Corporate investment decisions under asymmetric information and uncertainty

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Abstract. This paper develops a model to study corporate investment decisions using the principal-agent framework. The model has asymmetric information where the agent knows the true value of the company and the principal does not. The model also has uncertainty where the company is presented an investment opportunity with a certain cost and random benefit. The agent must decide whether they will sell stock to the principal and make the investment. Results show that the information asymmetry imposes a cost on the principal because the agent will forgo some profitable projects or undertake some with expected losses. A procedure for the principal to distinguish undervalued and overvalued companies is presented.

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1. Introduction

The relationship between information and incentives in context of corporate decision making is complex. It is possible to explore this complexity using the Principal-Agent model. In an important paper, Myers and Majluf (1984) showed there is an adverse selection problem in corporate investments due to asymmetric information. My research extends this result to include uncertainty and shows a rich new set of results.

This paper will start by reviewing the Myers and Majluf (1984) paper, henceforth called MM. Using simplified notation, I will show that the information asymmetry imposes a cost on the principal where the principal overpays for all investments. Keeping this notation, I will show that it is convenient to build uncertainty into the model by setting the benefit of the investment as a random variable. In the model with randomness, if there is no information asymmetry then the agent will invest in all projects with positive Net Present Value (NPV). With asymmetry, the agent may forgo positive NPV projects or undertake negative ones, both of which impose a cost on the principal. To mitigate these problems, I will show how the principal can distinguish some agents who value their company higher than the principal.

The type of information asymmetry in this model is hidden type, where the agent knows the true value of the company and the principal does not. This is a canonical framework and it is useful for analyzing corporate investment decisions. The agent decides when a corporation invests, yet it must raise capital from a principal; therefore, any difference of opinions between principal and agent may be an important driver in the agent's decision. The model starts with the agent owning all of the company. The agent represents management, or current owners, and an opportunity to invest in a new project is presented to the agent. In MM, the cost (C) and benefit (B) of the investment are certain and public information, whereas the benefit (B) is a random variable in my model. Therefore, my model has to propose a new decision making criteria that allows the agent to deal with randomness.

In order to make the investment, the agent must sell stock to the principal. In MM, the principal has bargaining power and the amount of stock that the principal receives is related to the benefit of the project. My model has to adjust this contract to deal with uncertainty, which can be done in two ways. One way gives the same results as MM, whereas another more realistic contract gives a new set of results. It is important to consider both of these contracts because they can be used to distinguish agents who are being overvalued by the principal from those who are undervalued.

2. Analysis

The following are the main technical sections of the paper. First, I present notation and review the MM model. I show that asymmetric information causes an adverse selection problem and this imposes a cost on the principal relative to perfect information. In the second section, I show how uncertainty can be included in the MM model using similar notation and assumptions. I show that the agent invests in all positive NPV projects when there is no asymmetric information, however, asymmetric information will impose a cost on the principal in one of several ways. The type of the cost depends on the parameter values, which I explore in detail. In the third section, I show how the principal can use two different types of contracts to distinguish different types of agents and mitigate the costs of asymmetric information.

2.1 Review of the MM model

The MM paper has made a large impact on research in corporate finance (Klein, O'Brien, Peters 2002). The paper has led to the 'pecking order' theory of capital structure, based on the way different securities effect information asymmetry. Further, the paper is actually increasing in popularity. Although other influential scholars have addressed the same issues as MM – see Fama (1980) or Jensen and Meckling (1976) – they have not had the same lasting impact. The average number of times that MM was cited per year was fifty from 1990-1995. However, from 2009-2011, the average number of citations has grown to approximately 160 (Thomson Reuters

2012). Despite this large amount of activity, it is not clear that anyone has extended the MM model to deal with uncertainty.

The MM paper considers a company that has value $\mathrm{V^A}$ known to the agent. Although it is a big assumption to say a company has a 'true' value, it is essential for the model. The principal believes the value of the company to be $\mathrm{V^P}$, which is calculated as an expectation in MM. The investment opportunity has cost C and benefit B, which are certain and public information in MM. After investment occurs, the true value of the company is defined as $\mathrm{V^A + B}$ and the principal believes it is $\mathrm{V^P + B}$. The MM paper assumes $\mathrm{B} > C$, which means the project has positive NPV and the value of the company increases after investment.

The agent decides whether to sell stock to the principal and make the investment. Here, the MM paper makes a strong assumption. Since the principal knows B, MM assume that the agent will give sufficient stock that the principal receives all of the benefits of the investment. This assumption can be justified as the theoretical solution to the 'ultimatum game'. Since 1984 we have learned a lot about behavioural biases which show that this theoretical solution is very impractical (Bearden 2001). Therefore, this is a contentious assumption. Formally, the amount of stock which the principal receives is equal to $1 - \mathrm{Q} = \frac{\mathrm{B}}{\mathrm{V^P + B}}$. This represents the value of the principal's contribution (B) divided by the value of the company after the investment ($\mathrm{V^P + B}$).

To decide whether to invest, the agent compares utility before and after the investment. The MM paper uses a linear utility function, which means the decision is based on profit maximization. The agent's value before the investment is $\mathrm{V^A}$, and value after is $\mathrm{Q(V^A + B)}$. The decision criteria involves the change in ownership (agent owns fraction $\mathrm{Q} < 1$ after investment) and the increase in value (true value becomes $\mathrm{V^A + B}$ after investment) of the company. The adverse selection result is derived in the appendix by combining the decision criteria and the amount of stock which the principal receives. Equation (1) states the result:

(1) Invest if $\mathrm{V^A \leq V^P}$

To see the cost of asymmetric information in the MM model, consider the case of perfect information. By definition, the principal and agent will both know the true value of the company and so Equation (1) will always be satisfied; agents will invest in all projects. Further, the amount of stock the principal will receive will be different in perfect information. The amount of stock exchanged will become the 'fair' amount based on the true value of the company: $\frac{V^A}{V^A+B}$. In the appendix, I show that the agent keeps a larger part of the company under asymmetric information. Therefore, the cost to the principal of asymmetric information can be seen as 'overpaying' for stock, or receiving less stock than they should based on their contribution.

2.2 Model with uncertainty

The new model that I propose will keep the information asymmetry of MM, where the agent knows the true value V^A and the principal knows an estimate V^P. The cost C will still be certain and public, however, the benefit B will be uncertain when the agent decides to invest. The timing is as follows: first, the agent and principal form their valuations; second, the agent decides whether to issue stock or not to the principal; third, if investment occurs then the value B is revealed. Although the timing of my model is based on MM, I need to adapt the agent's decision making criteria and the amount of shares that are exchanged to the case of uncertainty.

To extend the agent's decision making criteria, I propose a linear expected utility function. That is, $E\big(U(X)\big) = E(X)$ where X is a random variable, $U()$ denotes the linear utility function, and $E()$ the expectation of X. This means that the agent attempts to maximize expected profit when choosing whether to invest. As in MM, the agent compares the utility before and after the investment. For this utility function, the agent will use the following condition:

(2) Invest if $V^A \leq Q\left(V^A + E(B)\right)$

In Equation (2), the only random term is B. This is because Q has to be set when the investment occurs, before B is revealed. As in MM, Q is the fraction of the company which the agent owns after the investment. The principal receives $1-\mathrm{Q}$ for providing the cost C of the project. The contract $1-\mathrm{Q}$ needs to be revised to reflect uncertainty. The numerator of $1-\mathrm{Q}$ will be the value which the principal provides to the company after investment, whereas the denominator will be the total value of the company after investment.

One possible contract is $1-\mathrm{Q}=\frac{\mathrm{E(B)}}{\mathrm{V^P}+\mathrm{E(B)}}$. This is a 'mark to model' approach because the contract is set using the expected benefit, which is the output of some model. This contract gives the same results as MM because it only differs by a change of notation (replace B with $\mathrm{E(B)}$). The second case is $1-\mathrm{Q}=\frac{\mathrm{C}}{\mathrm{V^P}+\mathrm{C}}$, which is a cost based approach. For the intuition of this contract, consider how the value of the company is set in the time between the investment is approved and the benefit is revealed; the value of the company increases by the amount of money that is spent. This approach could be described by the expression 'don't count your chickens before the hatch'. This second case will be the focus of my attention:

(3) $$\mathrm{Q}=\frac{\mathrm{V^P}}{\mathrm{V^P}+\mathrm{C}}$$

With the decision making criteria, Equation (2), and the contract, Equation (3), it is possible to derive the solution for this problem. The solution determines when the agent will invest, based solely on variables that are known at the time of the decision. This solution is Equation (4):

(4) $$\frac{\mathrm{V^A}}{\mathrm{V^P}}\leq\frac{\mathrm{E(B)}}{\mathrm{C}}$$

In words, Equation (4) compares the amount by which the company is undervalued (if $\frac{\mathrm{V^A}}{\mathrm{V^P}}>1$ then the company is undervalued) to the profitability of the project (if $\frac{\mathrm{E(B)}}{\mathrm{C}}>1$ then the project has positive NPV). The condition states that all but the most undervalued companies will take a given project. Alternatively, it says that a company will only invest in the best projects available. In the next section, I will make these statements precise and show the cost imposed on the principal by information asymmetry.

2.3 Results

Using Equation (4), it is possible to consider a given project and compare what type of companies would invest in it. It is also possible to consider a specific company and compare what type of projects it would invest in. Each type of analysis can be represented graphically. However, the most important analysis of the results is based on whether a project has positive or negative NPV, and whether the company is overvalued or undervalued.

First, I present the case with no information asymmetry. As in MM, this means the agent and principal both know the true value of the company before investment ($\mathrm{V^A = V^P}$). Imposing this onto Equation (4) gives a familiar decision rule: invest in all projects with positive NPV. In simple terms, the NPV for a project is equal to the benefit minus the cost. It is reassuring that this new model gives this familiar result, which will be the benchmark for calculating the costs of information asymmetry. The positive-NPV decision rule is written as:

(5) Invest if $\mathrm{C \leq E(B)}$

To explore the effects of asymmetric information, I will discuss a given company. Let $\mathrm{y = \frac{V^A}{V^P}}$ then $\mathrm{y > 1}$ means the company is undervalued, whereas $\mathrm{y < 1}$ means the company is overvalued by the principal. An undervalued company will not invest in all positive NPV projects: all investments with $1 < \frac{\mathrm{E(B)}}{\mathrm{C}} < y$ will not be made. This imposes a cost on the principal relative to the benchmark case with no information asymmetry. Next, an overvalued company will invest in all positive NPV projects and even some negative NPV projects! This occurs because $y < \frac{E(B)}{C} < 1$ means that some projects with negative NPV will be approved. This imposes a different type of cost on the principal relative to perfect information. In either case, the principal is worse off under asymmetric information than perfect information.

In the case where $y = 1$, the company is perfectly valued and the agent will invest in all positive NPV projects. In this case, the information asymmetry has no effect and the outcome is the same as perfect information. Intuitively, this shows that there is an incentive for the principal to study the agent's business closely to best estimate the value and minimize agency costs.

Figure 1: Decision criteria for particular company

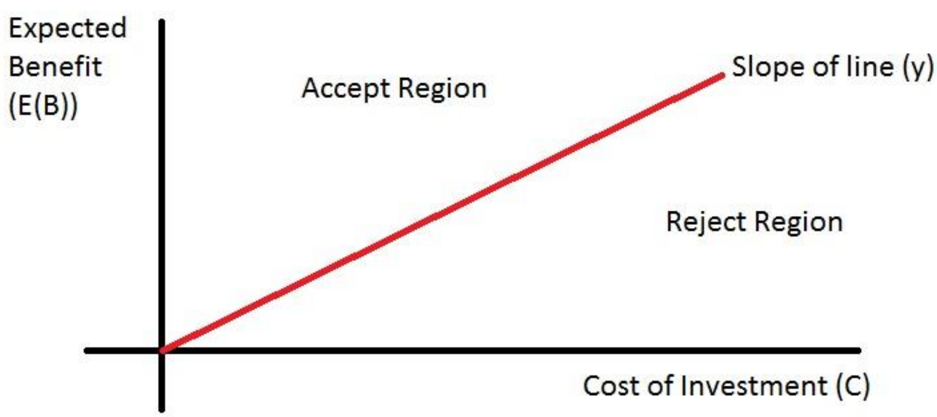


Figure 1 shows how a given company will evaluate all possible projects. The figure uses an arbitrary positive value for $y = \frac{V^A}{V^P}$ to show that there will always be some projects that the agent will accept and others they will reject. Naturally, the accept region is filled with projects that have the highest expected benefit. The line that is shown in Figure 1 is the indifference curve, where the agent's decision criterion is binding. Technically, this line is part of the acceptance region described above. Note that it may be possible to augment Figure 1 to show the costs of information asymmetry graphically, since the cost imposed by asymmetric information is related to the difference of y for a particular company and $y = 1$.

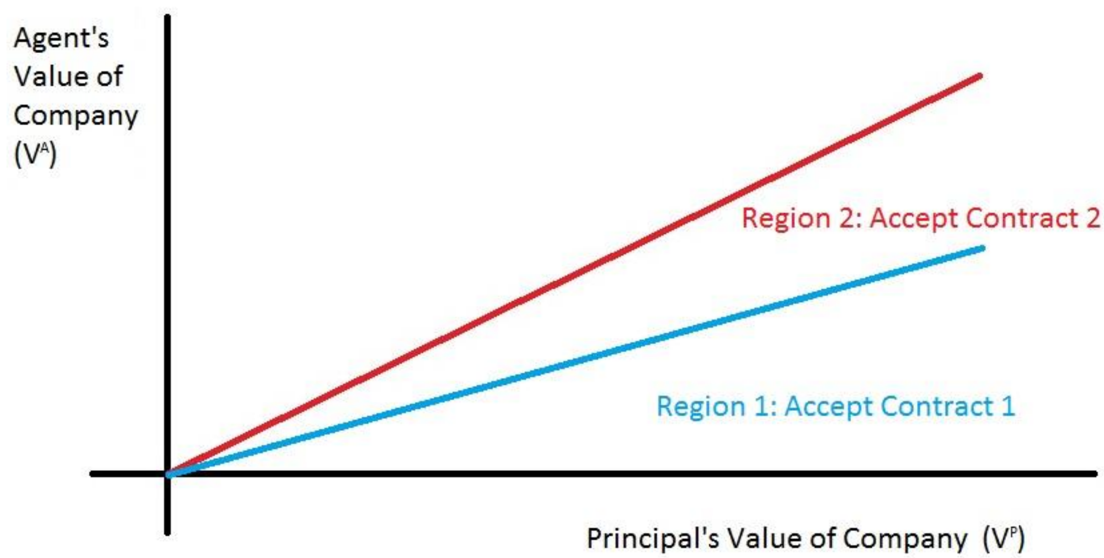
As mentioned before, it is also possible to look at $\mathrm{x} = \frac{\mathrm{E(B)}}{\mathrm{C}}$ as a given project and see who will invest. Based on Equation (4), only the companies which are the most overvalued will invest ($\frac{\mathrm{V^A}}{\mathrm{V^P}} \leq \mathrm{x}$). This means the principal is consistently making the worst investments possible and missing out on opportunities with undervalued firms, who represent the best bargains. This is another way to see the cost imposed on the principal by information asymmetry.

2.4 Use of contracts to separate agents

In the simple logic of this model, it is possible that the agent can distinguish between overvalued and (some) undervalued companies. This can be done using the two contracts discussed in Section 2.2. Recall contract one: $\mathrm{Q^1} = \frac{\mathrm{V^P}}{\mathrm{V^P+E(B)}}$, where the agent will invest if the company is overvalued, $\mathrm{V^A} \leq \mathrm{V^P}$. Contract two is: $\mathrm{Q^2} = \frac{\mathrm{V^P}}{\mathrm{V^P+C}}$, where the agent will invest if $\mathrm{V^A} \leq \frac{\mathrm{E(B)}}{\mathrm{C}}\mathrm{V^P}$. Suppose that you are the principal and you have a positive NPV project $\mathrm{x} = \frac{\mathrm{E(B)}}{\mathrm{C}} > 1$. There are a list of agents who you could partner with and you want to narrow the list down. The results of this model can help you make that decision.

First, the principal should offer contract one to all available firms and identify those who reject. Second, offer contract two to all firms and identify those who accept. Any firm who rejects contract one and accepts contract two is one that the principal should do business with. This is because these firms exist in the region where $\mathrm{V^P} < \mathrm{V^A} < x\mathrm{V^P}$, which says the company is undervalued by the principal but not so undervalued that they will reject the project. In this way, the principal can avoid making investments in overvalued firms and identify undervalued firms that will accept the investment opportunity. This is a compelling result and I will provide a graphical explanation below.

Figure 2: Decision criteria under different contracts for given project



Whereas Figure 1 showed which projects a given company would approve, Figure 2 shows which companies will approve a given project. The region where an agent will accept an investment is where the principal's value for the company is sufficiently high. This is why the acceptance region is on lower side of the indifference line, unlike in Figure 1.

In Figure 2, Region 1 is the set of companies that would accept contract one (Q^1). This region is all points below the line $V^A = V^P$. All of the companies in Region 1 are overvalued. Region 2 is the set of companies that would accept contract two (Q^2), only some of these companies are overvalued. Since the edge of Region 1 is the set of companies that are perfectly valued, the companies in Region 2 and not Region 1 are the ones that are undervalued and would approve your investment opportunity under contract two. Note that it is not hard to find an undervalued firm in this model, the real challenge is finding an undervalued firm that will accept your investment opportunity.

3. Conclusion

This paper shows that uncertainty can be included in a model of asymmetric information to deepen our understanding of corporate investment decisions. The model shows that a company will issue stock to pursue negative NPV projects if it is sufficiently overvalued, or it will pass on some positive NPV projects if it is undervalued by the principal. In either case, asymmetric information imposes a cost on the principal. This paper also shows that the principal can use two contracts to separate types of agents. It is possible to avoid all overvalued firms and identify the firms who are undervalued, but still willing to approve a given investment opportunity.

There are several ways to extend this analysis further. The normative recommendations in Section 2.4 could be studied more closely and made operational for a sophisticated investor. Or an interested researcher could revise Section 2.2 and allow the initial value of the company to be uncertain. Then, the investment could be viewed as an addition to the value of the company, or as an investment that improves the agent's knowledge about the value of the company. These models would use Bayesian game theory and may be relevant to decision making for mineral exploration businesses. In fact, I would very much like to discuss the relevance of this model with business executives involved in mineral exploration. I would like to explore if there is potential for software to support decision making based on the models presented here.

The myriad events that occur in the world of corporate investments can be difficult to reconcile with a basic model of adverse selection. The results of this paper show that surprising behaviour can appear when uncertainty is present. It is my hope that the surprising behaviour I have found can be useful to better understand the events that occur in our world today.

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Technical Appendix:

Result 1:

Assume $\mathrm{Q} = \frac{\mathrm{V^P}}{\mathrm{V^P+B}}$, then $\mathrm{V^A} \leq \mathrm{Q}(\mathrm{V^A} + \mathrm{B}) \rightarrow \mathrm{V^A}(\mathrm{Q}-1) \leq \mathrm{QB} \rightarrow \mathrm{V^A}\frac{\mathrm{B}}{\mathrm{V^P+B}} \leq \frac{\mathrm{V^P}}{\mathrm{V^P+B}}\mathrm{B} \rightarrow \mathrm{V^A} \leq \mathrm{V^P}$. This shows that there is an adverse selection problem in the MM model.

Result 2:

Assume $\mathrm{V^A} \leq \mathrm{V^P}$, then $\frac{\mathrm{V^A}}{\mathrm{V^A+B}} \leq \frac{\mathrm{V^P}}{\mathrm{V^P+B}} \rightarrow \mathrm{V^A V^P} + \mathrm{V^A}B \leq \mathrm{V^A V^P} + \mathrm{V^P B} \rightarrow \mathrm{V^A} \leq \mathrm{V^P}$. This shows that adverse selection problem in the MM model causes the principal to receive less stock in the company than they would under perfect information.

Result 3:

Assume $\mathrm{Q} = \frac{\mathrm{V^P}}{\mathrm{V^P+C}}$, then $\mathrm{V^A} \leq \mathrm{Q}(\mathrm{V^A} + \mathrm{E(B)}) \rightarrow \mathrm{V^A}(\mathrm{Q}-1) \leq \mathrm{QE(B)} \rightarrow \mathrm{V^A}\frac{\mathrm{C}}{\mathrm{V^P+C}} \leq \frac{\mathrm{V^P}}{\mathrm{V^P+C}}\mathrm{E(B)} \rightarrow \frac{\mathrm{V^A}}{\mathrm{V^P}} \leq \frac{\mathrm{E(B)}}{\mathrm{C}}$. This shows the decision criteria for the model with uncertainty.