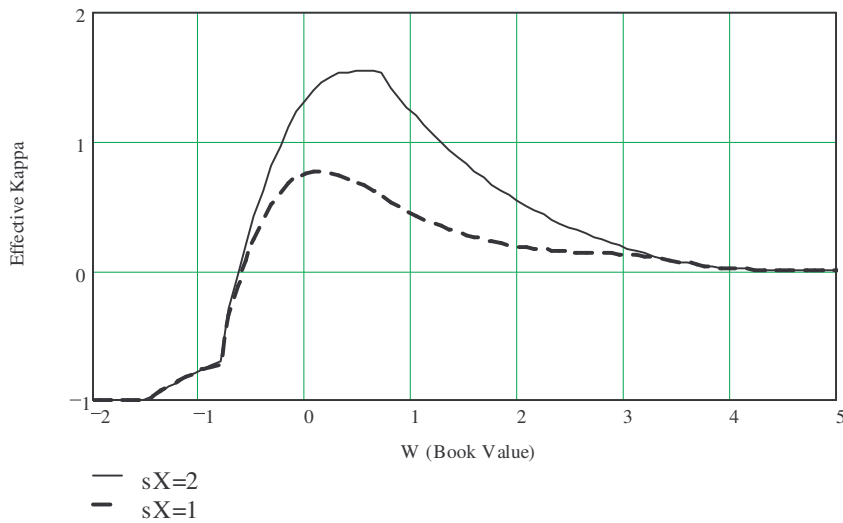

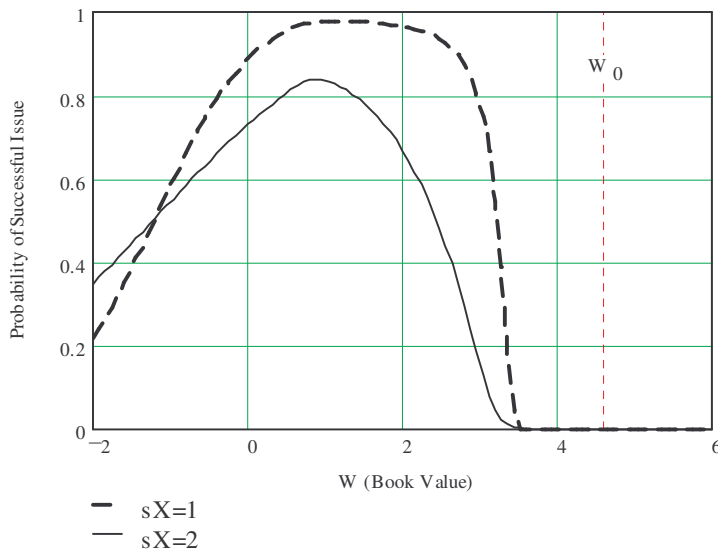**Figure 15: Effective Cost of External Capital When Uncertainty is Increased**

Figure 16: Probability of Successful Issue When Uncertainty is Increased

The numerical model used in this paper, representing the US P&C industry as a whole, implies a price/book ratio of 2.84 at the current level of industry surplus. Such a high ratio is rarely achieved by individual firms. For example, in Doherty & Lamm-Tennant (2009) a study of 63 insurers as of the second quarter 2009 found the top three p/b ratios were 2.47, 2.09, and 1.31. By rescaling the *M*-curve, we may achieve lower p/b ratios and examine the consequences for κ_{eff} and p_s. Define $M_\alpha(W) = (1-\alpha)W + \alpha M(W)$, in effect scaling the franchise value by a factor of α. Taking $\alpha = 0.5$ or 0.25 gives us a p/b ratio (at current surplus) of 1.92 or 1.46, respectively. Figure 17 shows the effective cost of capital and figure 18 shows the probability of successful issue associated with three M_α-curves.

alpha=1
alpha=0.5
alpha=0.25
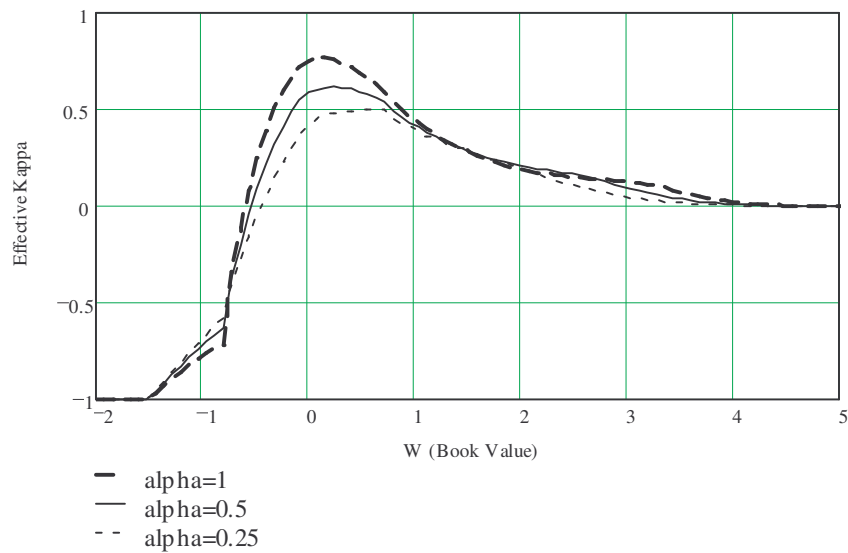
Figure 17: Effective κ for Various Franchise Scales

Whereas the effective cost moderates as the franchise value shrinks, the probability of successful issue also declines. The moderation in effective cost is due to both the falling market value (cost is the difference between self-funded and expected diluted share value, both of which decrease with decreasing franchise value) and falling success probability. With no franchise value, there is no possibility of issue and the effective cost is therefore zero.

Figure 18: Probability of Successful Issue for Various Franchise Scales

6. CONCLUSION

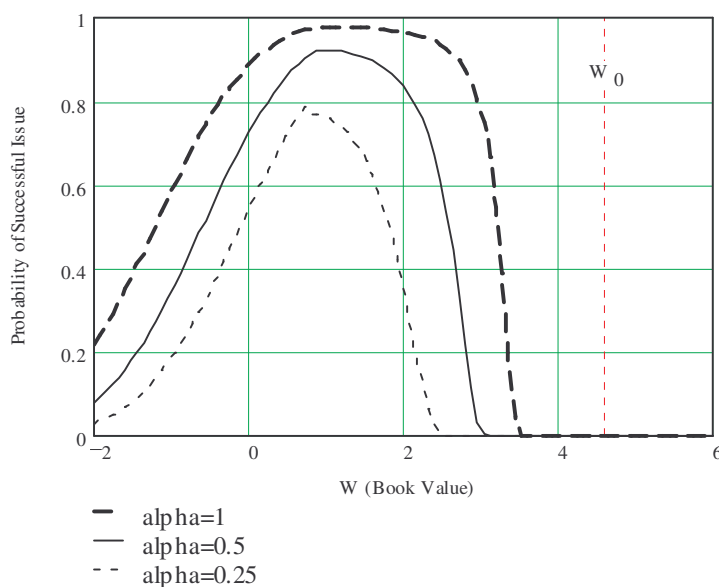This paper analyzed the impact that uncertainty concerning the firm's wealth (financial slack) has on the probability of success, and effective cost, of raising capital via seasoned equity offering. It did so by adapting the Myers-Majluf and Seog-Lee approaches to the Major-Froot *M*-curve model.

The numerical results – and to some extent the qualitative results – are merely indicative, however, because any particular firm will have its own distinct *M*-curve and parameters. A further complication is that here the *M*-curve is given exogenously, but in the model of Major (2008) it is the endogenously-derived solution to a Bellman equation. Because recapitalization enhances the survival of the firm, thereby raising the expected length of time to receive dividends, the endogenous solution raises the level of the *M*-curve; for this example, the effect can be worth as much as 1.5, depending on the cost of external capital. To fully conform to that model, the equilibrium informed pricing would need to be part of the equilibrium *M*-curve solution. Moreover, if an endogenous risk condition on profits

(Appendix A) defines customer risk aversion, this would arguably also need to form part of the equilibrium.

Nonetheless, this paper suggests the magnitudes of the effects that might be expected in a more sophisticated analysis. Based on a plausible *M*-curve and parameters representing the US property and casualty insurance industry as a whole, effective costs peaking in the range of 100% to 400% were calculated to arise from information asymmetry effects. This is much higher than the 3% to 5% transaction costs typically encountered (Butler et al. 2002). Moreover, it was found that there is a material risk – frequently in excess of 10% – that issue will not succeed. Both the effective cost and probability of success depend on wealth, size of issue, magnitude of uncertainty, and the magnitude of franchise value represented in the *M*-curve.

For very high values of surplus, where there is no economic value to be gained from a new issue, information effects drive the probability of successful issue to nearly zero. However, in some states of covert insolvency, there is a significant probability – perhaps 30% to 50% – of successful issue at a price that represents a transfer of wealth from new shareholders to existing shareholders.

List of symbols

W	Wealth, a.k.a. book value, balance sheet surplus or financial slack of the firm; variable
$M(W)$	(Theoretical, ultimate) market value of shareholder equity in the firm; fixed function; see figure 1 and Appendix A
ΔW	Amount of capital to be raised; fixed background parameter; 1.5 for example
ΔM	$M(W+\Delta W)- M(W)$
P	Price of new stock issue; generic variable
Q	Number of outstanding shares pre-issue; assume $= 1$
N	Number of new shares to be issued; $NP=(1+\kappa)\Delta W$
P_0	Actual market value of firm prior to any thought of stock issue
P_1	"Uninformed" (no information effects) investor bid price for the new issue; equation 2.4
κ	Transaction cost rate for new issue (applies to ΔW); fixed parameter; 0.05 for the example
$M_{dil}(P,W)$	Diluted value of existing shareholder equity at issue price P; equation 2.1
$\Theta(W)$	"Opportunity" $\Delta M /\Delta W$; figure 3
$\Psi(W)$	Will-issue minimum price from management's perspective; equation 2.2
Λ	Investor estimate of W; random variable
Λ_0	Λ value corresponding to P_0
X, resp. X_0	Estimation error Λ-W, resp. Λ_0-W; random variables; assumed zero mean
σ_X	Standard deviation of X; fixed background parameter; 1 for the example
$E_M(\Lambda)$	Investor Bayesian posterior mean estimate of M; equation 2.3; figure 2
Λ^u_{crit}	Lower bound of Λ values satisfying will-issue condition (equation 2.5) in the uninformed case
X^u_{crit}	X value corresponding to Λ^u_{crit}; figure 5
$P_{equil}(\Lambda_0)$	Equilibrium (information effects) investor bid price (cf. P_1); equation 3.2 and Appendix B
Λ^e_{crit} and X^e_{crit}	Critical pre-announcement Λ and X values for equilibrium successful issue; equation 3.2
EM_{dil}	Unconditional expected M_{dil} ; equation 4.1
p_s	Probability of successful issue; equation 4.1

Appendix A: The PCOMP *M*-Curve

For our model firm, we take the US Property & Casualty Industry Aggregate ("PCOMP") from Highline Data.[3] Analysis of the 1995-2008 data, supplemented with NCCI-reported 1985-2008 industry combined ratios (Mealy 2009), suggests the following modeling assumptions:

•   The current book value (surplus) of the "firm" is 4.625 (as in the main text, monetary figures are denominated in USD 100,000,000,000).

•   Annual underwriting profits before catastrophe losses are normally distributed with mean 0.06849 and standard deviation 0.3538.

•   Annual aggregate catastrophe losses are given by an empirical distribution function provided by Risk Management Solutions;[4] this distribution has a mean of 0.3163.

•   Investment income is normally distributed with mean 0.7285 and standard deviation 0.1541. This represents a 6% rate of return on invested assets of 12.14 or 50bp over the assumed long-run risk free rate of 5.5%; therefore a simplified approximate risk neutralization is to subtract 0.0607 from the investment income.

•   The previous three random variables are mutually independent.

•   Non-cat underwriting results and catastrophe losses are independent of the financial markets.

•   A tax rate of 20% applies to profits (and losses).

•   The investment rate of return on marginal surplus is the same as the average return on invested assets, 6%.

•   From 1996 to 2008, cash and invested assets grew at a compound rate of 4.5% and direct earned premium grew at 4.8%. The firm's future long-run growth rate is assumed 4.5%.

•   The cost of external capital is assumed infinite (no recapitalization).

•   Customer risk aversion is reflected in a premium adjustment described next.

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[3] www.highlinedata.com
[4] www.rms.com

The assumptions about profitability are based on year-end 2008 industry surplus. If a firm were to encounter financial difficulties, it is likely that it would experience a reduction in the premium rates it could charge, or an increase in expenses, or a shift in business towards policyholders with higher claim rates or claim severities, etc., all of which would tend to lower expected profits. Thus, expected profitability is modeled as a function of surplus.

At the current level of surplus, 4.625, the probability distribution for change in surplus is given by the baseline assumptions listed above. This is shown in figure A.1. The horizontal axis is pre-tax change in surplus. The vertical axis is the "logit" $\log_{10}(p/(1-p))$ where p is the probability of a lower result. A logit of 2 (resp., -2) corresponds approximately to a p of 0.99 (resp., 0.01).
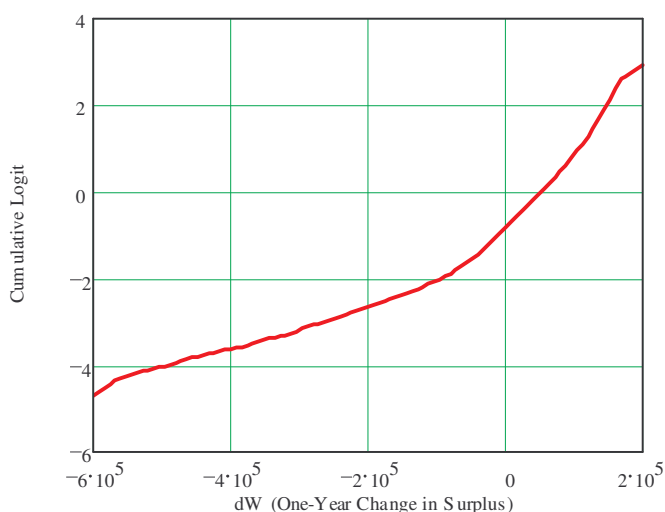

Figure A.1: Distribution Function for Change in Surplus (Baseline)

At other levels of surplus, the distribution for change in surplus is mean-shifted. In this model, we assume that for every dollar increase in the one-year expected policyholder deficit (EPD) (Venter & Major 2003), customers require a twenty dollar reduction in annual premium (Wakker et al. 1997). Note the EPD is calculated on a pre-tax profit and loss basis, as customers cannot expect the firm to benefit from tax relief in the event of insolvency. This downward adjustment to profitability *includes its own impact* on risk, so requires an equilibrium solution. This is shown in figure A.2.
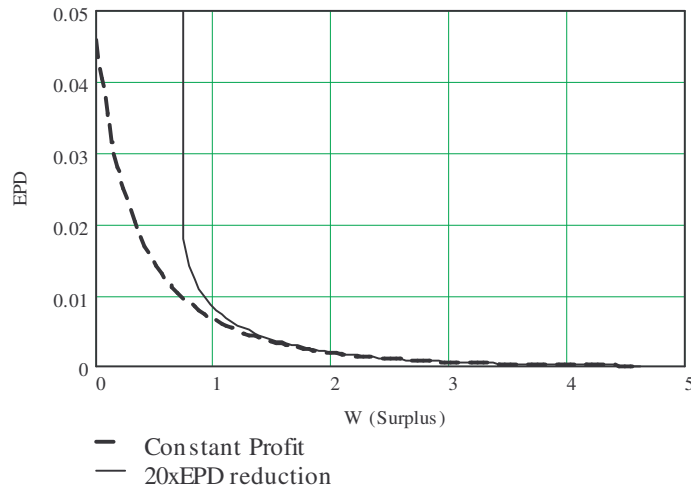
Figure A.2: Expected Policyholder Deficit as a Function of Starting Surplus

In figure A.2 the dashed line represents the expected policyholder deficit as a function of starting surplus if all distributional assumptions were held constant across W values. The solid line shows the EPD if the distributions were mean-shifted so that expected profit was reduced by 20 times (EPD(W)-EPD(W_0)). The two curves meet by definition at W_0=4.625, but they track closely, being within 5% of each other, down to W=2 where EPD is about 0.002. At surplus levels below that, the curves separate and the profit-adjusted EPD diverges around W=0.7, which, based on Best's Capital Adequacy Ratio (BCAR)[5] calculations, corresponds approximately to a "B" rating. The profit adjustment was capped at -5, roughly corresponding to a zero premium rate.

With the above assumptions, proprietary Guy Carpenter software was used to solve for the *M*-curve and optimal capital retention strategy that maximizes the expected present value of dividend flows to shareholders. Discounting was done at the risk-free rate and expectation was taken with respect to the previously mentioned risk-neutralized distribution for change in wealth. The solution is the *M*-curve depicted in figure 1 in the main text. The optimal capital strategy consists of three bands: $W \leq 0.73$ calls for immediate disbursal of all surplus to shareholders and subsequent going out of business, $0.73 < W \leq 4.95$ calls for retention of profits with no dividends, and $4.95 < W$ calls for immediate dividending of all profits, returning W back to the 4.95 optimal level.

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[5] A. M. Best, http://www.ambest.com/ratings/methodology.asp

Appendix B: The Equilbrium Price Condition

In this section, we derive the equilibrium issue price by examining a stepwise progression of price updates. We do not attempt to prove that there is an equilibrium; rather the goal is to derive the condition that any equilibrium, if it exists, must satisfy.

Investors start out thinking the firm's wealth is $\Lambda_0 = W + X_0$ instead of the true W. The uninformed issue price, given by equation 2.4 in the main text (assuming an issue is possible), is $P_1 = E_M(\Lambda_0 + \Delta W) - (1+\kappa)\Delta W$. Then investors hear that management finds P_1 an acceptable price. This tells them $P_1 > \Psi(W) = \Psi(\Lambda_0 - X_0)$ (equation 2.5) and they update their pricing. Rather than the previous

$$P_1 \equiv E\big[M\left(\Lambda_0 - X + \Delta W\right)\big] - \left(1 + \kappa\right)\cdot \Delta W ,\qquad (A.1)$$

(where expectation is taken with respect to the unconditional distribution of X) they update the bid price to

$$\hat{P}(1) \equiv E\big[M\left(\Lambda_0 - X + \Delta W\right) \big| P_1 > \Psi(\Lambda_0 - X)\big] - \left(1 + \kappa\right)\cdot \Delta W .\qquad (A.2)$$

That is, investors have trimmed their prior to include only X satisfying $P_1 > \Psi(\Lambda_0 - X)$.

The firm *still* finds the price acceptable, i.e. $\hat{P}(1) > \Psi(\Lambda_0 - X_0)$. The second update is then

$$\hat{P}(2) \equiv E\big[M\left(\Lambda_0 - X + \Delta W\right) \big| \hat{P}(1) > \Psi(\Lambda_0 - X)\big] - \left(1 + \kappa\right)\cdot \Delta W .\qquad (A.3)$$

If the firm continues to find bids acceptable, the sequence proceeds as

$$\hat{P}(n+1) \equiv E\big[M\left(\Lambda_0 - X + \Delta W\right) \big| \hat{P}(n) > \Psi(\Lambda_0 - X)\big] - \left(1 + \kappa\right)\cdot \Delta W \qquad (A.4)$$

and if it reaches an equilibrium, both $\hat{P}(n)$ and $\hat{P}(n+1)$ will be replaced by P_{equil}, as given in equation 3.1 in the main text.

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