Essays on Closed-End Funds and Advance Disclosure of Trading

by

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Abstract

My dissertation is comprised of three essays. In the first essay, I present a dynamic partial equilibrium model of a simple economy with a closed-end fund. My model demonstrates that a combination of management fees and a time-varying information advantage for a fund manager can account for several empirically observed characteristics of closed-end funds simultaneously. The model is consistent with the basic time-series behavior of fund discounts, explains why funds issue at a premium, accounts for the excess volatility of fund returns, justifies the underperformance of funds that trade at a premium, and is consistent with many time-series correlations between discounts, NAV returns, and fund returns.

In the second essay, I present a dynamic rational expectations model of closed-end fund discounts that incorporates feedback effects from activist arbitrage and lifeboat provisions. I find that the potential for activism and the existence of a lifeboat both lead to narrower discounts. Furthermore, both activist arbitrage and lifeboats effectuate an ex post transfer of wealth from managers to investors but an ex ante transfer of wealth from low-ability managers to high-ability managers. On average, investor wealth is unaffected by either activist arbitrage or lifeboats because their potential benefits are factored into higher fund prices. Although lifeboats can reduce takeover attempts, they do not increase expected managerial wealth.

In the third essay, I present a noisy rational expectations equilibrium model in which agents who possess private information regarding the profitability of a firm are required to provide advance disclosure of their trading activity. I analytically characterize an equilibrium and conduct a numerical analysis to evaluate the implications of advance disclosure relative to a market in which informed agents trade without providing advance disclosure. By altering the information environment along with managerial incentives, advance disclosure increases risk in the financial market while reducing risk in the real economy. I also find that advance disclosure has implications for equilibrium prices and allocations, managerial compensation contracts, investor welfare, and market liquidity.

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Chapter 1

The Closed-End Fund Puzzle: Management Fees and Private Information

We present a dynamic partial equilibrium model of a simple economy with a closed-end fund. Our model demonstrates that a combination of management fees and a time-varying information advantage for a fund manager can account for several empirically observed characteristics of closed-end funds simultaneously. The model is consistent with the basic time-series behavior of fund discounts, explains why funds issue at a premium, accounts for the excess volatility of fund returns, justifies the underperformance of funds that trade at a premium, and is consistent with many time-series correlations between discounts, NAV returns, and fund returns.

1.1 Introduction

For more than four decades, economists have struggled to understand the perplexing behaviors exhibited by closed-end fund prices. These behaviors, which over the years have become known collectively as the closed-end fund puzzle, are baffling on a number of levels. The most well-known feature of the puzzle is that a closed-end fund's discount, or the difference between the price of the fund's shares and its net asset value (NAV), tends to follow a predictable pattern over the fund's life cycle. There are, however, several aspects of the closed-end fund puzzle in addition to the basic time-series properties of discounts that are equally intriguing and important. One such aspect is that the returns on a fund's shares tend to be more volatile than the returns on the fund's underlying assets. If closed-end funds are merely a portfolio of assets, why are fund prices more volatile than the underlying assets? This question is especially fascinating in light of the fact that fund prices underreact to NAV returns. Another feature of the puzzle is that funds that trade at a premium tend to underperform relative to those that trade at a discount. This raises an obvious question: why do investors buy funds at a premium when they expect them to underperform? Furthermore, many of the correlations between the time-series of discounts, NAV returns, and fund returns appear to defy common sense. For example, why are discounts correlated with future fund returns but not future NAV returns? We address all of these features of the closed-end fund puzzle in this paper.

While numerous frictions have been suggested over the years as the basis for the behavior of closed-end fund prices, we demonstrate that a model combining two fundamental elements can explain most of the salient facts about closed-end funds simultaneously: (i) a time-varying infor-

mation advantage for a fund manager; and (ii) management fees. More specifically, we propose a dynamic partial equilibrium model in which a closed-end fund manager periodically acquires private information regarding the future performance of an underlying asset.[1] The manager then exploits her time-varying information advantage to earn positive abnormal returns for the fund prior to deducting management fees. Whether a fund trades at a discount or a premium depends on the value of the manager's information in relation to the fees she collects for managing the fund.

Because a closed-end fund issues a fixed number of nonredeemable shares that trade at a price determined by the market, the price of a fund's shares often diverges from the fund's NAV in an apparent violation of the Law of One Price. In fact, closed-end fund discounts tend to follow a predictable pattern over a fund's life cycle, as documented by Lee, Shleifer, and Thaler (1990) and others. Consistent with this well-documented time-series behavior of discounts, funds in our model issue at a premium when the expected benefit from the manager's information advantage outweighs the cost of the management fees. After the manager's private information is exploited, however, funds begin to trade at a discount because the capitalized future management fees outweigh the expected benefits from the manager's future information advantages. The rapid emergence of a discount in our model is consistent with existing empirical studies by Weiss (1989) and Peavy (1990) who find that funds usually begin to trade at a discount within 100 days following the initial public offering (IPO). Furthermore, the time-varying nature of the manager's information advantage leads to both cross-sectional and time-series fluctuations in discounts. Lastly, fund prices in our model converge to a fund's NAV when the fund is terminated, which is consistent with empirical evidence that prices converge to NAV when funds are liquidated (Brickley and Schallheim (1985)) or reorganized into an open-end mutual fund (Brauer (1984)).

In addition to accounting for the basic time-series behavior of discounts over a fund's life cycle, our model also explains *why* funds issue at a premium. According to our model, funds issue at a premium because issue premiums are utility-maximizing for fund managers, and investors are willing to pay a premium because doing so maximizes their own expected utility and clears the market. The driving force behind this result is the management fee, which simultaneously impacts both managerial wealth and the manager's incentive to exploit her information advantage by selecting the fund's portfolio of underlying assets. It turns out that the size of the fee that maximizes the risk-averse manager's expected utility also maximizes the value of the fund for investors because the fee influences how aggressively the manager trades on her private information.

Our model also accounts for the excess volatility of fund returns despite the fact that fund prices underreact to NAV returns, as reported by Pontiff (1997). Consistent with empirical observations, fund returns in our model are more volatile than NAV returns but covary negatively with changes in premiums. Moreover, the fundamental source of a fund's excess volatility in our model is the manager's information advantage, which is consistent with empirical evidence that market risk factors do not explain excess volatility.

We also demonstrate that a combination of management fees and a time-varying information advantage for a fund manager can justify one of the most anomalous characteristics of closed-end funds—the underperformance of funds that trade at a premium relative to those that trade at a discount, which has been documented by Thompson (1978) and Pontiff (1995). Funds that trade at a premium in our model tend to underperform because they provide insurance against extreme returns of the underlying assets. In our model, funds trade at a premium only when the manager possesses a large information advantage, but possessing a large quantity of private information gen-

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[1]Our use of the term "private information" should be broadly construed as the ability to more accurately predict future prices. While we do not rule out the possibility of a fund manager trading on "insider" information, a manager's information advantage could stem from, say, a skill set specially tailored to a particular economic environment. We discuss potential sources of the manager's information advantage in more detail in Section 1.3.1.

erates a large abnormal return only in the relatively rare instances where the private information indicates that there will be an extreme return for an underlying asset. In these rare cases, the manager can modify the fund's portfolio to capitalize on her information advantage and thereby generate a large abnormal return for the fund. Most of the time, however, the underlying assets will not produce an extreme return. In these cases, which occur with great frequency, the manager's capability to earn a large abnormal return net of management fees is greatly diminished because her private information is not very valuable. As a result, funds that trade at a premium tend to underperform on average. Nevertheless, risk-averse investors are willing to hold such funds even though they expect them to underperform since those funds protect investors from extreme losses.

Finally, our model is consistent with many of the time-series correlations between discounts, NAV returns, and fund returns. Discounts in our model are persistent over time, are unrelated to both past and future NAV returns, and are positively correlated with future fund returns but negatively correlated with lagged fund returns. Additionally, NAV returns and fund returns are not perfectly correlated.

In light of the fact that there is conflicting empirical evidence regarding both the existence of managerial ability and the impact of management fees on discounts, the appropriateness of modeling the source of the puzzling behaviors exhibited by closed-end fund prices as a tradeoff between a time-varying information advantage for a fund manager and management fees warrants further discussion. Intuitively, it seems like management fees should affect discounts because on some level fees represent a dead weight cost to a fund's shareholders. In line with this reasoning, Kumar and Noronha (1992) and Johnson, Lin, and Song (2006) report that discounts are significantly and positively related to fund expenses. At the same time, empirical studies by Malkiel (1977) and Barclay, Holderness, and Pontiff (1993) indicate that management fees do not significantly contribute to observed discounts. Our model provides a novel explanation for this conflicting empirical evidence, although a few arguments have previously emerged in the literature to reconcile our intuition with the facts.[2] In our model, the relationship between the management fee and the discount is nonlinear and non-monotonic because the size of the fee determines not only the amount of wealth transferred from investors to the manager but also influences how aggressively the manager trades on her private information. Since the degree to which the manager exploits her information advantage affects the value of the fund in a nonlinear and non-monotone fashion, it is not surprising that empirical studies have generated mixed evidence concerning the effect of management fees on discounts.

The empirical evidence regarding the existence of managerial ability is conflicted, as well. In recent work, Fama and French (2010) report that open-end mutual fund managers add little value over the long term. Once management fees are taken into account, managers seem to produce negative abnormal returns on average. On the other hand, Chay and Trzcinka (1999) find that closed-end fund premiums are positively related to future managerial performance over the short term but not the long term. Our model is not inconsistent with either of these studies. Most of the time, the fund manager in our model generates small positive abnormal returns. These abnormal returns become negative after deducting management fees, however, which is why funds usually trade at a discount. Nevertheless, in the relatively rare instances when the fund trades at a premium, the manager can generate large but short-lived gross abnormal returns. Managerial per-

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[2]One explanation by Gemmill and Thomas (2002) is that management fees frequently show up as being insignificantly related to discounts in reduced form empirical studies because fees are highly collinear with other variables that affect closed-end fund discounts. Another explanation by Chay and Trzcinka (1999) is that reported fees do not include soft dollar expenses. Alternatively, Deaves and Krinsky (1994) argue that higher fees increase the probability of a takeover attempt, which in turn results in lower discounts due to the price feedback effect created by the potential takeover.

formance is not persistent because the manager's information advantages dissipate rather quickly.

To our knowledge, our model is the first to simultaneously explain most of the prominent stylized facts about closed-end funds. Other theorists have made some progress in explaining the basic time-series behavior of discounts in recent years, but none have successfully explained the excess volatility of fund returns, the underperformance of funds that trade at a premium, or the several time-series correlations between discounts and returns. For instance, Berk and Stanton (2007) model a tradeoff between a reduced form managerial ability and management fees. By allowing a manager with high ability to extract the surplus she creates via a pay raise, their model is able to account for the predictable time-series pattern exhibited by discounts over a fund's life cycle. Additionally, Cherkes, Sagi, and Stanton (2009) demonstrate that liquidity concerns can lead to new funds issuing at a premium during times when seasoned funds are trading at a premium and then subsequently falling into a discount, but their model is unable to explain the behavior of discounts for funds that hold liquid assets. In contrast to these theories, our model explains not only the time-series behavior of discounts but also the excess volatility of fund returns, the underperformance of premium funds, and many of the time-series correlations between discounts and returns.

While the source of divergence between the price of a closed-end fund and its NAV has proven to be elusive, we are not the first to surmise that an information advantage of some sort may be the driving force behind the puzzling behavior of closed-end fund discounts. For example, Oh and Ross (1994) construct an equilibrium model based on an information asymmetry between a fund manager and investor. They show that the precision of the manager's private information can impact a fund's discount, but since trading takes place at only a single date in their model, it is unable to explain even the time-series properties of discounts, let alone the many other aspects of the closed-end fund puzzle. Similarly, Arora, Ju, and Ou-Yang (2003) propose a two-period model in which the fund manager has an initial information advantage but is constrained by contractually imposed investment restrictions. They numerically show that the fund can issue at a premium and later trade at a discount, but their model does not explain either the cross-sectional or time-series variation in discounts.

The other basic building block of our model, management fees, has also previously been proposed as a source of discounts. Ross (2002a) demonstrates that a closed-end fund will trade at a discount equal to the capitalized management fees if the manager receives a constant percentage of the fund's NAV in perpetuity. This simple model, however, fails to explain why funds issue at a premium or why discounts fluctuate over time. In related work, Ross (2002b) explores variations of the model and shows that with asymmetrically-informed investors funds may issue at a premium and that dynamic distribution policies can result in a fluctuating discount. Nevertheless, he does not simultaneously model both issue premiums and fluctuating discounts. In contrast to Ross (2002a) and Ross (2002b), our model can explain the time-series attributes of funds without relying on a dynamic distribution policy or information asymmetry among investors at the time of issuance.[3] Our model also accounts for the other prominent aspects of the closed-end fund puzzle.

Several other explanations for the behavior of closed-end fund discounts have been proposed with varying degrees of success. For example, taxes may provide a partial explanation for the existence of discounts. Since investors who purchase a closed-end fund with unrealized capital appreciation face a future tax liability, the shares of such a fund should trade at a price lower than an equivalent fund with no unrealized capital appreciation. Malkiel (1977) finds some empirical support for this argument, but he demonstrates that taxes alone cannot quantitatively account for

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[3]The information asymmetry in our model arises after the IPO and is between the fund manager and the investor. Although this may seem like a minor distinction, our model illustrates that contemporaneous asymmetric information among investors is not necessary to produce a premium at the IPO or a subsequent discount because only investors, who always have identical information sets, trade shares in the fund.

the observed discounts. Kim (1994) argues that tax-timing options also contribute to discounts. On the other hand, Brickley, Manaster, and Schallheim (1991) observe a negative correlation between unrealized capital appreciation and the discount, which is inconsistent with the taxation argument. Still, taxes do not explain why funds issue at a premium or why the price converges to NAV upon termination.

Malkiel (1977) provides some empirical evidence that funds investing in restricted stocks experience deeper discounts. Similarly, Bonser-Neal, Brauer, Neal, and Wheatley (1990) and Chan, Jain, and Xia (2005) find that international barriers can affect discounts of funds that hold foreign assets, but Kumar and Noronha (1992) find that holding a portfolio of foreign stock does not necessarily impact the discount. Nonetheless, investing in restricted or foreign assets does not explain discount dynamics for funds that hold liquid domestic assets. Agency costs also have been explored as a potential factor affecting discounts. Barclay, Holderness, and Pontiff (1993) find that funds with concentrated block ownership tend to have larger discounts, which they attribute to managers diverting fund resources for their own private benefit. However, agency costs do not explain the basic time-series pattern of fund discounts.

Lastly, De Long, Shleifer, Summers, and Waldmann (1990) speculate that the existence of irrational noise traders creates additional risk for rational investors with a short investment horizon and results in a lower price for closed-end funds. This theory predicts that new funds will issue at a premium when noise traders are overly optimistic about future performance and that discounts will vary with the fluctuations in noise trader opinion, or investor sentiment. Lee, Shleifer, and Thaler (1991) find empirical support for this hypothesis by conjecturing that the investor sentiment driving closed-end fund discounts also affects stock prices of small firms since individual investors, who are the source of noise-trader risk, are the predominant holders of both types of assets in the U.S. However, Dimson and Minio-Kozerski (1999) note that closed-end funds in the U.K. are predominantly held by institutions but nevertheless tend to trade at a discount. Furthermore, Chan, Jain, and Xia (2005) find that noise traders are not a significant contributor to fund discounts. Other studies have produced mixed evidence in support of the investor sentiment hypothesis (see, e.g., Chen, Kan, and Miller (1993), Chopra, Lee, Shleifer, and Thaler (1993) and Elton, Gruber, and Busse (1998)).

The remainder of this article is organized as follows. In Section 1.2, we outline the basic features of the model and solve for the equilibrium over a short time horizon using symbolic computational methods. We then demonstrate that our basic model with a short time horizon can account for the predictable pattern of discounts over a fund's life cycle and explain why funds issue at a premium. In Section 1.3, we extend the model to a longer time horizon using the techniques discussed in Section 1.2. We then simulate data and assess the model's ability to account for several empirical observations reported in the literature; namely, the puzzling time-series correlations between discounts and returns, the excess volatility of fund returns, and the underperformance of funds that trade at a premium. Finally, Section 1.4 concludes.

1.2   Basic Model

Time is discrete and indexed by $t \in \{1, 2, 3, 4\}$. Trading in the financial market occurs at $t = 1, 2, 3$ while consumption occurs at $t = 4$. A single fund manager (she) and a single representative investor (he) are present in the market. Both agents exhibit preferences, which are common knowledge, characterized by constant absolute risk aversion (CARA), where γ_i and γ_m denote the coefficients of risk aversion for the investor and manager, respectively.

The economy consists of three types of financial assets—a stock, a sequence of one-period bonds,

and a closed-end fund. The stock pays a random amount, $\tilde{Y}$, at $t = 4$ but does not pay any dividends prior to that time. The stock payoff consists of the sum of three independent and normally distributed random variables,

$$\tilde{Y} \equiv \tilde{X}_1 + \tilde{X}_2 + \tilde{X}_3, \tag{1.1}$$

where $\tilde{X}_t \sim \mathcal{N}\left(\mu_t, \sigma_t^2\right)$ for $t = 1, 2, 3$. As discussed in greater detail below, the value of each $\tilde{X}_t$ is initially unknown but is observed as time progresses. For simplicity, we assume that the stock price follows an exogenous process given by

$$P_t^s = \sum_{\tau=1}^{t-1} X_\tau + \sum_{\tau=t}^{3} \left(\mu_\tau - \frac{\gamma_i \gamma_m}{\Gamma} \sigma_\tau^2\right), \tag{1.2}$$

where $\Gamma \equiv \gamma_i + \gamma_m$. Hence, the price at time t is equal to the conditional expectation of the stock's payoff less an adjustment for risk. While the specific form of the exogenous price process is not terribly important for our analysis, this particular process is reflective of endogenous equilibrium prices in models with symmetrically-informed agents who have CARA preferences. Alternatively, the stock price can be determined endogenously within our framework without affecting the fundamental nature of our analysis. Details of the analysis of our model with endogenous stock prices are contained in Appendices A.1 and A.2.

A couple of simplifying assumptions are made regarding the bonds. Each one-period bond has a constant interest rate that is normalized to zero; accordingly, a bond costs one unit at time t and pays one unit at $t + 1$. Additionally, the supply of each one-period bond is elastic. These assumptions dramatically improve the tractability and computational efficiency of the model. Although a non-zero interest rate would impact the prices of the stock and closed-end fund, empirical studies have found that neither the short-term interest rate (Coles, Suay, and Woodbury (2000)) nor changes in interest rates (Gemmill and Thomas (2002) and Lee, Shleifer, and Thaler (1991)) significantly affect discounts.

The closed-end fund is an endogenous, time-varying portfolio of the stock and bond. This relatively simple setup highlights the effect of asymmetric information on the discount, though in reality closed-end funds typically specialize in a diversified portfolio of either stocks or bonds (see, e.g., Dimson and Minio-Kozerski (1999)). The fund, whose shares are traded in the market, is in unit supply, and the equilibrium price at time t is endogenous and denoted by P_t^f. At $t = 1$, the fund undergoes an IPO. The fund is liquidated at $t = 4$, and its assets are distributed to the fund's shareholders at that time after deducting management fees. Furthermore, the fund is prohibited from issuing new shares or repurchasing existing shares. Although the potential for early liquidation or open-ending can impact the discount (see Brauer (1988), Deaves and Krinsky (1994), Gemmill and Thomas (2002), Johnson, Lin, and Song (2006), Bradley et al. (2010), and Lenkey (2011)), we assume that the fund will not be liquidated prior to $t = 4$ with certainty.

At each trading date, the fund manager chooses the composition of the closed-end fund according to her preferences by allocating the fund's financial resources among the bond and stock while the investor optimally allocates his wealth across the bond, stock, and fund. At $t = 1$, the investor receives an exogenous endowment of wealth, W_i, and he observes the fund's initial wealth that is designated for investment, W_f, which is usually reported in a fund's prospectus. As is typical in practice, the investor is unable to observe the contemporaneous composition of the fund, but he acquires knowledge of the prior period composition as time progresses; that is, at time t the investor has knowledge of all fund portfolios through $t - 1$. In some cases, the investor can infer the fund's portfolio at the current date based on the fund's prior portfolios in addition to the other

parameters and state variables.[4]

The fund manager obtains utility solely from the consumption, c_m, of fees, ϕ, earned from managing the closed-end fund plus any issue premium, ρ. The management contract is exogenous and pays the manager a fixed amount, a, plus a fraction, b, of the fund's NAV return,[5]

$$\tilde{\phi} = a + b\big(S_3^f \tilde{Y} + B_3^f - V_1\big), \tag{1.3}$$

where S_t^f and B_t^f denote the quantity of stock and number of bonds held by the fund from time t to $t+1$ and

$$V_t \equiv S_t^f P_t^s + B_t^f \tag{1.4}$$

denotes the fund's time-t NAV, which is equal to the market value of the assets in the fund's portfolio. The initial NAV equals the fund's initial wealth designated for investment: $V_1 = W_f$. The fund's time-t discount, D_t, is defined as the difference between the price of the fund and NAV,

$$D_t \equiv V_t - P_t^f, \tag{1.5}$$

which means that the fund's issue premium is

$$\rho \equiv P_1^f - V_1. \tag{1.6}$$

Defining the discount as the simple difference, as opposed to the more conventional definition of percentage or log difference, between the price of the fund and its NAV results in simpler expressions for the discount. Percentage and log discounts can easily be obtained from D_t.

The investor, meanwhile, receives utility solely from the consumption, c_i, of the payoff from his portfolio. Hence,

$$\tilde{c}_i = S_3^i \tilde{Y} + B_3^i + F_3\big(S_3^f \tilde{Y} + B_3^f - \tilde{\phi}\big), \tag{1.7}$$

where S_t^i denotes the quantity of stock, B_t^i denotes the number of bonds, and F_t denotes the shares of the fund held by the investor from time t to $t+1$.

Information regarding the stock payoff, $\tilde{Y}$, evolves over time. Recall that trading in the financial market occurs at $t = 1, 2, 3$ and consumption occurs at $t = 4$. As time progresses, the manager obtains an information advantage over the investor which she exploits to earn an excess return for the fund. Let $\mathcal{I}_t^i$ and $\mathcal{I}_t^f$ denote the information set at time t for the investor and fund manager, respectively. Initially, the value of each X_t is unknown to both the investor and manager: $\mathcal{I}_1^i = \mathcal{I}_1^f = \emptyset$. At $t = 2$, both the manager and investor observe X_1. Additionally, the manager observes a portion of $\tilde{X}_2$, and it is at this point that the manager can exploit her information advantage to earn an excess return. We assume that the portion of $\tilde{X}_2$ observed by the fund manager depends on

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[4]Knowledge of prior fund compositions is a sufficient, but not a necessary, condition for the investor to be able to infer the fund's current composition when information is symmetric. The investor can still infer the fund's contemporaneous portfolio when information is symmetric if he instead only observes current NAV.

[5]This contractual form differs from most compensation contracts in the industry which pay the fund manager a fraction of the total assets under management. While the results of the basic model developed in this section are robust to these more prevalent contractual forms, the "two-part" contract produces more realistic solutions to the extended model presented in Section 1.3. In the extended model, the manager is compensated with a sequence of fees over a longer time horizon. If the compensation contract paid the manager a fraction of the total assets under management so that each fee depended on the NAV at a particular date, then portfolio choices would affect not only the contemporaneous fee but also all future fees. Hence, such a contract effectively makes holding stock riskier for the manager than when she is compensated via the two-part contract. Because she has CARA preferences, to offset the increased risk the manager would tend to allocate a small amount of the fund's wealth to the stock at early dates and gradually increase the allocation over time. In contrast, the two-part contract leads to stock allocations that are stationary, which is more realistic.

her ability, $\alpha \in (0, 1)$, to acquire information, with larger values of α representing a greater ability. Both the manager and investor are able to discern the value of α before the fund undergoes the IPO. We specifically assume that $\tilde{X}_2$ is the sum of two components,

$$\tilde{X}_2 \equiv \tilde{Z}_1 + \tilde{Z}_2, \tag{1.8}$$

and that the manager privately observes Z_1. Furthermore, we assume that $\tilde{Z}_1 \sim \mathcal{N}\left(\alpha\mu_2, \alpha\sigma_2^2\right)$ and $\tilde{Z}_2 \sim \mathcal{N}\left((1-\alpha)\mu_2, (1-\alpha)\sigma_2^2\right)$, which means that the distribution of the stock payoff, $\tilde{Y}$, is independent of ability, yet a manager with a higher ability level acquires more information than a manager with low ability. Consequently, the information sets at $t = 2$ are asymmetric: $\mathcal{I}_2^i = \{X_1\}$ and $\mathcal{I}_2^f = \{X_1, Z_1\}$. At $t = 3$, both agents observe X_2, so the information sets are once again symmetric: $\mathcal{I}_3^i = \mathcal{I}_3^f = \{X_1, X_2\}$. Finally, all information is available at the terminal date: $\mathcal{I}_4^i = \mathcal{I}_4^f = \{X_1, X_2, X_3\}$. This information structure enables the study of equilibrium dynamics and, in particular, the impact of an information advantage on the closed-end fund price. All acquisition of information is costless; consequently, potential moral hazard issues relating to information acquisition do not arise.

The sequence of events is as follows. The fund undergoes an IPO at $t = 1$, and the investor and manager subsequently choose portfolios at market-clearing prices. The investor allocates his wealth among the bond, stock, and fund while the manager allocates the fund's financial resources among the bond and stock. Because preferences are common knowledge and information is symmetric, the investor can infer the fund's portfolio composition from the equilibrium stock price. At $t = 2$, the fund discloses its portfolio holdings from the previous date, the manager acquires private information regarding the terminal payoff of the stock, and both the investor and manager rebalance their respective portfolios. The investor cannot infer the precise composition of the fund's current portfolio since he does not observe Z_1, although he does form beliefs about a distribution of the fund's portfolio based on the manager's preferences. At $t = 3$, the fund manager's information advantage disappears, both agents rebalance their respective portfolios, and the investor can once again infer the fund's portfolio from the equilibrium stock price and the composition of the fund's portfolio from the previous date, which is announced prior to trading. Finally, the management fees are paid, the portfolios are liquidated, and consumption occurs at $t = 4$.

We make one final technical assumption regarding the relative magnitudes of the agents' risk aversion coefficients to ensure well-defined and meaningful solutions: $\Gamma b > \gamma_i$. This assumption is entirely reasonable if $\gamma_m \gg \gamma_i$, which is not unrealistic since in actuality the mass of investors is far larger than that of fund managers and the coefficients of risk aversion are equivalent to the inverses of the agents' risk tolerances. In other words, this is an assumption about the relative masses of the agents rather than their risk preferences.

The equilibrium is solved recursively with the aid of symbolic computational methods. Section 1.2.1 characterizes the equilibrium at $t = 3$. Those results are then drawn on in Section 1.2.2 to derive the equilibrium at $t = 2$, which in turn is relied upon to characterize the equilibrium at $t = 1$ in Section 1.2.3. Some implications of the basic model are discussed in Section 1.2.4.

1.2.1 Equilibrium at $t = 3$

Information is symmetric at $t = 3$. The equilibrium price of the closed-end fund is derived from the utility-maximizing objectives of the manager and investor. The following proposition characterizes the equilibrium discount.

Proposition 1. *At $t = 3$, there exists a unique equilibrium in which the closed-end fund discount is given by*

$$D_3 = a + b\left(V_3 - V_1\right). \tag{1.9}$$

The remaining portion of this subsection describes the equilibrium derivation, beginning with the fund manager's objective. The fund manager's goal at $t = 3$ is to maximize her expected utility from consumption of the management fees and issue premium by choosing the composition of the closed-end fund subject to a budget constraint:

$$\max_{S_3^f} \quad \mathbb{E}_3\big[-\exp[-\gamma_m \tilde{c}_m] \,|\, X_1,\, X_2\big] \tag{1.10}$$

subject to

$$\tilde{c}_m = \tilde{\phi} + \rho \tag{1.11}$$

$$B_3^f = \big(S_2^f - S_3^f\big) P_3^s + B_2^f, \tag{1.12}$$

where $\mathbb{E}_t$ is the expectation operator conditional on information available at time t. Since, conditional on X_1 and X_2, the manager's consumption is log-normally distributed, her expected utility can be rewritten in closed form as

$$-\exp\Big[-\gamma_m\Big(\rho + a + b\big[S_3^f\big(X_1 + X_2 + \mu_3 - P_3^s\big) + S_2^f P_3^s + B_2^f - V_1\big] - \tfrac{1}{2}\gamma_m b^2 \big(S_3^f\big)^2 \sigma_3^2\Big)\Big] \tag{1.13}$$

after substituting (1.1), (1.3), (1.11), and (1.12) into (1.10) and integrating over $\tilde{X}_3$. The manager's stock allocation is then derived by differentiating (1.13) with respect to S_3^f and substituting the stock price, (1.2), into the corresponding first-order condition to obtain

$$S_3^f = \frac{\gamma_i}{\Gamma b}. \tag{1.14}$$

The investor faces a problem similar to that of the manager. The investor's objective is to maximize his expected utility from consumption of the assets in his portfolio subject to a budget constraint, taking into account the portfolio held by the fund:[6]

$$\max_{S_3^i,\, F_3} \quad \mathbb{E}_3\big[-\exp[-\gamma_i \tilde{c}_i] \,|\, X_1,\, X_2\big] \tag{1.15}$$

subject to

$$B_3^i = \big(S_2^i - S_3^i\big) P_3^s + B_2^i + \big(F_2 - F_3\big) P_3^f \tag{1.16}$$

as well as (1.12) and (1.14). Since the investor's consumption is also conditionally log-normally distributed, his expected utility can be rewritten as

$$-\exp\Big[-\gamma_i\Big(S_3^i\big(X_1 + X_2 + \mu_3 - P_3^s\big) + S_2^i P_3^s + B_2^i + F_2 P_3^f - \tfrac{1}{2}\gamma_i\big(S_3^i + (1-b)F_3 S_3^f\big)^2 \sigma_3^2$$
$$+ F_3\big[(1-b)\big(S_3^f\big(X_1 + X_2 + \mu_3 - P_3^s\big) + S_2^f P_3^s + B_2^f\big) + bV_1 - P_3^f - a\big]\Big)\Big] \tag{1.17}$$

after substituting (1.1), (1.3), (1.7), (1.12), and (1.16) into (1.15) and integrating over $\tilde{X}_3$. Differentiating (1.17) with respect to S_3^i and substituting (1.2) and (1.14) into the first-order condition provides the investor's stock allocation,

$$S_3^i = \frac{\Gamma b - \gamma_i}{\Gamma b}. \tag{1.18}$$

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[6]Recall that the investor can infer the fund's portfolio at $t = 3$ since he has knowledge of the prior composition of the fund in addition to the other state variables and parameters.

Finally, the fund price is obtained by differentiating the investor's expected utility, (1.17), with respect to F_3 and substituting the stock price, stock allocations, and market-clearing condition ($F_3 = 1$) into the first-order condition, which gives

$$P_3^f = V_3 - a - b(V_3 - V_1). \tag{1.19}$$

Thus, the fund price is equal to the fund's NAV minus an adjustment for the management fees. It follows immediately from (1.19) that the discount, which is given by (1.9), stems from the management fees when the investor and manager have identical information sets and there is no possibility of a future information asymmetry. The fund will trade at a discount (as opposed to a premium) whenever $a + bV_3 > bV_1$; that is to say, appreciation of the NAV is a sufficient condition for the fund to trade at a discount.

Since the closed-end fund generally trades at a price different from its NAV, it is conceivable that an arbitrage opportunity exists. We show here, however, that the discount does not present an arbitrage opportunity. If the fund is trading at a discount relative to NAV, then a potential arbitrage strategy would entail purchasing shares in the fund and simultaneously taking an offsetting position in a hedging portfolio. Since the fund payoff at $t = 4$, net of management fees, is

$$(1 - b)(S_3^f \tilde{Y} + B_3^f) + bV_1 - a,$$

an appropriate hedging portfolio would consist of $-((1 - b)B_3^f + bV_1 - a)$ bonds and $-(1 - b)S_3^f$ shares of stock, but because the cost of this hedging portfolio equals $-P_3^f$, there is no arbitrage opportunity. In other words, arbitrage does not exist because the discount at $t = 3$ arises solely from the future management fees, which also reduce the fund payoff.

1.2.2 Equilibrium at $t = 2$

The stock allocations and equilibrium fund price derived in Section 1.2.1 are used to determine the equilibrium fund price at $t = 2$. Recall that information is asymmetric at $t = 2$ as the fund manager observes the value of Z_1 but the investor does not. The following proposition characterizes the equilibrium in the presence of asymmetric information.

Proposition 2. *At $t = 2$, there exists a unique equilibrium in which the closed-end fund discount is given by*

$$D_2 = a + b(V_2 - V_1) - \lambda \tag{1.20}$$

where

$$\lambda \equiv \frac{\alpha(1 - b)(\Gamma b - \gamma_i)}{\alpha(1 - b)\gamma_i(\Gamma b - \gamma_i + \gamma_m b) + (1 - \alpha)\gamma_m^2 b^2}. \tag{1.21}$$

The derivation of the equilibrium is described in the remaining portion of this subsection. Since the manager's expected utility is independent of the investor's portfolio, the manager's problem is relatively straightforward and is analogous to her problem at $t = 3$. On the other hand, because the investor does not observe the manager's private information, his situation is more complicated and involves additional uncertainty.

At $t = 2$, the manager chooses the fund allocation to maximize her expected utility subject to a budget constraint, bearing in mind the future stock price and fund portfolio:

$$\max_{S_2^f} \quad \mathbb{E}_2\left[-\exp\left[-\gamma_m\left(\rho + a + b\left[\frac{\gamma_i\gamma_m}{\Gamma}S_3^f\sigma_3^2 + S_2^f\tilde{P}_3^s + B_2^f - V_1\right] - \tfrac{1}{2}\gamma_m b^2\left(S_3^f\right)^2\sigma_3^2\right)\right]\Big| X_1, Z_1\right] \tag{1.22}$$

subject to
$$B_2^f = (S_1^f - S_2^f)P_2^s + B_1^f \qquad (1.23)$$

in addition to (1.14), where the manager's objective function follows from (1.13). Substituting (1.2), (1.4), (1.8), (1.14), and (1.23) into (1.22) and integrating over $\tilde{Z}_2$ provides the following closed-form expression for the manager's expected utility at $t = 2$:

$$- \exp\Big[-\gamma_m\Big(\rho + a + \tfrac{\gamma_i^2 \gamma_m}{2\Gamma^2}\sigma_3^2 - \tfrac{1}{2}(1-\alpha)\gamma_m b^2 \big(S_2^f\big)^2 \sigma_2^2$$
$$+ b\big[S_2^f\big(X_1 + Z_1 + (1-\alpha)\mu_2 + \mu_3 - P_2^s - \tfrac{\gamma_i \gamma_m}{\Gamma}\sigma_3^2\big) + S_1^f\big(P_2^s - P_1^s\big)\big]\Big)\Big]. \qquad (1.24)$$

Then, differentiating (1.24) with respect to S_2^f and substituting the stock price into the first-order condition gives the manager's demand function,

$$S_2^f = \frac{Z_1 - \alpha\mu_2 + \tfrac{\gamma_i \gamma_m}{\Gamma}\sigma_2^2}{(1-\alpha)\gamma_m b \sigma_2^2}. \qquad (1.25)$$

Thus, the fund's stock holdings are directly proportional to the manager's private information, Z_1. Furthermore, the presence of Z_1 in the manager's demand function represents an additional source of risk for the investor.

Since the investor does not observe Z_1 at $t = 2$, he cannot infer the precise composition of the fund's portfolio. Given knowledge of the fund's portfolio from the previous period, however, he can infer a distribution of the fund's current composition. Therefore, the investor's problem at $t = 2$ is to maximize his expected utility subject to a budget constraint, taking into consideration the results from $t = 3$ and the uncertainty surrounding the fund's current portfolio:

$$\max_{S_2^i, F_2} \quad \mathbb{E}_2\Big[-\exp\Big[-\gamma_i\Big(\tfrac{\gamma_i \gamma_m}{\Gamma}S_3^i\sigma_3^2 + S_2^i\tilde{P}_3^s + B_2^i + F_2\tilde{P}_3^f - \tfrac{1}{2}\gamma\big(S_3^i + (1-b)F_3 S_3^f\big)^2\sigma_3^2$$
$$+ F_3\big[(1-b)\big(\tfrac{\gamma_i \gamma_m}{\Gamma}S_3^f\sigma_3^2 + \tilde{S}_2^f\tilde{P}_3^s + \tilde{B}_2^f\big) + bV_1 - \tilde{P}_3^f - a\big]\Big)\Big]\,\Big|\,X_1\Big] \qquad (1.26)$$

subject to
$$B_2^i = (S_1^i - S_2^i)P_2^s + B_1^i + (F_1 - F_2)P_2^f \qquad (1.27)$$

plus (1.14), (1.18), (1.19), (1.23), and (1.25), and $F_3 = 1$, where the investor's objective function follows from (1.17). Because the fund's stock holdings, (1.25), do not depend on Z_2, conditional on Z_1 the investor's utility is log-normally distributed. Therefore, integration with respect to $\tilde{Z}_2$ is relatively straightforward. Substituting the aforementioned equations (except (1.25)) and (1.8) into (1.26) and integrating over $\tilde{Z}_2$, the investor's expected utility can be rewritten as

$$\mathbb{E}_2\Big[-\exp\Big[-\gamma_i\Big(\big(S_2^i + F_2(1-b)\tilde{S}_2^f\big)\big(X_1 + \tilde{Z}_1 + (1-\alpha)\mu_2 + \mu_3 - P_2^s - \tfrac{\gamma_i \gamma_m}{\Gamma}\sigma_3^2\big)$$
$$+ S_1^i P_2^s + B_1^i + F_1 P_2^f + F_2\big[\big(S_1^f P_2^s + B_1^f\big)(1-b) + bV_1 - P_2^f - a\big] + \tfrac{\gamma_i \gamma_m^2}{2\Gamma^2}\sigma_3^2$$
$$- \tfrac{1}{2}(1-\alpha)\gamma_i\big(S_2^i + (1-b)F_2\tilde{S}_2^f\big)^2\sigma_2^2\Big)\Big]\,\Big|\,X_1\Big]. \qquad (1.28)$$

The investor must also consider his uncertainty regarding the fund's portfolio when selecting his own portfolio. As (1.25) reveals, the manager's stock demand is linear in Z_1. Hence, the investor's expected utility is log-quadratic in $\tilde{Z}_1$. Using symbolic computational methods to integrate (1.28)

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after substituting (1.25) and $F_1 = 1$ provides a closed-form expression for the investor's expected utility,[7]

$$-\frac{1}{\sqrt{1 - 2\alpha\sigma_2^2 I_2^i}} \exp\left[G_2^i + \frac{\alpha\mu_2 H_2^i + \frac{1}{2}\alpha\sigma_2^2 (H_2^i)^2 + (\alpha\mu_2)^2 I_2^i}{(1 - 2\alpha\sigma_2^2 I_2^i)}\right], \tag{1.29}$$

where

$$G_2^i \equiv G_2^i\big(X_1, S_2^i, F_2, P_2^s, P_2^f, S_1^i, S_1^f, B_1^i, B_1^f, P_1^s, W_f; \alpha, \gamma_i, \gamma_m, \mu_2, \mu_3, \sigma_2^2, \sigma_3^2, a, b\big)$$
$$H_2^i \equiv H_2^i\big(X_1, S_2^i, F_2, P_2^s; \alpha, \gamma_i, \gamma_m, \mu_2, \mu_3, \sigma_2^2, \sigma_3^2, b\big)$$
$$I_2^i \equiv I_2^i\big(F_2; \alpha, \gamma_i, \gamma_m, \sigma_2^2, b\big)$$

are functions of the underlying parameters and state variables.[8] Differentiating this expression with respect to S_2^i and substituting (1.2) and $F_2 = 1$ into the first-order condition provides the investor's stock demand at $t = 2$,

$$S_2^i = \frac{\Gamma b - \gamma_i}{\Gamma b}. \tag{1.30}$$

Lastly, the closed-end fund price is obtained by substituting (1.30) into (1.29), differentiating the resulting expression with respect to F_2, substituting (1.2) and $F_2 = 1$ into the first-order condition, and solving for price,

$$P_2^f = V_2 - a - b(V_2 - V_1) + \lambda, \tag{1.31}$$

where λ is defined in Proposition 2 and represents the expected benefit from the manager's private information, i.e., the expected value of the manager's private information before Z_1 is realized. The discount, which is given by (1.20), follows immediately from (1.31). Notice that the size of the closed-end fund discount depends on the manager's ability to acquire information, the management fees, and the risk preferences of the agents. The discount does not depend on either the expected return or volatility of the underlying asset. The fund will trade at a discount (as opposed to a premium) whenever $b(V_2 - V_1) > \lambda - a$. In contrast to $t = 3$ where any amount of NAV appreciation leads to a discount, at $t = 2$ the NAV must appreciate beyond a particular level in order for a discount to emerge. Furthermore, the investor cannot arbitrage the discount by taking a position in the fund along with an offsetting position in a hedging portfolio because he cannot infer the exact composition of the fund.

1.2.3   Equilibrium at $t = 1$

The results from $t = 2, 3$ are utilized in deriving the equilibrium at $t = 1$. Like at $t = 3$, information is symmetric at $t = 1$. Accordingly, many of the results parallel those derived earlier. The following proposition characterizes the equilibrium.

Proposition 3. At $t = 1$, there exists a unique equilibrium in which the closed-end fund discount is given by

$$D_1 = a - \lambda. \tag{1.32}$$

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[7] $\int e^{-\xi x^2 - 2\nu x} dx = \sqrt{\frac{\pi}{\xi}} e^{\frac{\nu^2}{\xi}}$ if $\xi > 0$. The assumption that $\Gamma b > \gamma_i$ ensures that the restriction on ξ is satisfied.

[8] The expressions for G_2^i, H_2^i, and I_2^i, as well as the analogous expressions for the constant terms in (1.35) and (1.40), are not reported but are available upon request.

Although the results are similar to those obtained at $t = 3$, the derivation here is much more complicated due to the presence of a future information asymmetry. We describe the derivation in the remaining portion of this subsection, starting with the fund manager's objective.

Taking into account the $t = 2$ fund portfolio and stock price, the manager's goal at $t = 1$ is to maximize her expected utility subject to a budget constraint:

$$\max_{S_1^f} \quad \mathbb{E}_1\Big[-\exp\Big[-\gamma_m\Big(\rho + a + \tfrac{\gamma_i^2 \gamma_m}{2\Gamma^2}\sigma_3^2 - \tfrac{1}{2}(1-\alpha)\gamma_m b^2\big(\tilde{S}_2^f\big)^2\sigma_2^2$$

$$+ b\big[\tilde{S}_2^f\big(\tilde{X}_1 + \tilde{Z}_1 + (1-\alpha)\mu_2 + \mu_3 - \tfrac{\gamma_i \gamma_m}{\Gamma}\sigma_3^2 - \tilde{P}_2^s\big) + S_1^f\big(\tilde{P}_2^s - P_1^s\big)\big]\Big)\Big]\Big] \quad (1.33)$$

subject to

$$B_1^f = W_f - S_1^f P_1^s \quad (1.34)$$

as well as (1.25), where her objective function follows from (1.24). Since (1.33) is log-quadratic in $\tilde{Z}_1$, we again utilize symbolic computational methods to obtain a closed-form expression for the manager's expected utility,

$$-\frac{1}{\sqrt{1 - 2\alpha\sigma_2^2 I_1^f}}\exp\left[G_1^f + \frac{\alpha\mu_2 H_1^f + \tfrac{1}{2}\alpha\sigma_2^2\big(H_1^f\big)^2 + (\alpha\mu_2)^2 I_1^f}{\big(1 - 2\alpha\sigma_2^2 I_1^f\big)}\right], \quad (1.35)$$

after substituting the $t = 2$ stock price and (1.25), where

$$G_1^f \equiv G_1^f\big(X_1, S_1^f, P_1^s; \alpha, \gamma_i, \gamma_m, \mu_2, \mu_3, \sigma_2^2, \sigma_3^2, a, b, \rho\big)$$
$$H_1^f \equiv H_1^f\big(\alpha, \gamma_i, \gamma_m, \mu_2, \sigma_2^2\big)$$
$$I_1^f \equiv I_1^f\big(\alpha, \sigma_2^2\big).$$

Then, since (1.35) is log-normally distributed, integrating over $\tilde{X}_1$ is relatively straightforward and leads to the following expression for the manager's expected utility at $t = 1$:

$$-\sqrt{1-\alpha}\exp\Big[-\gamma_m\Big(\rho + a + bS_1^f\big(\mu_1 + \mu_2 + \mu_3 - P_1^s - \tfrac{\gamma_i\gamma_m}{\Gamma}\big(\sigma_2^2 + \sigma_3^2\big)\big)$$

$$+ \tfrac{\gamma_i^2\gamma_m}{2\Gamma^2}\big(\sigma_2^2 + \sigma_3^2\big) - \tfrac{1}{2}\gamma_m b^2\big(S_1^f\big)^2\sigma_1^2\Big)\Big] \quad (1.36)$$

Lastly, differentiating (1.36) with respect to S_1^f and substituting the stock price into the first-order condition gives the manager's stock allocation,

$$S_1^f = \frac{\gamma_i}{\Gamma b}, \quad (1.37)$$

which is the same constant fraction as at $t = 3$.

Turning to the investor, his problem at $t = 1$ is to maximize his expected utility subject to a budget constraint while considering the results from $t = 2$ as well as the closed-end fund's current composition:[9]

$$\max_{S_1^i, F_1} \quad \mathbb{E}_1\Big[-\exp\Big[-\gamma_i\Big(\big(S_2^i + F_2(1-b)\tilde{S}_2^f\big)\big(\tilde{X}_1 + \tilde{Z}_1 + (1-\alpha)\mu_2 + \mu_3 - \tilde{P}_2^s - \tfrac{\gamma_i\gamma_m}{\Gamma}\sigma_3^2\big)$$

$$+ S_1^i \tilde{P}_2^s + B_1^i + F_1 \tilde{P}_2^f + F_2\big[(1-b)\big(S_1^f \tilde{P}_2^s + B_1^f\big) + bV_1 - \tilde{P}_2^f - a\big] + \tfrac{\gamma_i\gamma_m^2}{2\Gamma^2}\sigma_3^2$$

$$- \tfrac{1}{2}(1-\alpha)\gamma_i\big(S_2^i + (1-b)F_2\tilde{S}_2^f\big)^2\sigma_2^2\Big)\Big]\Big]. \quad (1.38)$$

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[9]As at $t = 3$, the investor can infer the fund's current portfolio composition.

subject to

$$B_1^i = W_i - S_1^i P_1^s - F_1 P_1^f \tag{1.39}$$

in addition to (1.25), (1.30), (1.31), (1.34), (1.37), and $F_2 = 1$, where his objective function follows from (1.28). Substituting these constraints into (1.38) and integrating over $\tilde{Z}_1$ provides a closed-form expression for the investor's expected utility at $t = 1$,

$$-\frac{1}{\sqrt{1 - 2\alpha\sigma_2^2 I_1^i}} \exp\left[G_1^i + \frac{\alpha\mu_2 H_1^i + \frac{1}{2}\alpha\sigma_2^2 (H_1^i)^2 + (\alpha\mu_2)^2 I_1^i}{(1 - 2\alpha\sigma_2^2 I_1^i)}\right], \tag{1.40}$$

where

$$\begin{aligned}
G_1^i &\equiv G_1^i\left(X_1, S_1^i, F_1, P_1^s, P_1^f, W_i, W_f; \alpha, \gamma_i, \gamma_m, \mu_2, \mu_3, \sigma_2^2, \sigma_3^2, a, b\right) \\
H_1^i &\equiv H_1^i\left(\alpha, \gamma_i, \gamma_m, \mu_2, \sigma_2^2, b\right) \\
I_1^i &\equiv I_1^i\left(\alpha, \gamma_i, \gamma_m, \sigma_2^2, b\right).
\end{aligned}$$

The investor's stock allocation is then found by integrating (1.40) over $\tilde{X}_1$, differentiating the resulting expression with respect to S_1^i, and substituting the stock price and market-clearing condition into the first-order condition to obtain

$$S_1^i = \frac{\Gamma b - \gamma_i}{\Gamma b}. \tag{1.41}$$

Similarly, the price of the closed-end fund is found by integrating (1.40) over $\tilde{X}_1$, differentiating the resulting expression with respect to F_1, and substituting (1.41) and $F_1 = 1$ into the first-order condition, which gives

$$P_1^f = V_1 - a + \lambda. \tag{1.42}$$

Thus, the fund price is equal to NAV plus an adjustment for the management fees and the manager's future information advantage. The fund's discount at $t = 1$ is given by (1.32). Note that the fund will issue at a premium if $\lambda > a$.

Like at $t = 3$, it is conceivable that an arbitrage opportunity exists because the fund price generally does not equal NAV. Though as we now show, the discount does not present an arbitrage opportunity. If the fund is issued at a premium, as is typical in practice, then an arbitrage strategy would involve taking a short position in the fund along with an offsetting position in a hedging portfolio. It is easy to verify that P_2^f can be replicated by forming a portfolio consisting of $(1-b)S_1^f$ shares of stock and $bS_1^f P_1^s + B_1^f - a + \lambda$ bonds at $t = 1$. Since the cost of this portfolio equals P_1^f, however, there is no arbitrage.

1.2.4 Implications of the Basic Model

Though relatively simple, the basic model described in the previous subsections can account for some of the puzzling behaviors exhibited by closed-end funds. First, the basic model shows that a combination of private information and management fees can explain the predictable pattern of discounts observed over a fund's life cycle, as outlined by Lee, Shleifer, and Thaler (1990). The closed-end fund will issue at a premium if $\lambda > a$, and a discount will emerge as time progresses. Furthermore, a simple comparison of the discounts reveals that the size of the closed-end fund discount fluctuates over time. In particular, NAV appreciation leads to an increase in the discount, which is consistent with the empirical findings of Malkiel (1977) and Pontiff (1995). Additionally,

Variable	Symbol	Value
Investor's coefficient of risk aversion	γ_i	1
Manager's coefficient of risk aversion	γ_m	40
Fixed component of management fee	a	0.01675
Variance of $\tilde{X}_1$	σ_1^2	0.00417
Variance of $\tilde{X}_2$	σ_2^2	0.01667
Variance of $\tilde{X}_3$	σ_3^2	0.00417

the principle of no arbitrage along with (1.9) suggest that the discount will disappear once the management fees are paid immediately prior to liquidation at $t = 4$.

As noted above, the fund will issue at a premium if $\lambda > a$. Moreover, since λ is a function of managerial ability and the variable component of the management fee, for any given ability level the contract parameters, a and b, can be chosen so that the fund issues at a premium. There is no inherent reason, though, why a closed-end fund should issue at a premium rather than at NAV.[10] After all, the investor receives the equilibrium rate of return over the life of the fund regardless of whether it issues at a premium or at NAV. As we discuss below, however, there is a direct relationship between the issue premium and the manager's ex ante expected utility.

The relationship between the issue premium and the manager's expected utility is best understood graphically. In order to plot this relationship, we assume reasonable numerical values for various parameters in the model. The investor's coefficient of risk aversion is normalized to one, and the manager's coefficient of risk aversion of 40 is chosen to satisfy the assumption that $\Gamma b > \gamma_i$ and still accommodate relatively low values for b. The fixed component of the management fee is set to 0.01675, but it affects neither the shape of the issue premium nor the manager's expected utility. Finally, the variance of the stock payoff is chosen to match the return precision from Berk and Stanton (2007), with two-thirds of the total variance allocated to the portion of the payoff that can potentially comprise the manager's private information, $\tilde{X}_2$, and one-sixth allocated to each of the remaining portions, $\tilde{X}_1$ and $\tilde{X}_3$. These parameter values are summarized in Table 1.I.

Figure 1.1(a) plots the issue premium and Figure 1.1(b) plots the manager's expected utility as a function of managerial ability, α, and the variable component of the management fee, b. Comparing these figures, it is evident that the choice of b that maximizes the manager's expected utility for a given ability level also maximizes the issue premium.[11] This relationship explains why closed-end funds tend to issue at a premium. Provided that a is not too large, the fund manager's utility-maximizing choice of b gives rise to an issue premium, and given that choice of b, the investor will pay a premium because doing so maximizes his own expected utility and clears the market.

Note that choosing the variable component of the management contract to maximize the manager's expected utility is not merely a transfer of wealth from the investor to the manager, as changes in b influence how aggressively the manager trades on her private information and affect the risk characteristics of the fund. In contrast, decreasing the value of the fixed component of the management contract, a, leads to a larger issue premium and constitutes a pure wealth transfer from the investor to the manager at the outset but also results in lower management fees and

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[10]Pursuant to the Investment Company Act of 1940, a closed-end fund may sell its common stock at a price less than NAV only in certain limited circumstances.

[11]This can be verified numerically. The relationship also holds if instead the management contract pays the manager a fraction of the total assets under management, although the shape of the issue premium is slightly different. We provide robustness checks of this result when the stock price is endogenously determined in Appendices A.1 and A.2.

(a) Issue Premium (b) Manager's Expected Utility
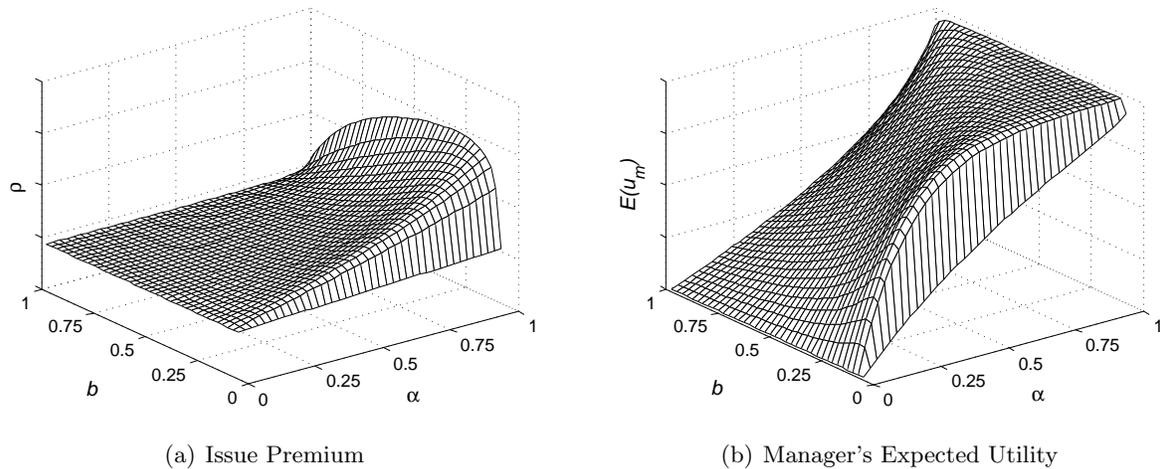
Figure 1.1: Issue Premium and Expected Utility.

an offsetting wealth transfer from the manager to the investor when the fund terminates. Hence, adjustments to a do not affect the manager's expected utility.

Additionally, the fact that the issue premium is not monotonic in b may shed some light on why there is mixed empirical evidence regarding the impact of management fees on discounts. Since the variable component of the management fee affects the manager's incentive to exploit her information advantage, which in turn affects the fund's risk characteristics, the management fee indirectly affects the fund price and, ultimately, the size of the closed-end fund discount. As is evident from Figure 1.1(a), the relationship between b and the discount is nonlinear and non-monotonic. Therefore, it is not terribly surprising, at least according to our model, that empirical studies have produced mixed evidence concerning the effect of fees on discounts.

1.3 Extended Model

The basic model described in Section 1.2 can be extended to an economy that includes a longer time horizon and random ability. The aims of this section are to illustrate the evolution of the discount over time and test whether the combination of management fees and a time-varying information advantage can explain some puzzling empirical features of closed-end funds—namely, the correlations between discounts and returns, the excess volatility of fund returns, and the under-performance of premium funds. We first describe the framework of the extended model in Section 1.3.1 and present the equilibrium in Section 1.3.2. We then simulate data in Section 1.3.3 and compare the model's predictions to some empirical characteristics of closed-end funds reported in the literature.

1.3.1 Assumptions

This subsection outlines the assumptions of the extended model. Most of these assumptions parallel those of basic model described in Section 1.2 but are modified to encompass a longer time horizon and time-varying managerial ability. Extending the time horizon allows us to evaluate the behavior of discounts and returns over a fund's life cycle. In particular, we can use the extended version of the model to simulate data and assess its ability to account for and explain some stylized

facts documented in the literature. Unless otherwise noted, the assumptions of the basic model continue to hold in the extended setting.

Time is now indexed by $t = 1, 2, \ldots, T + 1$, where T is a multiple of 3. As described in more detail below, the information and trading sequences of the basic model repeat for $N = \frac{T}{3}$ cycles, which are indexed by n. Each cycle is comprised of three dates. Throughout this section, for all $n = 1, 2, \ldots, N$, we refer to $t = 3n - 2$ as the "beginning" of a cycle, $t = 3n - 1$ as the "middle" of a cycle, and $t = 3n$ as the "end" of a cycle, which are analogous to $t = 1, 2, 3$, respectively, in the basic model. Consumption occurs at $T + 1$.

The stock pays a random amount, $\tilde{Y}$, at $T + 1$. As in the basic model, the stock payoff consists of the sum of independent and normally distributed random variables; accordingly, $\tilde{Y}$ is redefined as

$$\tilde{Y} \equiv \sum_{t=1}^{T} \tilde{X}_t, \tag{1.43}$$

where $\tilde{X}_t \sim \mathcal{N}\big(\mu_t, \sigma_t^2\big)$ for all $t \leq T$. Likewise, the exogenous stock price process is now given by

$$P_t^s = \sum_{\tau=1}^{t-1} X_t + \sum_{\tau=t}^{T} \Big(\mu_\tau - \frac{\gamma_i \gamma_m}{\Gamma} \sigma_\tau^2\Big). \tag{1.44}$$

The assumptions regarding the bonds remain unchanged.

The closed-end fund undergoes an IPO at $t = 1$ and is liquidated at $T + 1$, but it does not make any distributions prior to liquidation. The fund manager collects a sequence of fees, $\tilde{\phi}_n$, at the end of each cycle and consumes $c_m = \rho + \sum_{n=1}^{N} \tilde{\phi}_n$ at $T + 1$. The parameters of the management contract, a and b, are constant over time, and the n-th cycle fee is given by

$$\tilde{\phi}_n = a + b\big(S_{3n}^f \tilde{P}_{3n+1}^s + B_{3n}^f - V_{3n-2}\big). \tag{1.45}$$

The fees are deducted from the fund's NAV at the time they are earned; hence, between cycles the fund's NAV evolves according to

$$V_{3n+1} = S_{3n}^f P_{3n+1}^s + B_{3n}^f - \phi_n \tag{1.46}$$

for all n, and within a cycle the fund's NAV evolves according to

$$V_{t+1} = S_t^f P_{t+1}^s + B_t^f \tag{1.47}$$

for all $t \neq 3n$. Additionally, no arbitrage requires that the terminal stock price be equal to its payoff: $\tilde{P}_{T+1}^s = \tilde{Y}$.

Like in the basic model, the investor obtains utility solely by consuming the payoff from his portfolio,

$$\tilde{c}_i = S_T^i \tilde{Y} + B_T^i + F_T\big(S_T^f \tilde{Y} + B_T^f - \tilde{\phi}_N\big). \tag{1.48}$$

The investor's budget constraint satisfies

$$S_t^i P_t^s + B_t^i + F_t P_t^f = S_{t-1}^i P_t^s + B_{t-1}^i + F_{t-1} P_t^f \tag{1.49}$$

for all $t \leq T$.

An important feature of the extended model is that the manager's ability to acquire information at the middle of every cycle is stochastic. This leads to a time-varying information advantage for the fund manager. For tractability, we assume that the manager's ability for a given cycle can be

either low, α_ℓ, or high, α_h, with probability Υ_ℓ and Υ_h, respectively, and $0 < \alpha_\ell < \alpha_h < 1$. Both the manager and investor observe the manager's ability for cycle n at the beginning of the cycle, i.e., $t = 3n - 2$, but the ability is unknown to both of them prior to that time. Similar to the basic model, for each cycle n we assume that $\tilde{X}_{3n-1}$ is the sum of two components, $\tilde{Z}_{n,1}$ and $\tilde{Z}_{n,2}$, the distributions of which depend on the manager's ability for a particular cycle and are given by $\tilde{Z}_{n,1} \sim \mathcal{N}(\alpha_q \mu_{3n-1}, \alpha_q \sigma_{3n-1}^2)$ and $\tilde{Z}_{n,2} \sim \mathcal{N}((1 - \alpha_q)\mu_{3n-1}, (1 - \alpha_q)\sigma_{3n-1}^2)$ for $q \in \{\ell, h\}$.

Modeling ability in this fashion reflects the notion that the value of the manager's skills depends on (unmodeled) economic conditions which evolve over time. One historical example of evolving economic conditions that likely affected the value of a manager's skills is the reunification of Germany. Shortly after the fall of the Berlin Wall in 1989, a closed-end country fund specializing in German assets experienced a dramatic rise in price, moving from a discount of roughly 10% to a premium of 100%. This rapid change in value could be attributed to investors recognizing that the fund manager was in a position to capitalize on new investment opportunities due to the manager's familiarity with the marketplace. Granted, this occurred under very unusual circumstances, but it illustrates how investors might react to changes in economic conditions that are not extraordinary in nature. For example, a technological or political innovation could suddenly enhance the value of a manager with expertise in a particular industry.

The information structure follows a pattern similar to that of the basic model. At the beginning of every cycle, the investor and fund manager have knowledge of all prior realizations of X_t: $\mathcal{I}_{3n-2}^i = \mathcal{I}_{3n-2}^f = \{X_1, X_2, \ldots, X_{3n-3}\}$ for $n = 1, 2, \ldots, N$. Both the manager and investor observe X_{3n-2} at the middle of every cycle. Furthermore, the manager acquires private information at the middle of every cycle through observation of $Z_{n,1}$, which is unobservable to the investor. Consequently, the information sets are asymmetric: $\mathcal{I}_{3n-1}^i = \mathcal{I}_{3n-1}^f = \{X_1, X_2, \ldots, X_{3n-2}\}$ and $\mathcal{I}_{3n-1}^f = \{X_1, X_2, \ldots, X_{3n-2}, Z_{n,1}\}$. At the end of every cycle, the information sets are once again symmetric: $\mathcal{I}_{3n}^i = \mathcal{I}_{3n}^f = \{X_1, X_2, \ldots, X_{3n-1}\}$. For the sake of completeness, note that $\mathcal{I}_0^i = \mathcal{I}_0^f = \emptyset$ and $\mathcal{I}_{T+1}^i = \mathcal{I}_{T+1}^f = \{X_1, X_2, \ldots, X_T\}$.

The sequence of events is modified as follows. At $t = 1$, the fund undergoes an IPO. At the beginning of every cycle, both the investor and manager observe the manager's ability for that cycle and choose portfolios at market-clearing prices subject to their respective budget constraints. The management fee earned during the immediately preceding cycle is deducted from the NAV of the fund and placed into escrow until $T + 1$ prior to selecting the fund's new portfolio. At the middle of every cycle, the manager acquires private information regarding the stock payoff. The investor and manager then proceed to rebalance their respective portfolios. At the end of every cycle, the fund manager's information advantage disappears, and both agents select new portfolios. At $T + 1$, all management fees are paid, the fund is liquidated, and consumption occurs.

1.3.2 Equilibrium

The equilibrium in the extended setting is complicated by the fact that the manager's ability to acquire information is now stochastic. However, since the manager's ability remains unchanged between dates within a cycle and there are no wealth effects associated with CARA preferences, the same techniques utilized to solve for the equilibrium in the basic setting can be used to solve for the equilibrium closed-end fund discount at the beginning and middle of each cycle in the extended setting. Solving for the equilibrium discount at the end of a cycle is slightly more complicated due to the uncertainty surrounding the manager's ability for the immediately ensuing cycle.

When selecting their respective portfolios at the end of each cycle (except cycle N), the investor and manager are exposed to risk associated with both a component of the stock payoff and the

manager's ability for the immediately ensuing cycle.[12] Since the manager's ability is independent of the stock payoff and the agents' preferences do not exhibit wealth effects, however, the uncertainty surrounding the manager's ability does not impact the stock allocations. Moreover, because the manager and investor possess symmetric information, the respective equilibrium stock allocations at the end of cycle n are the same constant fractions as in the basic setting:

$$S_{3n}^f = \frac{\gamma_i}{\Gamma b} \tag{1.50}$$

and

$$S_{3n}^i = \frac{\Gamma b - \gamma_i}{\Gamma b}. \tag{1.51}$$

While the investor is able to infer the fund's portfolio at the end of each cycle since it contains a constant fraction of the stock, owning the fund exposes the investor to risk associated with the manager's ability for the next cycle. If the manager's ability happens to be high during the next cycle then she will obtain a greater information advantage and the fund price will be higher at the beginning of the next cycle than if the manager's ability turns out to be low. This uncertainty is incorporated into the fund price as a weighted average of the investor's expected benefit from the manager's private information,

$$\delta \equiv \frac{\lambda_\ell \Upsilon_\ell \sqrt{1 + \frac{\alpha_h \gamma_i (1-b)(\Gamma b - \gamma_i + \gamma_m b)}{(1-\alpha_h)\gamma_m^2 b^2}} + \lambda_h \Upsilon_h \sqrt{1 + \frac{\alpha_\ell \gamma_i (1-b)(\Gamma b - \gamma_i + \gamma_m b)}{(1-\alpha_\ell)\gamma_m^2 b^2}}}{\Upsilon_\ell \sqrt{1 + \frac{\alpha_h \gamma_i (1-b)(\Gamma b - \gamma_i + \gamma_m b)}{(1-\alpha_h)\gamma_m^2 b^2}} + \Upsilon_h \sqrt{1 + \frac{\alpha_\ell \gamma_i (1-b)(\Gamma b - \gamma_i + \gamma_m b)}{(1-\alpha_\ell)\gamma_m^2 b^2}}} \tag{1.52}$$

where

$$\lambda_q \equiv \frac{\alpha_q (1-b)(\Gamma b - \gamma_i)}{\alpha_q \gamma_i (1-b)(\Gamma b - \gamma_i + \gamma_m b) + (1-\alpha_q)\gamma_m^2 b^2} \tag{1.53}$$

for $q \in \{\ell, h\}$. The discount at the end of cycle n,

$$D_{3n} = a + b(V_{3n} - V_{3n-2}) - (N-n)(\delta - a), \tag{1.54}$$

is a combination of the future management fees and the expected benefits from the manager's future information advantages.

At the middle of each cycle, the manager has an information advantage over the investor. Like in the basic setting, the information asymmetry is incorporated into the manager's stock demand. The equilibrium stock allocations at the middle of cycle n are

$$S_{3n-1}^f = \frac{Z_{n,1} - \alpha_q \mu_{3n-1} + \frac{\gamma_i \gamma_m}{\Gamma} \sigma_{3n-1}^2}{(1-\alpha_q)\gamma_m b \sigma_{3n-1}^2} \tag{1.55}$$

and

$$S_{3n-1}^i = \frac{\Gamma b - \gamma_i}{\Gamma b}. \tag{1.56}$$

The discount at the middle of cycle n,

$$D_{3n-1} = a + b(V_{3n-1} - V_{3n-2}) - \lambda_q - (N-n)(\delta - a), \tag{1.57}$$

depends on the current level of managerial ability as well as the future management fees and benefits from private information.

At the beginning of each cycle, the investor and manager bear the risk associated with a

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[12]Only uncertainty with respect to $\tilde{X}_T$ exists at the end of cycle N.

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component of the stock payoff but are not exposed to risk associated with managerial ability. Since the information sets are symmetric, the equilibrium here is analogous to the equilibrium at $t = 1$ in the basic setting. At the beginning of cycle n, the stock allocations are

$$S^f_{3n-2} = \frac{\gamma_i}{\Gamma b} \tag{1.58}$$

and

$$S^i_{3n-2} = \frac{\Gamma b - \gamma_i}{\Gamma b}. \tag{1.59}$$

Although there is no current uncertainty regarding managerial ability, the future uncertainty is incorporated into the fund price. Accordingly, the discount at the beginning of cycle n is given by

$$D_{3n-2} = a - \lambda_q - (N - n)(\delta - a). \tag{1.60}$$

Similar to the middle of each cycle, the discount at the beginning of each cycle is a combination of management fees and the benefits from the manager's current and future information advantages.

A few basic themes emerge from the extended model. First, the closed-end fund will trade at a discount when the management fees outweigh the expected benefits from the manager's private information, and vice versa. Second, the expected benefit from the manager's information advantage, which is captured by λ_q and δ, evolves over time. Specifically, at the turn of a cycle (from $t = 3n$ to $t = 3n + 1$), the expected benefit from all future private information changes by an amount equal to $\lambda_q - \delta$. Since this adjustment is positive whenever a high ability level is realized and negative whenever a low ability level is realized, the expected benefit from the manager's private information (and hence the discount) changes even when her ability level remains unaltered. Third, the equilibrium discounts and portfolio allocations are analogous to those in the basic model, but there is additional uncertainty which stems from the time-varying ability of the manager and causes the discount to fluctuate. We next evaluate the model's ability to account for several empirical observations documented in the literature.

1.3.3 Simulation

Since the focus of our analysis is private information and management fees, the only parameters that may vary across simulations are managerial ability and the realizations of the components of the stock payoff, and we assume that the distributions of these parameters are independent across simulations. The parameter values used in the simulations are listed in Tables 1.I and 1.II. Although there are a total of 13 free parameters in our model, we impose restrictions on many of these so that only a few are truly discretionary. Here we discuss our rationale for selecting the parameter values, beginning with those listed in Table 1.I. As previously mentioned, γ_i is normalized to one, and γ_m is conservatively chosen to satisfy our assumption that $b\Gamma > \gamma_i$ while still accommodating relatively low values for b. Additionally, we choose the stock volatility to match the return precision from Berk and Stanton (2007).

Next, we explain our reasons for choosing the parameter values listed in Table 1.II. The variable component of the management fee, b, is set at 20% to be consistent with contracts in the money management industry that charge a fixed percentage of returns. Like the stock volatility, the time horizon of 50 cycles matches the horizon in Berk and Stanton (2007), and the fund's initial wealth designated for investment is set to 1. The mean stock payoff for a cycle is fixed at 0.15 so that negative payoffs occur only when the payoff realization is more than roughly one standard deviation below the mean. Additionally, we assume that two-thirds of the total payoff for a cycle can potentially comprise the manager's private information, $\tilde{X}_{3n-1}$, and that the remaining one-third

Table 1.II: Parameter Values.

Variable	Symbol	Value
Variable component of management fee	b	0.20
Low ability level	α_ℓ	0.05
High ability level	α_h	0.65
Probability of low ability	Υ_ℓ	0.90
Probability of high ability	Υ_h	0.10
Mean of $\tilde{X}_{3n-2}$	μ_{3n-2}	0.025
Mean of $\tilde{X}_{3n-1}$	μ_{3n-1}	0.10
Mean of $\tilde{X}_{3n}$	μ_{3n}	0.025
Fund's initial wealth	W_f	1
Number of cycles	N	50

of the total payoff is split equally between $\tilde{X}_{3n-2}$ and $\tilde{X}_{3n}$ for all n.

After selecting these parameter values, only a handful of parameters remain that can be used to match the empirically observed discount dynamics—these are the fixed component of the management contract, the manager's ability levels, and the distribution of ability. To be consistent with empirical observations, the values for the ability levels and their accompanying probability distribution are chosen so that funds issue at a premium and are likely to begin trading at a discount very quickly. The probability of the manager having a high ability level for a cycle, Υ_h, is set at 10%, but in each simulation the initial level of ability is set at α_h so that the fund issues at a premium. This results in issue premiums and the emergence of discounts within a single cycle, but it also reflects the fact that funds rarely move from trading at a discount to a premium.[13] To create a large rise in the discount following the IPO, the expected benefit from the manager's private information must dramatically decrease, which means that λ_h must be much greater than λ_ℓ. This is achieved through a large "ability-spread," so we set the respective levels of low and high ability, α_ℓ and α_h, equal to 0.05 and 0.65. Hence, the manager adds little value in low-ability states but has the potential to add a great deal of value in high-ability states. Finally, the fixed component of the management fee, a, basically shifts the discount distribution and is chosen so that the magnitude of the issue premium coincides with empirical measurements.

Figure 1.2 plots the distribution of discounts over 1000 simulations. Only the discount at the beginning of each cycle is plotted to avoid the periodic fluctuations that arise from the acquisition of new information. The cross-sectional distribution of discounts is evident from the figure. Furthermore, the average fund issues at a premium of 2.6% and subsequently begins to trade at a discount of 7.4%, which is slightly smaller than the mean discount of 8.6% reported by Chay and Trzcinka (1999) and likely due to other unmodeled factors that contribute to discounts.[14] The discount eventually converges to zero when the fund is liquidated, and the downward trend is a result of the finite horizon of the funds.

Because the existing literature is a hodgepodge of studies that uses various measurements for

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[13]Due to the low likelihood of realizing and maintaining a high ability level, the manager's ability to earn a positive abnormal return net of fees dissipates rather quickly. This could reflect, for example, changes in economic conditions which make a particular manager's skill set more valuable. In the short-term, the manager can exploit her ability to earn excess returns, but her advantage is quickly competed away by other managers who adapt to the changes. Mandatory periodic disclosures of asset holdings could also cause the manager's information advantage to dissipate. In any case, empirical evidence by Chay and Trzcinka (1999) indicates that managerial ability is short-lived.

[14]Section 1.1 discusses other potential factors that may influence the discount.
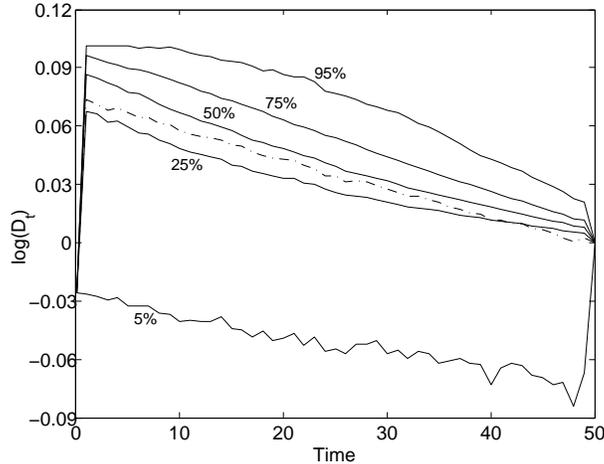
Figure 1.2: Distribution of Closed-End Fund Discounts. The plot shows the log discount at the beginning of each cycle, defined as $\log(V_{3n-2}/P^f_{3n-2})$. The dashed line represents the average discount, and the solid lines represent various fractiles of the discount distribution for 1000 simulated funds.

the discount—some use percentage discounts while others use log discounts or simple discounts[15]—in comparing the predictions of our model to existing empirical observations, we align our measurements with and attempt to replicate as close as possible the particular empirical study being compared. Additionally, the simulated data are modified prior to conducting our analyses. First, the data are smoothed, meaning that only observations from the beginning of each cycle are included. This reduces the effects of the synchronous information acquisition. Second, the first and last observations are purged from each simulation, thereby eliminating the large and predictable rise (fall) in the discount that occurs during the first (last) cycle for almost every fund in the simulated sample.

Relations Between Discounts and Returns

We first check whether the relations between discounts and returns in our model are compatible with empirical observations. As a preliminary matter, augmented Dickey-Fuller tests reject a unit root at the 10% level for over 95% of the simulated funds, which indicates that the discounts are stationary. This result compares favorably to Pontiff (1995), where a unit root is rejected for only 53% of funds in his sample.

Next, we evaluate the time-series correlations between log premiums, fund price returns, and NAV returns. To be consistent with Pontiff (1995), each individual pairwise correlation is weighted proportional to the inverse of the correlation's standard error, and the weighted averages of these correlations are presented in Table 1.III. The columns contain the contemporaneous variable, and the rows contain the time-t variable.

The results from the simulation account for some prominent stylized facts found in the literature and are for the most part qualitatively consistent with those reported by Pontiff (1995), although rigorous quantitative comparisons are difficult due to the mismatched frequency of the data. Some of the more puzzling statistical relations with which the model is consistent include: positively au-

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[15]Percentage discounts are defined as one minus the ratio of the fund price to the fund's NAV. Log discounts are defined as the natural logarithm of the ratio of the fund's NAV to the fund price. Simple discounts are defined as the difference between the fund's NAV and the fund price.

Table 1.III: Average Correlation Coefficients. A weighted average of the beginning-of-cycle individual pairwise correlation coefficients between premiums and returns over 1000 simulations is reported. The columns contain the contemporaneous variables, and the rows contain the time-τ variables, where $\tau \equiv 3n - 2$ is the beginning of the contemporaneous cycle, $\tau - 1 \equiv 3n - 5$ is the beginning of the previous cycle, and $\tau + 1 \equiv 3n + 1$ is the beginning of the next cycle. Premiums are defined as $-\log(V_\tau/P_\tau^f)$, fund returns are defined as $\log(P_{\tau+1}^f/P_\tau^f)$, and NAV returns are defined as $\log(V_{\tau+1}/V_\tau)$. The weight of each individual pairwise correlation coefficient is equal to the inverse of that correlation coefficient's standard error.

	Premium$_\tau$	Fund Return$_\tau$	NAV Return$_\tau$
Premium$_{\tau-1}$	0.381		
Fund Return$_{\tau-1}$	0.416	-0.007	
Fund Return$_\tau$	0.020		
Fund Return$_{\tau+1}$	-0.064		
NAV Return$_{\tau-1}$	0.020	-0.025	-0.022
NAV Return$_\tau$	0.415	0.829	
NAV Return$_{\tau+1}$	-0.055	0.243	

tocorrelated premiums (discounts are persistent); a negative correlation between current premiums and future fund returns (premiums predict fund returns); near zero correlation between current premiums and future NAV returns (premiums do not predict NAV returns); and less than perfect contemporaneous correlation between fund returns and NAV returns (something besides NAV affects fund prices). Consistent with other empirically observed statistical relations, our model also predicts that current premiums are positively correlated with lagged fund returns but unrelated to lagged NAV returns and that current fund returns are unrelated to lagged NAV returns.

There are, however, a few discrepancies between the simulation results and empirical observations. Pontiff (1995) finds that both fund returns and NAV returns are negatively autocorrelated while our simulation produces autocorrelations near zero. He also reports a negative contemporaneous correlation between premiums and NAV returns and a negative correlation between current fund returns and future NAV returns while our simulation yields positive correlations. Despite these differences, the model performs relatively well in matching the time-series correlations between discounts and returns reported in the literature.

Our model also accounts for some cross-sectional relations between discounts and returns. The average correlation between changes in percentage discounts and the returns on the stocks held by a fund in the simulation is -0.019, which is analogous to an observation by Lee, Shleifer, and Thaler (1991) that the correlation between changes in discounts and returns on a market index is about zero. Furthermore, our model produces an average correlation between changes in log premiums and NAV returns of -0.334, which is consistent with a finding by Pontiff (1997) that the monthly covariance between changes in log premiums and NAV returns is negative.

Based on the above comparisons, it appears as though the model adequately accounts for the empirically observed relations between discounts and returns. We next test whether fund returns in our model are more volatile than NAV returns, as documented in the literature.

Excess Volatility of Fund Returns

Pontiff (1997) finds that fund returns are more volatile than the returns of their underlying assets. He also reports a negative correlation between NAV returns and changes in premiums, which means that fund prices underreact to NAV returns. Together, these two observations are

perplexing because they indicate that fund prices are more volatile than NAV returns even though prices tend to underreact to NAV returns. In the previous subsection, we report that our model leads to a negative correlation between changes in premiums and NAV returns. In this subsection, we assess whether our model produces fund returns that are more volatile than the underlying NAV returns. We find that it does.

For each fund in the sample, the log of the ratio of the fund return variance to the fund's NAV return variance is calculated. A positive log variance ratio indicates that the volatility of the fund return is greater than the volatility of the underlying NAV return. The average log variance ratio from the simulations is approximately 0.122 and is significantly different from zero, although it is smaller than the four-month average log variance ratio of 0.434 reported by Pontiff (1997). Nevertheless, our model accounts for the excess volatility of fund returns.

The primary source of excess volatility is the discount itself, which is best appreciated by considering the NAV return over a single cycle, $R^v \equiv V_{3n+1}/V_{3n-2}$, and the fund return over a single cycle, $R^f \equiv P^f_{3n+1}/P^f_{3n-2}$. Given V_{3n-2}, the conditional variance of the NAV return is

$$\mathbb{V}\big[R^v \,|\, V_{3n-2}\big] = \frac{\mathbb{V}[V_{3n+1}]}{V^2_{3n-2}}, \tag{1.61}$$

where $\mathbb{V}$ is the variance operator, and the conditional variance of the fund return can be written as

$$\mathbb{V}\big[R^f \,|\, P_{3n-2},\, V_{3n-2}\big] = \frac{\mathbb{V}[V_{3n+1}] + \mathbb{V}[\lambda]}{(V_{3n-2} - D_{3n-2})^2} \tag{1.62}$$

after substituting (1.60) since the NAV return for the current cycle is independent of the manager's ability during the ensuing cycle. Comparing these expressions, it is evident that if the fund is trading at a discount (i.e., $D_{3n-2} > 0$) then the variance of the fund return is greater than the variance of the NAV return. On the other hand, if the fund is trading at a premium then the variance of the fund return may or may not be greater than the variance of the NAV return, depending on the size of the premium and the variance of λ. Furthermore, our conclusion that the discount is the primary source of a fund's excess volatility is consistent with a finding by Pontiff (1997) that the excess volatility is unrelated to market factors since discounts in our model depend on the ability of the manager.

Profitable Trading Strategies

Perhaps one of the most anomalous empirical observations is that closed-end funds with large discounts tend to outperform the market while those with large premiums tend to underperform the market, adjusted for risk, as documented by Thompson (1978) and Pontiff (1995). Given our current set of assumptions, our model is unable to account for such underperformance. By slightly modifying our assumptions, however, our model not only produces underperforming premium funds but also provides an economic explanation for this phenomenon. Specifically, our model produces underperforming premium funds when the stock price is endogenously determined. We formally describe the modifications to our model that will generate underperformance of premium funds in Appendix A.1, though we note here that endogenizing the stock price does not alter either the fundamental concept of our model or the nature of our analysis. Indeed, the only practical difference between the equilibrium in our featured model described in Section 1.3.2 and in our modified model is the extent to which the manager can profit from her information advantage, as an endogenous stock price influences how aggressively the manager trades on her private information. In this subsection, we first demonstrate the aforementioned underperformance using simulated data from our

Table 1.IV: Risk-Adjusted Performance. The returns from an equally-weighted dynamic portfolio that is long the 2% of funds with the largest discount are regressed on the returns from an equally-weighted portfolio of the stocks traded by the those funds and the returns from an equally-weighted dynamic portfolio that is short the 2% of funds with the largest premium are regressed on the returns from an equally-weighted portfolio of the stocks traded by those funds. The returns from an equally-weighted portfolio of all funds are regressed on the returns from a portfolio of all stocks. The coefficients from these regressions are presented with t-statistics in parentheses. Significance at the 95% level is indicated by **, and significance at the 99% level is indicated by ***.

	Discount	Premium	All Funds
Jensen's alpha	−0.083	3.714	−0.003
	(−0.46)	(3.73)***	(−0.01)
Beta with stock index	0.756	−2.269	0.416
	(4.17)***	(−2.28)**	(1.48)

modified model with an endogenous stock price. We then explain why significant underperformance does not occur under our original set of assumptions with an exogenous price process.

To assess whether our model generates premium (discount) funds that underperform (outperform) the market, we analyze two distinct investment strategies as in Pontiff (1995). The first strategy entails forming an equally-weighted dynamic portfolio, which we refer to as the "discount portfolio," consisting of the 2% of funds that have the largest discount. The second strategy involves the construction of another equally-weighted dynamic portfolio, which we refer to as the "premium portfolio," consisting of the 2% of funds that have the largest premium.[16] These portfolios are initially created at the beginning of the second cycle and are held until the beginning of the next cycle, at which point they are rebalanced. The process repeats for $N - 2$ cycles.

The returns from holding a long position in the discount portfolio and a short position in the premium portfolio are regressed on the returns from an equally-weighted portfolio comprised of the stocks traded by the funds in the respective portfolios. As a benchmark, the returns from an equally-weighted portfolio comprising all simulated funds are regressed on the returns from an equally-weighted portfolio of all simulated stocks. The coefficients from these regressions are reported in Table 1.IV. There is a positive and highly significant risk-adjusted abnormal return for the shorted premium portfolio, measured as the intercept from the aforementioned regressions as in Jensen (1968). The risk-adjusted abnormal returns for the discount portfolio and the benchmark portfolio are not significantly different from zero. Thus, it appears as though funds in our model that trade at a premium significantly underperform the market, adjusted for risk, but funds that trade at a discount do not outperform the market on a risk-adjusted basis.

To illustrate the extent of the profits that can be earned by buying funds that trade at a large discount and selling funds that trade at a large premium, we calculate the returns accruing to both the discount portfolio and the premium portfolio. Table 1.V reports the terminal value of one dollar invested at the beginning of the second cycle for each of these strategies, along with an equally-weighted benchmark portfolio comprising all simulated funds. The discount portfolio outperforms the benchmark portfolio by 16%, while the premium portfolio underperforms the benchmark portfolio by 55% over $N - 2$ cycles.

Given the documented poor relative performance of closed-end funds that trade at a premium, the question remains: why do investors purchase closed-end funds that trade at a premium? The answer, we argue, is that large-premium funds provide insurance against extreme realizations of

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[16]The results presented below are robust to portfolios of various sizes within the neighborhood of 2%.

Table 1.V: Illustration of Returns. One dollar is invested in an equally-weighted dynamic portfolio consisting of the 2% of funds with the largest discount and an equally-weighted dynamic portfolio consisting of the 2% of funds with the largest premium. Each portfolio is rebalanced at the beginning of every cycle. A portfolio comprising all funds serves as a benchmark. The terminal value is the return from the investment over $N-2$ cycles. The intra-cycle return is the return accruing within cycles, and the inter-cycle return is the return accruing between cycles. The average excess return is the time-series average of the difference between either the discount portfolio or the premium portfolio and the benchmark portfolio. t-statistics are in parentheses. Significance at the 95% and 99% levels are indicated by ** and ***, respectively.

	Discount	Premium	All Funds
Terminal value	1.126	0.442	0.974
Intra-cycle return	1.086	0.436	1.011
Inter-cycle return	1.037	1.012	0.963
Average excess return	0.309	−1.568	
	$(2.00)^{**}$	$(-3.06)^{***}$	

the manager's private information. A fund will trade at a premium in our model only when the manager has a high level of ability, which allows her to observe a larger portion of the stock payoff. The high ability level, however, does not necessarily translate into positive abnormal returns net of management fees. If the realization of $\tilde{Z}_{n,1}$ is close to $\alpha_q \mu_{3n-1}$, then the manager's private information is less valuable in the sense that knowledge of $Z_{n,1}$ does not dramatically alter the fund's portfolio composition. On the other hand, the private information is tremendously valuable given an extreme realization of $\tilde{Z}_{n,1}$. If $Z_{n,1}$ is very small, then the fund will hold less stock and thereby avoid a hefty loss that otherwise would have been incurred; alternatively, if $Z_{n,1}$ is really large, then the fund will hold more stock and thereby earn a sizable gain that otherwise would not have been realized. Because the investor is risk-averse, he is willing to purchase shares in the fund to obtain the abnormal return when the stock payoff is low even though he expects the fund to underperform on average. Conversely, there is no insurance component of a fund that trades at a large discount since the manager of such a fund has low ability. As is evident from Figure 1.3, which plots the net-of-fee returns of premium and discount funds as a function of $Z_{n,1}$, the single-cycle returns for funds that trade at a premium tend to be quite large for extreme realizations of $\tilde{Z}_{n,1}$ but negative for non-extreme realizations, while the returns for funds that trade at a discount tend to cluster around zero.

The concept of insurance in the portfolio delegation setting is not unique to closed-end funds. For instance, Glode (2011) demonstrates that insurance concerns drive the negative risk-adjusted performance of open-end mutual funds. In his model, fund managers actively seek abnormal returns in bad states of the economy, and these active returns covary positively with the pricing kernel. In our model, however, insurance does not necessarily imply a positive relation between the pricing kernel and abnormal returns of funds that trade at a premium since abnormal returns are also earned in extremely good states.

A closer inspection of the returns accruing to the discount and premium portfolios from the above illustration provides some evidence in favor of the insurance argument. The aggregate return of each portfolio can be decomposed into the return accruing within cycles (from $t = 3n-2$ to $3n$) and the return accruing between cycles (from $t = 3n$ to $3n+1$), and Table 1.V lists the intra-cycle and inter-cycle returns of both the discount portfolio and the premium portfolio. A fair portion of the returns accruing to the discount portfolio occurs between cycles. This suggests that high ability shocks, which possibly could be attributed to manager replacement as in Wermers, Wu, and Zechner (2008), contribute to the excess return for the discount portfolio. Conversely, the premium

(a) Premium Fund Returns   (b) Discount Fund Returns
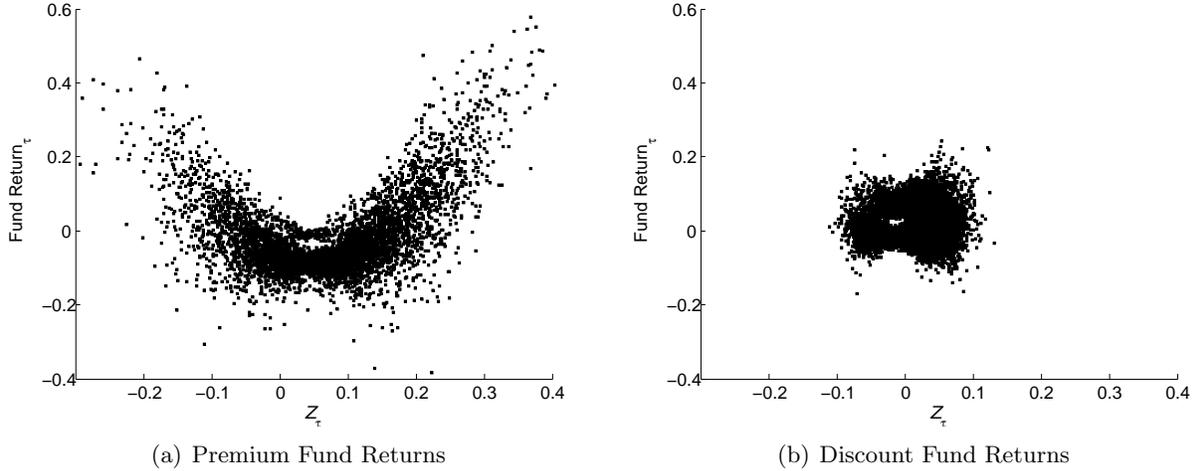
Figure 1.3: Fund Returns. The plots show the log fund returns over a cycle, defined as $\log(P^f_{3n+1}/P^f_{3n-2})$, as a function of the realization of $\tilde{Z}_{n,1}$. Panel (a) plots the returns for funds that are trading at a premium at the beginning of the cycle, and panel (b) plots the returns for funds that are trading at a discount at the beginning of the cycle.

portfolio losses are amassed within cycles, suggesting that ability shocks play a minimal role in the returns of funds that trade at a premium. Since a premium fund earns negative returns net of management fees when there are non-extreme realizations of $\tilde{Z}_{n,1}$, the losses accruing to the premium portfolio are a result of the insurance against extreme realizations of $\tilde{Z}_{n,1}$ failing to pay.

While premium funds in our model tend to underperform when the stock price is endogenously determined, no such underperformance occurs when the stock price follows an exogenous process. This is due to the fact that the stock price influences how aggressively the manager trades on her private information, but the price does not respond to the manager's trades when it follows an exogenous process. As a result, the manager can better exploit her information advantage when the stock price is exogenous. At the times when the manager possesses an information advantage over the investor, her stock allocations with an exogenous (from (1.55)) and endogenous (from (A.2) Appendix A.1) price can be rewritten as

$$S^f_{3n-1} = \frac{1}{(1-\alpha_q)\gamma_m b\sigma^2_{3n-1}}\left[\left(Z_{n,1} - \alpha_q\mu_{3n-1}\right) + \frac{\gamma_i\gamma_m}{\Gamma}\sigma^2_{3n-1}\right] \qquad (1.63)$$

and

$$S^f_{3n-1} = \frac{\Gamma b - \gamma_i}{\gamma_m b\left(\alpha_q\gamma_i + (1-\alpha_q)\Gamma b\right)\sigma^2_{3n-1}}\left[\left(Z_{n,1} - \alpha_q\mu_{3n-1}\right) + \frac{\gamma_i\gamma_m b}{\Gamma b - \gamma_i}\sigma^2_{3n-1}\right], \qquad (1.64)$$

respectively. The first term inside the brackets in each of these equations represents the aggressiveness with which the manager trades on her information advantage while the second term captures the portfolio adjustment resulting from a reduction in risk (since the manager observes a portion of $\tilde{X}_{3n-1}$) that is independent of the specific realization of the manager's private information. Comparing the coefficients on these two equations reveals that the manager trades more aggressively when the stock price is exogenous. Consequently, she can better capitalize on her information advantage to earn much larger abnormal returns with an exogenous stock price, which means that premium funds in our model do not underperform when the stock price is exogenous.

1.4   Conclusion

We present a dynamic partial equilibrium model in which a closed-end fund manager periodically acquires private information about the future performance of an underlying asset. Although the manager adds value by exploiting her information, whether the fund trades at a premium or discount depends on the value of her private information in relation to the management fees. Our model accounts for several empirically observed characteristics of closed-end funds. Funds in our model issue at a premium but rapidly move into a discount, and there is both cross-sectional and time-series variation in discounts. The model also is consistent with the observed relations between discounts and returns, as well as the excess volatility of fund returns. The model explains why funds issue at a premium and provides a justification as to why investors purchase seasoned funds that trade at a premium even though they are expected to underperform funds that trade at a large discount.

Chapter 2

Activist Arbitrage, Lifeboats, and Closed-End Funds

We present a dynamic rational expectations model of closed-end fund discounts that incorporates feedback effects from activist arbitrage and lifeboat provisions. We find that the potential for activism and the existence of a lifeboat both lead to narrower discounts. Furthermore, both activist arbitrage and lifeboats effectuate an ex post transfer of wealth from managers to investors but an ex ante transfer of wealth from low-ability managers to high-ability managers. On average, investor wealth is unaffected by either activist arbitrage or lifeboats because their potential benefits are factored into higher fund prices. Although lifeboats can reduce takeover attempts, they do not increase expected managerial wealth.

2.1 Introduction

Closed-end funds are investment companies that hold a portfolio of financial assets, but unlike mutual funds, closed-end funds issue a fixed number of non-redeemable shares that trade at prices determined by the market. Most funds tend to trade at a discount relative to their net asset value (NAV), which means that a profit can be earned by terminating the fund and distributing its assets to the shareholders, as demonstrated by Brickley and Schallheim (1985). This potential for a quick profit creates an incentive for an outsider to purchase shares in a discounted fund and force a liquidation—a process known as activist arbitrage.

Activist arbitrage involves purchasing shares in a fund that is trading at a discount, taking some action in an attempt to eliminate the discount, and subsequently redeeming the shares at NAV if the endeavor is successful. Although accurately predicting which funds an activist arbitrageur will target is extremely difficult, Bradley, Brav, Goldstein, and Jiang (2010) find that activists tend to seek out funds that trade at large discounts, likely because there are greater financial returns to be realized when these funds restructure. Since ordinary investors share in the profit created by an activist, rational investors will recognize that a fund with a deep discount may become the target of an activist and purchase shares in the fund, hoping to piggy-back on the activist's efforts. In doing so, they will bid up the fund price, thereby causing the discount to shrink. This makes the closed-end fund a less attractive target and activist arbitrage less likely to occur. Thus, the potential for activist arbitrage creates an interesting "feedback loop" whereby, in equilibrium, the discount accurately reflects investors' beliefs regarding the probability of activism.

Lifeboats are another source of feedback on closed-end fund prices. A lifeboat is a provision, usually contained in a fund's prospectus, that describes remedial actions for the fund to undertake

to reduce or eliminate the discount if the fund price drops below a predetermined level. Common lifeboats include implementing a managed distribution plan (MDP), conducting a tender offer at NAV, repurchasing shares at market price, or converting to an open-end mutual fund. For reasons outlined below, we focus solely on MDPs, which mandate minimum periodic dividend distributions to a fund's shareholders. Regardless of the specific type of lifeboat, the potential beneficial effects of a lifeboat will result in higher prices, thereby making it less likely that the lifeboat will be triggered. Like with the potential for activist arbitrage, the equilibrium discount must incorporate this feedback effect in a way that accurately reflects investors' expectations about the future impact of the lifeboat.

Due to the aforementioned feedback loops, the interaction between closed-end fund prices, activist arbitrage, and lifeboat provisions is nontrivial. To better understand the equilibrium relationships between activist arbitrage, lifeboats, and closed-end funds, we construct a dynamic rational expectations equilibrium model of closed-end fund discounts that incorporates the feedback effects from these two important institutional features.[1] Our model is a discrete-time extension of the model presented by Berk and Stanton (2007) but differs from theirs by allowing for the endogenous triggering of a lifeboat provision and initiation of a restructuring attempt. In our model, the divergence between NAV and the fund price arises from a tradeoff between management fees and a manager's ability to generate excess returns. As the discount grows, the probability of an activist initiating a restructuring attempt increases, as does the probability of triggering the lifeboat. At the same time, the presence of activist arbitrageurs and lifeboat provisions exerts upward pressure on the fund price, causing the discount to shrink. Our model also incorporates the fact that fund governance characteristics, such as supermajority voting requirements (Bradley, Brav, Goldstein, and Jiang (2010)) or the existence of staggered boards (Del Guercio, Dann, and Partch (2003)), affect the incidence of activism as well as the fact that different lifeboat parameters, such as the dividend payout rate and lifeboat trigger level, influence the impact of lifeboats on closed-end funds.

We obtain analytical expressions for the discount in a variety of settings: where no activist or lifeboat exists, where only an activist exists, where only a lifeboat exists, and where both an activist and a lifeboat exist. Our solutions are not in closed-form, however, so we conduct a numerical simulation to ascertain the impact of activist arbitrage and lifeboats on closed-end funds. In the absence of both activist arbitrageurs and lifeboats, a discount emerges whenever investors believe that management fees outweigh the manager's contribution. Using this setting as a benchmark, we discover that activist arbitrage and lifeboat provisions influence funds in a number of ways.

Both activism and lifeboats independently cause fund prices to rise, which results in funds issuing at a larger premium than when neither an activist nor a lifeboat is present. The magnitude and persistence of the increased prices depends on the ability of the fund manager, with a greater effect on funds with low-ability managers. The primary function of activism and lifeboats, however, is to provide insurance against poor management. When prompted, both activist arbitrage and lifeboat provisions effectuate an ex post transfer of wealth from managers to investors, but since funds with high-quality management are less likely to have their lifeboats triggered or encounter an activist arbitrageur, the increased issue premium results in an ex ante expected wealth transfer from low-ability managers to high-ability managers. On average, investors neither gain nor lose from either activist arbitrage or lifeboat provisions because their potential benefits are incorporated into higher fund prices.

Consistent with empirical observations by Brauer (1984) and Brickley and Schallheim (1985), funds in our model that are successfully liquidated tend to have deeper discounts prior to the liq-

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[1]In contrast to previous studies by Lee, Shleifer, and Thaler (1991), Berk and Stanton (2007), Cherkes, Sagi, and Stanton (2009), Lenkey (2011), and others, we do not attempt to explain the source of closed-end fund discounts. See, e.g., Dimson and Minio-Kozerski (1999) for a survey of the closed-end fund literature.

uidation event than funds that are not liquidated, and large abnormal returns occur at the time of a liquidation announcement. Additionally, funds in our model with an MDP have narrower discounts than funds without an MDP, and discounts shrink upon the adoption of an MDP, which is consistent with empirical findings by Johnson, Lin, and Song (2006) and Wang and Nanda (2008).

When activist arbitrageurs and lifeboat provisions coexist, MDPs tend to be adopted less frequently and fewer reorganizations take place. We find that introducing a lifeboat has the greatest impact when activist arbitrage is unlikely to occur and that activist arbitrage has the biggest effect when the lifeboat is unlikely to be triggered. In other words, activism and lifeboats serve as substitutes for one another. Furthermore, introducing a lifeboat to an environment where an activist arbitrageur already exists provides additional insurance against low-ability management only when the lifeboat is liable to be triggered.

Since fund managers face a loss of wealth and non-pecuniary benefits when a restructuring occurs, as demonstrated by Brauer (1984), some authors have suggested that a lifeboat can be used to ward off activist arbitrageurs by mitigating a fund's discount.[2] While lifeboats do indeed lessen the severity of discounts and decrease the incidence of restructuring events, our results indicate that lifeboats are not a suitable means for enhancing managerial wealth. On the contrary, we find that an MDP decreases the expected value of management fees over the life of a fund, even when the fund might potentially face a premature liquidation caused by an activist arbitrageur. This is because an MDP itself facilitates a partial liquidation of the fund.

Despite an extensive amount of academic research on closed-end funds, there is a paucity of theoretical models in the closed-end fund literature that include either activist arbitrage or lifeboats. To the best of our knowledge, our work is the first truly dynamic model of fund discounts that incorporates activist arbitrage and lifeboat provisions. In a static setting, Deaves and Krinsky (1994) model a tradeoff between managerial ability and fees, with an exogenous probability of open-ending that depends on the difference between ability and fees. They demonstrate numerically that the relationship between the discount and probability of restructuring is not monotonic, but that a higher probability of restructuring leads to a narrower discount over a range of values. Cherkes, Sagi, and Wang (2009) model a sequential game between a fund manager and activist wherein the fund manager can implement an MDP with the purpose of reducing the financial incentive for an activist to attempt a restructuring. Empirically, they find that funds with an MDP experience fewer attacks and are less likely to be liquidated than funds without an MDP. Their model, however, does not account for the time-series dynamics of closed-end funds.

Our current work also contributes to the growing literature on feedback loops in more general financial market settings. Edmans, Goldstein, and Jiang (2012) study the interaction between market prices and takeover attempts of industrial firms. Empirically, they find that investors anticipating takeovers drive up prices, thereby deterring takeover activity. Bond, Goldstein, and Prescott (2010) investigate the equilibrium implications where a market activist does not observe fundamentals but decides whether to intervene based on prices. In contrast to their model, prices in our model affect the likelihood of activism but do not influence the activist's beliefs about fundamentals (managerial ability). Moreover, our analysis focuses on how different fund governance characteristics as well as various parameterizations of a lifeboat provision affect equilibrium discounts, returns, and expected wealth.

The remainder of the paper is organized as follows. In Section 2.2, we derive analytical expressions for the discount in a variety of settings. We then present the results from a simulation analysis in Section 2.3. Finally, Section 2.4 concludes.

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[2]See, e.g., Cherkes, Sagi, and Wang (2009) and Johnson, Lin, and Song (2006).

2.2 Model

The general framework of our benchmark model, which does not include either activist arbitrage or lifeboats, is a discrete-time analog of Berk and Stanton (2007). We later incorporate activism and lifeboats in Sections 2.2.2 and 2.2.3, respectively. In our benchmark model, closed-end fund discounts result from a tradeoff between management fees and a fund manager's perceived ability to generate excess returns. Rational investors form beliefs about managerial ability and update them over time based on observed fund returns. Accordingly, funds trade at a discount whenever investors believe that management fees outweigh the expected value created by the manager's ability, and vice versa. The key insight of Berk and Stanton (2007), which we also incorporate into our model, is that the fund manager's compensation can never fall but will increase whenever his perceived ability rises above a certain level. This compensation structure reflects the optimal managerial contract derived by Harris and Holmström (1982) (where wages are never decreased but employees receive pay raises) extended to a labor market with frictions, such as costly job switching. The specific (unmodeled) form of the manager's pay raise is assumed to be an influx of capital to manage through a rights offering or the creation of a new fund, which reduces his ability to generate excess returns since his fixed skill level is spread thinner over the additional capital under management. This mechanism is also employed by Berk and Green (2004) to explain the flow of capital in mutual funds.

Although conceptually identical to Berk and Stanton (2007), our benchmark model is mathematically very different from theirs. While they model an economy in continuous time with normally distributed excess returns and normally distributed managerial ability, we find it more natural to model activism and lifeboat events in discrete time due to the existing institutional practices surrounding reorganizations and lifeboats, as both reorganizations and lifeboat implementations frequently require shareholder approval, which often comes from proxy votes at a shareholder meeting that may not occur until months after a lifeboat is triggered or an attack is initiated by activist. Furthermore, since activist arbitrage and lifeboat provisions can give rise to truncated distributions of otherwise normally distributed future fund discounts, we assume that excess returns are Bernoulli distributed to lessen the computational burden. We also find it computationally convenient to assume a uniform distribution for managerial ability when we conduct our simulation analysis in Section 2.3. These different assumptions necessitate the construction of a model that is distinct from Berk and Stanton (2007), even though the broad concepts are the same.

We explicitly model only a single asset—a closed-end fund. Trading in the financial market occurs at discrete dates indexed by $t = 1, 2, \ldots, T$. The closed-end fund undergoes an initial public offering (IPO) at $t = 1$ and is scheduled to liquidate at T, at which time the fund's shareholders receive the value of the assets under management.

The closed-end fund earns a gross return during each period that is comprised of two components. The first component is a random return from a portfolio of financial assets held by the fund. Let $\tilde{r}_{t+1}$ denote the return on the fund's portfolio from time t to $t+1$. This return is serially independent and observable by all parties. The second component of the fund's gross return is a random excess return generated by a fund manager. The excess return, which is also observable by all parties, from time t to $t+1$ is given by the product $\gamma_t \tilde{\alpha}_{t+1}$, where $\tilde{\alpha}_{t+1} \in \{\alpha_\ell, \alpha_h\}$ and $\gamma_t \in [0, 1]$. Here, $\tilde{\alpha}_{t+1}$ denotes the potential excess return that can be generated during a period, but as discussed in more detail below, this potential excess return is scaled by γ_t. Additionally, $\tilde{\alpha}_{t+1}$ is uncorrelated with the return on the fund's portfolio both contemporaneously and across time. To compensate the manager, a management fee, ϕ, that is equal to a fixed percentage of the assets under management is assessed on the fund each period.

The true probability that the manager earns a high excess return, α_h, during a period is denoted

by Π and is constant over time. Accordingly, a low excess return, α_ℓ, will be realized with probability $1 - \Pi$. This probability is exogenous and unobservable, but investors form beliefs regarding Π which evolve over time in a Bayesian fashion. Let π_t denote the investors' beliefs about Π at time t. The posterior probability of π_t, conditional on observing n high excess returns after t periods, follows a beta distribution with parameters a_t and b_t: $\pi_t \sim \text{Beta}(a_t, b_t)$. If the prior parameters are a_1 and b_1 so that $\pi_1 \sim \text{Beta}(a_1, b_1)$, then it follows immediately from DeGroot (2004, p. 160, Theorem 1) that the posterior parameters are $a_t = a_1 + n$ and $b_t = b_1 + t - n$. Furthermore, since $\tilde{\alpha}_{t+1}$ is Bernoulli distributed, the marginal distribution of $\tilde{\alpha}_{t+1}$ is a beta-binomial distribution but reduces to a Bernoulli distribution. Therefore, investors rationally believe that a high excess return will occur with posterior probability given by

$$\pi_t = \frac{a_t}{a_t + b_t},$$

which evolves according to

$$\pi_{t+1} = \pi_t + \frac{\chi_{t+1}(a_t + b_t) - a_t}{(a_t + b_t)(a_t + b_t + 1)}, \tag{2.1}$$

where χ_{t+1} is an indicator function that takes the value one if $\alpha_{t+1} = \alpha_h$ and zero otherwise.

As in Berk and Stanton (2007), we assume that the fund manager is compensated using an insurance contract, pursuant to which the manager's wage may never fall but may increase whenever the manager's perceived ability,

$$\alpha_t^* \equiv \gamma_t [\pi_t \alpha_h + (1 - \pi_t) \alpha_\ell],$$

rises above a particular exogenous threshold, Υ.[3] Specifically, we assume that if α_t^* would otherwise be greater than Υ, then γ_t is adjusted downward to the point where the perceived ability at time t equals Υ. For all future dates, γ_t retains its newly-adjusted value unless the investors' updated beliefs would necessitate an additional downward adjustment. This mechanism reflects the manager's capability to raise additional capital when his perceived ability to generate excess returns is high, which in turn reduces his ability to produce excess returns. Because the investors' beliefs regarding Π are unaffected by the adjustment process, the evolution of π_t is still described by (2.1).

Assets in our model are priced as though investors are risk neutral. Consequently, the equilibrium expected rate of return for all financial assets, including both the closed-end fund and the portfolio held by the fund, must equal the market expected rate of return, which is denoted by μ. Additionally, P_t denotes the fund price, V_t denotes the NAV of the fund, and

$$D_t \equiv \frac{P_t}{V_t} \tag{2.2}$$

denotes the fund discount at time t. A discount greater than one means that the fund trades at a premium.

We now proceed to derive analytical expressions for the closed-end fund discount in various settings. We first derive an expression for the discount in the absence of both an activist arbitrageur

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[3]We assume that Υ is constant and independent of the existence of activist arbitrageurs or lifeboat provisions. Consequently, the evolution of γ_t is unaffected by the presence of either activists or lifeboats. Since managerial pay raises lead to larger discounts, *ceteris paribus*, it is plausible that managers could attempt to ward off activists or decrease the likelihood of triggering a lifeboat by foregoing pay raises until the expected benefit from a raising additional capital outweighs the costs associated with an increased probability of an activist attack or a lifeboat trigger. In terms of our model, this would entail increasing the excess return adjustment threshold, Υ, which is liable to lead to less severe discounts. Therefore, our simulation results presented in Section 2.3 likely underestimate the impact of activist arbitrage and lifeboats on closed-end fund discounts.

and a lifeboat provision in Section 2.2.1 to provide a benchmark for additional analysis. We then investigate the impact of activist arbitrage in Section 2.2.2 and the effect of a lifeboat provision in Section 2.2.3. Finally, we derive an expression for the discount in an environment with both an activist arbitrageur and a lifeboat in Section 2.2.4.

2.2.1 Benchmark Discount

In the absence of both an activist arbitrageur and a lifeboat provision, the fund's NAV return is a combination of the return on the fund's portfolio, the excess return generated by the manager, and the management fee. Therefore, NAV evolves as

$$\tilde{V}_{t+1} = V_t \left(1 + \tilde{r}_{t+1} - \phi + \gamma_t \tilde{\alpha}_{t+1} \right), \tag{2.3}$$

and the expected one-period NAV return is

$$E_t \left[\tilde{R}_{t+1}^v \right] = M + \gamma_t E_t \left[\tilde{\alpha}_{t+1} \right], \tag{2.4}$$

where

$$M \equiv 1 + \mu - \phi.$$

It is apparent from (2.4) that the expected NAV return generally will not equal the market expected rate of return, μ. As a result, for the market to clear the fund price must adjust so that the expected fund return,

$$E_t \left[\tilde{R}_{t+1}^f \right] \equiv \frac{E_t \left[\tilde{P}_{t+1} \right]}{P_t}, \tag{2.5}$$

equals the market expected rate of return. Typically, the fund price will not equal NAV. Instead, the closed-end fund will trade at a discount described by the following proposition.[4]

Proposition 1. *In the absence of both an activist arbitrageur and a lifeboat provision, the closed-end fund discount at each date $t < T$ is*

$$D_t = \frac{1}{1+\mu} E_t \left[\tilde{D}_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} \right) \right]. \tag{2.6}$$

While this proposition describes the discount for all dates $t < T$, the principle of no arbitrage implies that at time T the discount vanishes, i.e., $D_T = 1$.[5] Additionally, the primary determinant of the discount is the relation between the management fee and the excess return generated by the manager. A fund that generates zero expected excess return for all dates and charges no fees always trades at NAV.

2.2.2 Activist Arbitrage

The goal of an activist arbitrageur is to eliminate the discount through a reorganization. While discounts can be eliminated in a variety of ways—for instance, by converting the closed-end fund to an open-end mutual fund or by merging with an existing mutual fund—we focus solely on fund liquidation because it allows us to compute the impact of activism but avoids unnecessary complications that might arise if the fund were to continue operating in a different form. Furthermore,

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[4] Proofs for all Propositions are contained in Appendix B.2.

[5] No arbitrage also implies that the discount at time T equals one in the other versions of the model discussed in Sections 2.2.2, 2.2.3, and 2.2.4.

we make no assumptions regarding the specific mechanisms through which a restructuring attempt occurs, although in reality activists tend to rely on proxy contests and non-binding shareholder proposals. As we demonstrate numerically in Section 2.3, activist arbitrage has the potential to impact closed-end fund discounts through actual liquidation, unsuccessful liquidation attempts, and the possibility of future liquidation attempts, even if the fund is never actually liquidated or attacked by an activist. In this section, we outline our assumptions and derive analytical expressions for the discount in the presence of an activist arbitrageur.

Liquidating a fund via shareholder activism can take a substantial amount of time, possibly entailing several rounds of shareholder proposals and proxy votes in the face of managerial resistance.[6] While there is no guarantee that a liquidation attempt will be successful, the likelihood of successfully liquidating a closed-end fund through activism depends, to a large extent, on the fund's governance characteristics. Del Guercio, Dann, and Partch (2003) report that out of 42 fund restructuring proposals over a 4 year period, the board of directors recommended against approval in all 17 proposals that failed and in favor of approval in almost all 25 successful reorganizations. In a separate study, Brauer (1988) finds that managerial entrenchment can also hinder activism. Apparently, a fund's board and management both strongly influence the success of a liquidation attempt. In our model, we assume that, given a liquidation attempt, the fund will successfully liquidate with probability q, which is exogenous and constant over time. Although we do not explicitly model the source of the liquidation probability, q could represent, *inter alia*, supermajority voting requirements, the existence of staggered boards, the presence of large blockholders, or the ease of communication between an activist and shareholders. Empirical evidence that these features affect the probability of a successful restructuring is provided by Barclay, Holderness, and Pontiff (1993), Del Guercio, Dann, and Partch (2003), and Bradley et al. (2010).

If at time $t-1$ an activist takes steps to initiate a liquidation attempt, the fund is considered to be under attack at t, and the uncertainty regarding whether the undertaking will be successful is resolved during the ensuing period. This could occur through, for example, a proxy vote or adoption of a shareholder proposal. If the liquidation attempt is successful, the closed-end fund will liquidate at $t+1$. In such a case, the fund's expected liquidation value is

$$V_t \left(M + \gamma_t E_t \left[\tilde{\alpha}_{t+1} \right] \right). \tag{2.7}$$

If, on the other hand, the liquidation attempt fails, the fund retains its closed-end form with NAV evolving according to (2.3), but additional attempts may be made in the future. Because there is a two-period lag between the initiation of an attempt and the liquidation event, no attacks will commence later than $T-3$.[7]

For attempting a liquidation, an activist incurs a cost, $c \in (0,1)$, that is equal to a constant percentage of NAV. We do not model the source of this cost, but it could comprise the costs of activism outlined by Grossman and Hart (1980), i.e., the cost of acquiring information about the target fund and administrative expenses associated with soliciting shareholders to approve the liquidation as well as with liquidating the fund if the attempt succeeds. Since an activist will not initiate a liquidation attempt unless the expected gains from doing so outweigh the costs, we assume that no attempts will occur unless the discount falls below a certain threshold, $\kappa(c, q)$, which is a continuous function $\kappa : (0,1) \times (0,1) \to [0,1]$ that is decreasing in the cost of activism and

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[6]See Bradley et al. (2010) for a detailed account of a restructuring attempt and Barclay, Holderness, and Pontiff (1993) or Del Guercio, Dann, and Partch (2003) for techniques that a large blockholder or board of directors may utilize to defeat restructuring attempts.

[7]Barclay, Holderness, and Pontiff (1993) find that fund restructuring attempts are usually either successfully completed or abandoned within two years, and Brav et al. (2008) report that the median holding period for activist hedge funds that target industrial corporations is about 1.5 years.

increasing in the probability of liquidation. This attack threshold reflects the need for a larger profit margin when costs are high or the likelihood of successful liquidation is low.

While the existence of a discount lower than the attack threshold is a necessary condition for activism, it is not by itself sufficient. Empirically, not every fund that trades at a deep discount becomes a target. Perhaps this is due to some idiosyncratic features of funds which we do not explicitly model, such as managerial entrenchment, in combination with the small number of activists who target closed-end funds.[8] We incorporate this uncertainty of activism by assuming that the occurrence of an attempt is random, with a deeper discount giving rise to a greater likelihood of an attack. Specifically, we assume that the probability of activism is given by

$$\rho_\kappa \equiv \frac{\kappa - D_t}{\kappa - \theta_\kappa} \tag{2.8}$$

for $D_t \in (\theta_\kappa, \kappa)$, where, similar to the attack threshold, $\theta_\kappa(c, q)$ is a continuous function $\theta_\kappa : (0, 1) \times (0, 1) \to [0, 1]$ that is decreasing in the cost of activism and increasing in the probability of liquidation. No attempt will be made if $D_t \geq \kappa$, but an activist is certain to initiate an attempt if $D_t \leq \theta_\kappa$. The role of θ_κ is to control the rate at which the probability of activism increases as the discount widens. Whether a liquidation attempt is made at time t is purely a function of the current discount, the probability of success, and the cost structure. Previous liquidation attempts, including any that may have occurred at $t - 1$, have no bearing on whether an attempt is made at t, provided, of course, that no prior attempts were successful.

As in the case where no activist arbitrageur is present, the expected NAV return typically will not equal the market expected rate of return, and the fund price must adjust in order for the market to clear. The following proposition describes the discount if a liquidation is attempted at time t and there is some uncertainty as to whether an additional attempt will be made at $t + 1$ if the current attempt is unsuccessful. The discount in the case of an attempt at $t + 1$ is denoted by $\tilde{D}_{t+1}^A$ while $\tilde{D}_{t+1}^{\neg A}$ denotes the discount if no attempt occurs at $t + 1$.

Proposition 2. *In the presence of an activist arbitrageur and the absence of a lifeboat provision, the closed-end fund discount at each date $t < T$ is*

$$D_t = \frac{E_t\left[\left(q(\kappa - \theta_\kappa) + (1 - q)\left(\kappa\tilde{D}_{t+1}^A - \theta_\kappa\tilde{D}_{t+1}^{\neg A}\right)\right)(M + \gamma_t\tilde{\alpha}_{t+1})\right]}{(\kappa - \theta_\kappa)(1 + \mu) + (1 - q)E_t\left[\left(\tilde{D}_{t+1}^A - \tilde{D}_{t+1}^{\neg A}\right)(M + \gamma_t\tilde{\alpha}_{t+1})\right]}, \tag{2.9}$$

provided that there is uncertainty regarding whether a liquidation attempt will occur at $t + 1$.

Proposition 2 provides a general expression for the discount in the presence of an activist arbitrageur and the absence of a lifeboat provision. Depending on the situation, however, this expression may take a simpler form. For instance, if $D_t \leq \theta_\kappa$ then an activist will attack at $t + 1$ with certainty, provided, of course, that any current attempt is unsuccessful and the fund still exists. In such a case, $\rho_\kappa = 1$, which is equivalent to setting $\tilde{D}_{t+1}^{\neg A}$ equal to $\tilde{D}_{t+1}^A$ in (2.9) (this follows from making the same substitution in (B.1) in the proof). Thus, the discount reduces to

$$D_t = \frac{1}{1 + \mu}E_t\left[\left(q + (1 - q)\tilde{D}_{t+1}^A\right)(M + \gamma_t\tilde{\alpha}_{t+1})\right]. \tag{2.10}$$

Conversely, if $D_t \geq \kappa$ then there is no possibility of a liquidation attempt at $t + 1$. In this case, $\rho_\kappa = 0$, which is equivalent to setting $\tilde{D}_{t+1}^A$ equal to $\tilde{D}_{t+1}^{\neg A}$ in (2.9), and the discount is given by

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[8]Brauer (1984) finds that there is less managerial resistance to restructuring for funds that are actually restructured while Bradley et al. (2010) observe that "there are only a handful of arbitrageurs who actively engage in attempts to liquidate" closed-end funds and that "successful open-ending attempts are not easy to predict."

(2.10) with $\tilde{D}_{t+1}^{\neg A}$ in place of $\tilde{D}_{t+1}^{A}$.

The above equations describe the discount during a liquidation attempt. Alternatively, in the absence of a liquidation attempt there is zero chance of liquidating at $t+1$, which means that $q = 0$. Then, if $D_t \in (\theta_\kappa, \kappa)$ so that there is a positive probability of an attempt at $t+1$, it follows from (2.9) that the discount at time t is

$$D_t = \frac{E_t\left[\left(\kappa\tilde{D}_{t+1}^{A} - \theta_\kappa\tilde{D}_{t+1}^{\neg A}\right)(M + \gamma_t\tilde{\alpha}_{t+1})\right]}{(\kappa - \theta_\kappa)(1 + \mu) + E_t\left[\left(\tilde{D}_{t+1}^{A} - \tilde{D}_{t+1}^{\neg A}\right)(M + \gamma_t\tilde{\alpha}_{t+1})\right]}. \tag{2.11}$$

Following the same logic as above, if $D_t \leq \theta_\kappa$ then the discount reduces to (2.6) with $\tilde{D}_{t+1}$ replaced by $\tilde{D}_{t+1}^{A}$ since an activist is certain to initiate an attempt at $t+1$ in this case. Furthermore, if $D_t \geq \kappa$ then there is no possibility of an attempt at $t+1$ and the discount is given by (2.6) with $\tilde{D}_{t+1}^{\neg A}$ substituted for $\tilde{D}_{t+1}$. A summary of these situation-dependent discounts is provided in Table B.I in Appendix B.1.

2.2.3   Lifeboats

Lifeboats are widely used, with empirical studies estimating that anywhere from 53% to 88% of all funds have some sort of lifeboat provision (see Curtis and Robertson (2008) and Bradley et al. (2010)). In some instances lifeboat provisions call for mandatory action to reduce the discount while in other cases they only require that a fund consider taking action, thereby giving discretion to the fund's board of directors. Not surprisingly, discretionary lifeboats have been found to be ineffective at preventing large discounts from developing since the fund's board, which may have an incentive to maintain the status quo, can prevent implementation of the lifeboat if it determines that taking corrective action would not be in the best interests of the shareholders. On the other hand, as we show in Section 2.3, mandatory lifeboats are able to reduce discounts even if the lifeboat is never triggered because investors anticipate future corrective action should the fund price fall.

In this section, we investigate how a single type of lifeboat—a managed distribution plan—impacts the closed-end fund discount. We choose to study MDPs due to their relative prevalence and prolonged effect on funds.[9] Pursuant to an MDP, a fund is required to distribute a periodic dividend to its shareholders. We assume that the dividend rate, δ, is a constant percentage of NAV. If an MDP is in effect at time t, the fund pays a dividend at $t+1$,

$$d_{t+1} = \delta V_t. \tag{2.12}$$

Since the dividend is distributed from the assets under management, the NAV dynamics, which must incorporate the dividend payment, are given by

$$\tilde{V}_{t+1} = V_t\left(1 + \tilde{r}_{t+1} - \phi + \gamma_t\tilde{\alpha}_{t+1} - \delta\right) \tag{2.13}$$

once an MDP has been implemented. If an MDP has not been adopted, however, the shareholders do not receive a dividend at $t+1$, and NAV evolves according to (2.3). As is evident from (2.13), the dividend distribution reduces the value of the assets under management relative to the benchmark case, which diminishes both expected future gross earnings as well as management fees. Thus, when the management fee is larger than the expected managerial contribution, an MDP enhances the

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[9]Johnson, Lin, and Song (2006) report that 20% of funds in their sample have an MDP commitment while Wang and Nanda (2008) report that the percentage of funds with an MDP had grown from roughly 10% to 40% over the period from 1994 to 2006.

market value of the fund, resulting in a narrower discount. The implication is similar to Cherkes, Sagi, and Wang (2009), who show that an MDP acts as a mechanism to transfer wealth from management to investors.[10]

The fund is initially issued without any dividend policies, and it will not adopt an MDP unless the lifeboat is triggered, i.e., the fund price falls below the predetermined level specified in the lifeboat provision, which we denote by $\lambda \in (0,1)$. If $D_t < \lambda$, then the lifeboat is triggered at time t. As is typical in practice, during the ensuing period the fund's shareholders vote on whether the lifeboat should be implemented, and the results are known by the market participants at $t+1$. The first dividend is paid at $t+2$ if the shareholders approve the lifeboat; otherwise, the fund remains without an MDP. We assume that the fund contains only a single lifeboat provision and that the dividend rate cannot be increased if the discount once again falls below λ after the MDP has been implemented. Furthermore, because there is a lag between shareholder approval and the first dividend payment, an MDP will not be adopted later than $T-2$ since all assets are liquidated and distributed at T.

Although the prospectus may mandate a shareholder vote whenever the lifeboat is triggered, as noted by Curtis and Robertson (2008) and Bradley et al. (2010), the board of directors often objects to implementing an MDP.[11] Consequently, because shareholders may be influenced by the board's recommendation to reject adoption of the MDP, there is no guarantee that shareholders will vote in favor of the MDP when the lifeboat is triggered. Moreover, the board's recommendations are likely to be influential when the discount is not very deep, but shareholders are more prone to ignore the board's advice when the fund price deviates from NAV by a wide margin. To incorporate this uncertainty of adoption into our model, we assume that the probability of implementation is given by

$$\rho_\lambda \equiv \frac{\lambda - D_t}{\lambda - \theta_\lambda} \tag{2.14}$$

for $D_t \in (\theta_\lambda, \lambda)$, where θ_λ is an exogenous parameter that controls the rate at which the probability of approval increases as D_t falls. If $D_t \geq \lambda$, then the lifeboat is not triggered and the probability of adoption is zero. Conversely, if $D_t \leq \theta_\lambda$, then the MDP will be adopted with certainty.

Similar to the cases discussed above where there is no lifeboat provision, the expected fund return,

$$E\left[\tilde{R}_{t+1}^f\right] \equiv \frac{E\left[\tilde{P}_{t+1} + d_{t+1}\right]}{P_t}, \tag{2.15}$$

generally will not equal the market expected rate of return. Hence, the fund price must adjust in order for the market to clear. The following proposition describes the discount in the presence of a lifeboat provision. The discount when an MDP is in effect at $t+1$ is denoted by $\tilde{D}_{t+1}^{\delta}$ while $\tilde{D}_{t+1}^{-\delta}$ denotes the discount if an MDP is not in effect at $t+1$.

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[10]Since an MDP reduces the amount of capital under management, the mechanism used to explain the existence of discounts in our benchmark model—namely, that the manager's ability to earn excess returns is inversely related to the amount of capital under management—implies that the potential excess returns should increase whenever a dividend is paid (i.e., γ_t should undergo an upward adjustment). For computational efficiency, we do not adjust γ_t upward when a dividend is paid in our simulation in Section 2.3. Consequently, our results likely underestimate the impact of lifeboats on closed-end funds.

[11]For example, in 2003 the board of The Zweig Total Return Fund advised shareholders to vote against converting the closed-end fund to a mutual fund because the fund "may be forced to pay for redemptions by selling portfolio securities at inopportune times and incurring increased transaction costs" even though such a conversion would likely result in "short-term profits." Furthermore, albeit in a different context, Choi, Fisch, and Kahan (2009) demonstrate that the advice provided by independent proxy voting advisers depends on a firm's governance characteristics.

Proposition 3. *In the presence of a lifeboat provision and the absence of an activist arbitrageur, at each date $t < T$ (i) if an MDP has previously been adopted then the discount is*

$$D_t = \frac{1}{1+\mu}\left(\delta + E_t\left[\tilde{D}_{t+1}^{\delta}\left(M + \gamma_t\tilde{\alpha}_{t+1} - \delta\right)\right]\right),\tag{2.16}$$

but (ii) if an MDP has not previously been adopted then the discount is

$$D_t = \frac{E_t\left[\left(\lambda\tilde{D}_{t+1}^{\delta} - \theta_\lambda\tilde{D}_{t+1}^{\neg\delta}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right]}{(\lambda - \theta_\lambda)(1+\mu) + E_t\left[\left(\tilde{D}_{t+1}^{\delta} - \tilde{D}_{t+1}^{\neg\delta}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right]},\tag{2.17}$$

provided that there is uncertainty regarding whether an MDP will be adopted by $t+1$.

Like the case where an activist arbitrageur is present, Proposition 3 provides general expressions for the discount in the presence of a lifeboat, but these expressions may take a simpler form in certain situations. Specifically, if an MDP is not in effect but $D_t \le \theta_\lambda$, then the MDP definitely will be adopted by $t+1$ so $\rho_\lambda = 1$. Because dividend distributions will not begin until $t+2$, however, this is equivalent to setting $\tilde{D}_{t+1}^{\neg\delta}$ equal to $\tilde{D}_{t+1}^{\delta}$ in (2.17) (this follows from making an identical substitution in (B.2) in the proof). In this case, the discount is equal to (2.6) with $\tilde{D}_{t+1}^{\delta}$ in place of $\tilde{D}_{t+1}$. In contrast, if $D_t \ge \lambda$ then the lifeboat is not triggered and $\rho_\lambda = 0$, which is equivalent to setting $\tilde{D}_{t+1}^{\delta}$ equal to $\tilde{D}_{t+1}^{\neg\delta}$ in (2.17). Thus, the discount in this scenario also is given by (2.6) but with $\tilde{D}_{t+1}^{\neg\delta}$ substituted for $\tilde{D}_{t+1}$. A summary of these state-dependent discounts is provided in Table B.I.

2.2.4 Combination of Activist Arbitrage and a Lifeboat

The two previous subsections explore how the presence of an activist arbitraguer or a lifeboat provision, in isolation, can impact the closed-end fund discount. In reality, though, activism and lifeboats are intertwined, as funds that contain a lifeboat provision can become a target of an activist arbitrageur. Furthermore, the presence of a lifeboat provision can affect the discount and thereby influence the timing or occurrence of activism while at the same time the presence of an activist can affect whether a lifeboat provision is triggered. In this section, we derive expressions for the discount in the presence of both an activist arbitrageur and a lifeboat provision.

The assumptions outlined in the previous sections also apply here. Because an activist may contemplate an attack under the conditions outlined in Section 2.2.2 even when a lifeboat provision is triggered, given our assumptions for the probability of a liquidation attempt, ρ_κ, and the probability of adopting an MDP, ρ_λ, the expression for the discount happens to be quadratic in the specific case where there is uncertainty regarding both whether an MDP will be implemented and whether an activist will attempt a liquidation at $t+1$. As a result, multiple equilibria may potentially exist. We consider this potential for multiple equilibria when deriving analytical expressions for the discount and when conducting our simulation analysis.

Depending on the situation, the expression for the discount may take one of several possible forms. While there are numerous scenarios to consider, the following proposition generally describes the discount in the presence of both an activist and a lifeboat provision. The discount is denoted by $\tilde{D}_{t+1}^{\neg\delta A}$ when there is neither a liquidation attempt nor an MDP in effect, by $\tilde{D}_{t+1}^{\delta A}$ where an MDP has been adopted and the fund is under an activist attack, by $\tilde{D}_{t+1}^{\delta\neg A}$ where an MDP has been adopted and there is no liquidation attempt, and by $\tilde{D}_{t+1}^{A\neg\delta}$ where there is a liquidation attempt but no MDP in effect at $t+1$.

Proposition 4. *At each date $t < T$, if both an activist arbitrageur and a lifeboat provision exist and (i) if an MDP has previously been adopted then the discount is*

$$D_t = \frac{\delta\left(\kappa - \theta_\kappa\right) + E_t\left[\left(q\left(\kappa - \theta_\kappa\right) + \left(1 - q\right)\left(\kappa\tilde{D}_{t+1}^{\delta A} - \theta_\kappa\tilde{D}_{t+1}^{\delta\neg A}\right)\right)\left(M + \gamma_t\tilde{\alpha}_{t+1} - \delta\right)\right]}{\left(\kappa - \theta_\kappa\right)\left(1 + \mu\right) + \left(1 - q\right)E_t\left[\left(\tilde{D}_{t+1}^{\delta A} - \tilde{D}_{t+1}^{\delta\neg A}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1} - \delta\right)\right]}, \quad (2.18)$$

(ii) if an MDP has not previously been adopted, the lifeboat is triggered, and there is no possibility of a liquidation attempt at $t + 1$ then the discount is

$$D_t = \frac{E_t\left[\left(q\left(\lambda - \theta_\lambda\right) + \left(1 - q\right)\left(\lambda\tilde{D}_{t+1}^{\delta\neg A} - \theta_\lambda\tilde{D}_{t+1}^{\neg\delta A}\right)\right)\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right]}{\left(\lambda - \theta_\lambda\right)\left(1 + \mu\right) + \left(1 - q\right)E_t\left[\left(\tilde{D}_{t+1}^{\delta\neg A} - \tilde{D}_{t+1}^{\neg\delta A}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right]}, \quad (2.19)$$

and (iii) if an MDP has not previously been adopted, the lifeboat is triggered, and there is uncertainty regarding both whether an MDP will be adopted and the possibility of a liquidation attempt at $t + 1$ then the discount is

$$D_t = \frac{-y \pm \sqrt{y^2 - 4xz}}{2x}, \quad (2.20)$$

where

$$x \equiv \left(1 - q\right)E_t\left[\left(\tilde{D}_{t+1}^{\delta A} + \tilde{D}_{t+1}^{\neg\delta A} - \tilde{D}_{t+1}^{A\neg\delta} - \tilde{D}_{t+1}^{\delta\neg A}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right]$$

$$y \equiv -\left(1 + \mu\right)\left(\kappa - \theta_\kappa\right)\left(\lambda - \theta_\lambda\right)$$

$$-\left(1 - q\right)E_t\left[\left(\left(\kappa + \lambda\right)\tilde{D}_{t+1}^{\delta A} + \left(\theta_\kappa + \theta_\lambda\right)\tilde{D}_{t+1}^{\neg\delta A} - \left(\kappa + \theta_\lambda\right)\tilde{D}_{t+1}^{A\neg\delta} - \left(\lambda + \theta_\kappa\right)\tilde{D}_{t+1}^{\delta\neg A}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right]$$

$$z \equiv E_t\left[\left(q\left(\kappa - \theta_\kappa\right)\left(\lambda - \theta_\lambda\right) + \left(1 - q\right)\left(\kappa\lambda\tilde{D}_{t+1}^{\delta A} + \theta_\kappa\theta_\lambda\tilde{D}_{t+1}^{\neg\delta A} - \kappa\theta_\lambda\tilde{D}_{t+1}^{A\neg\delta} - \lambda\theta_\kappa\tilde{D}_{t+1}^{\delta\neg A}\right)\right)\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right].$$

Depending on the situation, the general expressions for the closed-end fund discount contained in Proposition 4 may reduce to simpler equations, which are summarized in Table B.II in Appendix B.1. For the case where an MDP has previously been adopted, the logic is similar to Section 2.2.2 where an activist arbitrageur is present and there is no lifeboat provision, but here the discount incorporates the effects of the previously implemented MDP. If $D_t \leq \theta_\kappa$ then a liquidation attempt is certain to occur at $t + 1$ so $\rho_\kappa = 1$, which is equivalent to setting $\tilde{D}_{t+1}^{\delta\neg A}$ equal to $\tilde{D}_{t+1}^{\delta A}$ in (2.18) (this results from making the same substitution in (B.3) in the proof). Thus, the discount is

$$D_t = \frac{1}{1 + \mu}\left(\delta + E_t\left[\left(q + \left(1 - q\right)\tilde{D}_{t+1}^{\delta A}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1} - \delta\right)\right]\right). \quad (2.21)$$

On the other hand, if $D_t \geq \kappa$ then there is zero probability of a liquidation attempt at $t + 1$ and the discount is equal to (2.21) with $\tilde{D}_{t+1}^{\delta\neg A}$ in place of $\tilde{D}_{t+1}^{\delta A}$.

The discount takes a different form when the fund is not currently under an activist attack and $q = 0$. If $D_t \in \left(\theta_\kappa, \kappa\right)$ so that there is uncertainty regarding whether an activist will initiate a liquidation attempt at $t + 1$, the discount is derived by setting q equal to zero in (2.18), which results in

$$D_t = \frac{\delta\left(\kappa - \theta_\kappa\right) + E_t\left[\left(\kappa\tilde{D}_{t+1}^{\delta A} - \theta_\kappa\tilde{D}_{t+1}^{\delta\neg A}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1} - \delta\right)\right]}{\left(\kappa - \theta_\kappa\right)\left(1 + \mu\right) + E_t\left[\left(\tilde{D}_{t+1}^{\delta A} - \tilde{D}_{t+1}^{\delta\neg A}\right)\left(M + \gamma_t\tilde{\alpha}_{t+1} - \delta\right)\right]}. \quad (2.22)$$

The discount takes an even simpler form whenever $D_t \notin \left(\theta_\kappa, \kappa\right)$. If an activist attack is certain to occur at $t + 1$ then the discount reduces to (2.16) with $\tilde{D}_{t+1}^{\delta A}$ in place of $\tilde{D}_{t+1}^{\delta}$, but if there is no

possibility of an attack then the discount reduces to (2.16) with $\tilde{D}_{t+1}^{\delta}$ replaced by $\tilde{D}_{t+1}^{\delta\neg A}$.

The preceding discussion describes the discount when an MDP has previously been implemented. If, however, an MDP has not been adopted, there are several possibilities for the discount. In the simplest scenarios there is no uncertainty regarding either the possibility of an attack or adoption of the MDP at $t+1$. When this lack of uncertainty results from a discount weakly greater than both κ and λ, the MDP will not be adopted and no liquidation attempt will occur at $t+1$. If the fund is not currently under attack then the discount is given by (2.6) with $\tilde{D}_{t+1}^{\neg\delta A}$ in place of $\tilde{D}_{t+1}$, but if the fund is currently under attack then the discount is equal to (2.10) with $\tilde{D}_{t+1}^{\neg\delta A}$ substituted for $\tilde{D}_{t+1}^{A}$. On the other hand, the lack of uncertainty could result from a discount weakly less than both θ_{κ} and θ_{λ}. In this case, the MDP will be adopted and an attempt definitely will take place at $t+1$. Similar to the other situation without uncertainty, if the fund is not currently under attack then the discount is given by (2.6) with $\tilde{D}_{t+1}$ replaced by $\tilde{D}_{t+1}^{\delta A}$, but if the fund is currently under attack then the discount is given by (2.10) with $\tilde{D}_{t+1}^{\delta A}$ instead of $\tilde{D}_{t+1}^{A}$. Alternatively, if $D_t \in (\lambda, \theta_{\kappa})$ then an attack will occur with certainty but an MDP will not be adopted at $t+1$. Here, the discount is equal to (2.6) with $\tilde{D}_{t+1}$ replaced by $\tilde{D}_{t+1}^{A\neg\delta}$ if the fund is not currently under attack or (2.10) with $\tilde{D}_{t+1}^{A\neg\delta}$ substituted for $\tilde{D}_{t+1}^{A}$ if the fund is currently under attack. Finally, if $D_t \in (\kappa, \theta_{\lambda})$ then an MDP definitely will be adopted but an attack will not take place at $t+1$. Accordingly, the discount is given by (2.6) with $\tilde{D}_{t+1}$ replaced by $\tilde{D}_{t+1}^{\delta\neg A}$ if the fund is not currently under attack or (2.10) with $\tilde{D}_{t+1}^{\delta\neg A}$ substituted for $\tilde{D}_{t+1}^{A}$ if the fund is currently under attack.

Expressions for the discount are slightly more complicated when there is uncertainty regarding either the possibility of a liquidation attempt or adoption of an MDP at $t+1$. We first describe the situations where there is uncertainty with respect to an activist attack but not with respect to adoption. If $D_t \in (\lambda, \kappa)$ then an attack may possibly take place but an MDP will not be adopted at $t+1$ because the lifeboat is not triggered. In this situation, the discount is equal to (2.9) if the fund is currently under attack or (2.11) if the fund is not currently under attack, with $\tilde{D}_{t+1}^{A\neg\delta}$ and $\tilde{D}_{t+1}^{\neg\delta A}$ substituted for $\tilde{D}_{t+1}^{A}$ and $\tilde{D}_{t+1}^{\neg A}$, respectively, in both cases. Conversely, if $D_t \in (\theta_{\kappa}, \theta_{\lambda})$ then an MDP will definitely be adopted and an attack is possible at $t+1$. Here, the discount is given by (2.9) if the fund is currently under attack or (2.11) if the fund is not currently under attack, with $\tilde{D}_{t+1}^{\delta A}$ and $\tilde{D}_{t+1}^{\delta\neg A}$ substituted for $\tilde{D}_{t+1}^{A}$ and $\tilde{D}_{t+1}^{\neg A}$, respectively, in both cases.

Alternatively, there could be uncertainty with respect to adoption of an MDP but not with respect to an activist attack. If $D_t \in (\kappa, \lambda)$ then an MDP might be adopted but an attack will not occur at $t+1$. When the fund is currently under an attack the discount is given by (2.19). When the fund is not currently under an attack, however, $q=0$ and the discount reduces to 2.17 with $\tilde{D}_{t+1}^{\delta\neg A}$ and $\tilde{D}_{t+1}^{\neg\delta A}$ substituted for $\tilde{D}_{t+1}^{\delta}$ and $\tilde{D}_{t+1}^{\neg\delta}$, respectively. In contrast, if $D_t \in (\theta_{\lambda}, \theta_{\kappa})$ then an MDP may be adopted and an attack will definitely occur at $t+1$. In this situation, the discount is equal to (2.19) with $\tilde{D}_{t+1}^{\delta\neg A}$ and $\tilde{D}_{t+1}^{\neg\delta A}$ replaced by $\tilde{D}_{t+1}^{\delta A}$ and $\tilde{D}_{t+1}^{A\neg\delta}$ if the fund is currently under an attack or (2.17) with $\tilde{D}_{t+1}^{\delta}$ and $\tilde{D}_{t+1}^{\neg\delta}$ replaced by $\tilde{D}_{t+1}^{\delta A}$ and $\tilde{D}_{t+1}^{A\neg\delta}$ if the fund is not currently under an attack.

Finally, there may be uncertainty surrounding the possibility of both a liquidation attempt and an MDP adoption, in which case the expression for the discount is quadratic. If the fund is under attack then the discount is given by (2.20) with x, y, and z defined in Proposition 4. Conversely, if the fund is not currently under attack then x, y, and z are redefined by setting $q=0$.

In sum, the discount may take any one of several possible expressions when both an activist arbitrageur and a lifeboat provision exist, depending on the situation. All of these possibilities are summarized in Table B.II.

2.3 Simulation

Analytical expressions for the closed-end fund discount in various settings were derived in Section 2.2 and are summarized in Tables B.I and B.II in Appendix B.1. Since these expressions are not in closed form, however, we conduct a numerical simulation analysis to determine how closed-end funds are affected, both qualitatively and quantitatively, by activist arbitrageurs and lifeboat provisions. We first briefly consider the benchmark case in Section 2.3.1. We then explore how changes in the cost of activism and the probability of shareholder approval impact closed-end funds in an activist environment in Section 2.3.2 before examining the effect of various dividend rates and trigger thresholds in a lifeboat setting in Section 2.3.3. Lastly, we investigate the joint impact of activism and lifeboats in Section 2.3.4.

The parameters used in our analysis are contained in Table B.III. The time horizon of the fund is 25 years. While shorter than most other dynamic models of closed-end funds in the literature, this is the maximum attainable horizon due to computational constraints. We set the expected rate of return, μ, to 2.5%. In "high" states the manager earns an excess return of 10% while in "low" states the manager earns zero excess return, as we assume that even in bad states the fund manager does not destroy value. The prior parameters for the distribution of π_t, a_1 and b_1, are both set to one, meaning that the investors' initial beliefs regarding Π follow a uniform distribution. These beliefs, combined with an initial excess return scale factor, γ_1, of one, correspond to an initial expected excess return of 5%. The management fee is fixed at 2% of the value of the assets under management and approximates the average fee charged by closed-end funds.[12] Finally, the excess return adjustment threshold, Υ, is chosen so that the fund issues at NAV in the benchmark case.

To be consistent with investors' initial beliefs about the manager's ability level, we divide the unit interval into deciles and simulate discounts for eleven different values of Π ranging from zero to one. These discounts are equally weighted when computing relevant statistics. As a result, the manager's actual ability level is uniformly distributed and is compatible with investors' inital beliefs. We simulate 1,000 discount paths for each level of ability.

Numerical values for the discounts are obtained through a four-step procedure. First, we construct a binomial tree for investors' beliefs regarding the manager's ability, π_t, where each branch represents a potential realization of $\tilde{\alpha}_{t+1}$. Second, we use this tree to create another binomial tree for the excess return scale factor, γ_t. Third, we recursively solve a binomial tree for each discount scenario by exploiting the fact that all of the terminal nodes must equal one since no arbitrage requires that the discount vanish upon termination.[13] Lastly, we simulate paths through the discount trees.

2.3.1 Benchmark Simulation

Figure 2.1 plots the distribution of discounts in the absence of both an activist arbitrageur and a lifeboat provision. Figure 2.1(a) plots the distribution of aggregate discounts for all ability levels while Figure 2.1(b) plots the distribution of mean discounts for individual levels of ability. As is evident from the figures, the closed-end funds issue at NAV, and most begin to trade at a discount during the next period. At any point in time, the vast majority of funds trade at a discount, but

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[12]Over different periods of time, Bradley et al. (2010) report that the average management fee ranges from 1.45 to 2.22 percent of NAV.

[13]In the benchmark setting there is only one discount tree to solve. In the activist setting we solve two trees—one where the fund is currently under attack and one where it is not. Similarly, in the lifeboat setting we solve trees where an MDP has been adopted and where an MDP has not been adopted. The combined setting requires four trees.
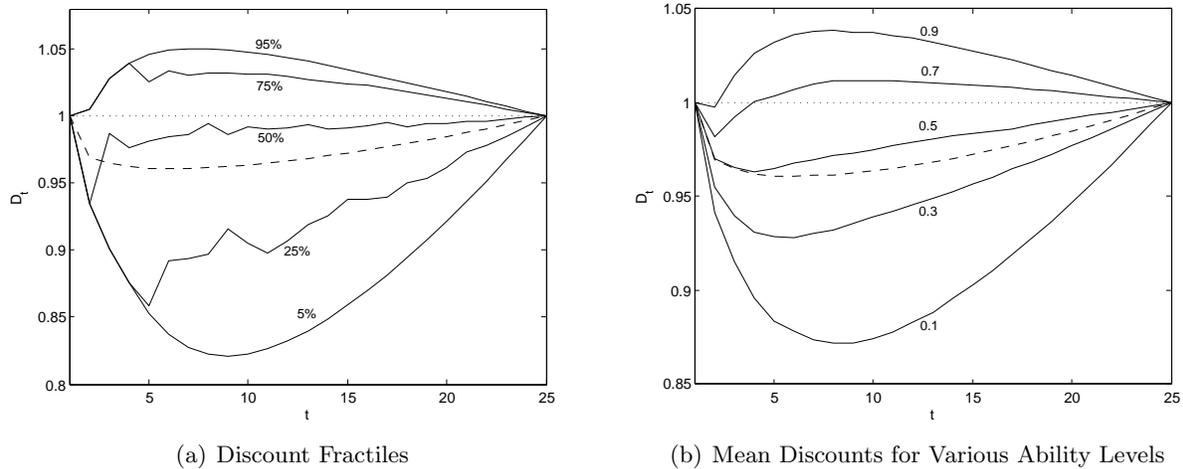
Figure 2.1: **Discount Distributions.** The plots show distributions of simulated closed-end fund discounts. In Figure (a), the solid lines represent various discount fractiles of the entire simulated sample of 11,000 funds. In Figure (b), the solid lines represent the mean discount of 1,000 simulated funds for various ability levels. In both figures, the dashed line denotes the mean discount of the aggregate sample.

some funds trade at a premium. Furthermore, a lower ability level is associated with a deeper discount.

2.3.2 Activist Simulation

We now investigate the effects of activism. Before conducting the simulation, we must first parameterize the functions which regulate the probability of an attack, κ and θ_κ. We define the attack threshold as $\kappa \equiv (1-c)\, q^\sigma$, which is decreasing in the cost of activism and increasing in the probability of liquidation. The probability of success is scaled by an exogenous parameter $\sigma > 0$, with lower values leading to a higher attack threshold. Similarly, we define $\theta_\kappa \equiv (1-c)\, q^\eta$ where $\eta > \sigma$. Note that if the liquidation probability is one then an attack is certain to occur when the discount falls below $1 - c$. On the other hand, no attempt will take place when the probability of liquidation is zero since this corresponds to an attack threshold of zero. Likewise, if the cost of activism is equal to one then no liquidation attempts will occur. However, a zero cost does not lead to a certainty of attack, reflecting the fact that the few activists who target closed-end funds tend to seek out funds with deeper discounts.

In some of our analysis we examine how changes in the cost structure and liquidation probability affect closed-end funds while in other cases it is convenient to isolate the impact of a single parameter. Therefore, unless otherwise noted, we fix the probability of liquidation, q, at 60% and the cost of activism, c, at 4%.[14] We also set σ equal to 1/9 and η equal to 2/3. With these parameter values the attack threshold, κ, is 0.907 and θ_κ is 0.683, meaning that the probability of attack increases by roughly 4.5% when the discount drops by one percentage point within the

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[14]The cost of activism does not represent the actual cost borne by a single activist. Rather, it a normalization that balances the disproportionate costs and benefits of activism. On one hand, activists typically own only a small fraction of a fund's shares, meaning that they receive only a portion of the gains from liquidation. On the other hand, activists usually coordinate their liquidation efforts with other activists and thereby share the costs associated with a liquidation attempt. In any case, while c possesses some economic content, the choice of c merely affects the shape of κ and θ_κ.

(a) Ability Levels with Activism   (b) Cost of Activism and Liquidation Probability
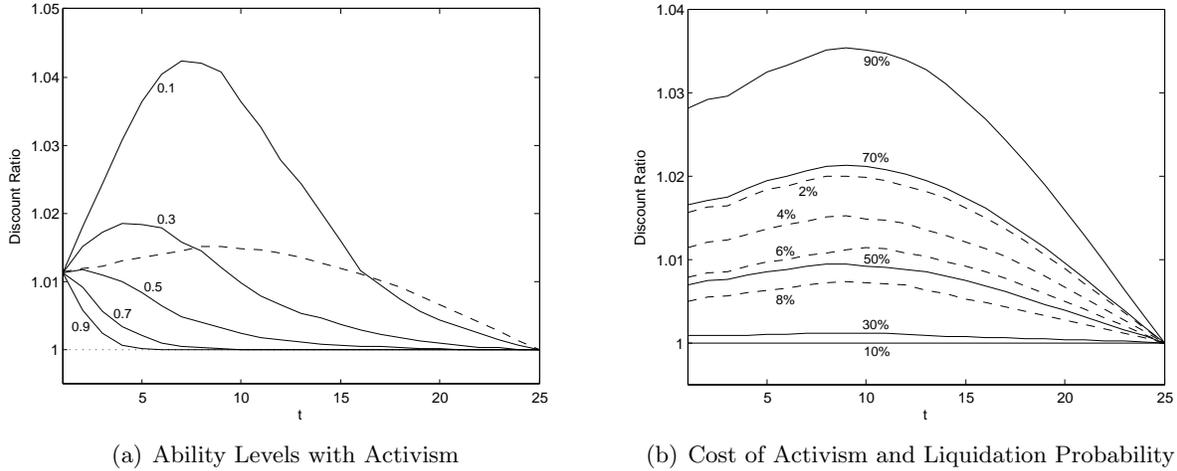
Figure 2.2: Discount Ratios with Activism. In Figure (a), the solid lines represent the ratio of the mean discount in an activist setting to the mean discount in the benchmark case for various ability levels while the dashed line represents the ratio for the entire sample of 11,000 funds where $c = 4\%$ and $q = 60\%$. In Figure (b), the solid lines show the ratio of the mean discount in an activist setting to the mean discount in the benchmark case for various values of q when c is fixed at 4%, and the dashed lines depict the ratio for various values of c when q is fixed at 60%.

range defined by θ_κ and κ. The values for σ and η also ensure the existence of equilibrium.[15]

Results

A comparison of discounts in the presence of an activist to discounts in the benchmark case is depicted in Figure 2.2 and illustrates the feedback effect from potential activism. Figure 2.2(a) plots time series of ratios of mean discounts when an activist is present to mean discounts in the benchmark case for various levels of managerial ability. There are a couple of noteworthy consequences of activist arbitrage evident from the figure. First, the presence of an activist leads to a 1.14% increase in the issue premium for all funds. Second, while mean discounts are weakly less severe than in the benchmark case regardless of ability level, the impact of activism is most pronounced when the fund manager has a low level of ability because, on average, a low ability level results in a deeper discount, which in turn leads to a greater likelihood of liquidation.

The quantitative effect of potential activism on the discount depends on the liquidation probability as well as the cost of activism, as evidenced by Figure 2.2(b), which plots time series of ratios of mean discounts in an activist setting to mean discounts in the benchmark case for the entire sample of simulated funds. The solid lines depict the ratios for various values of q when c is fixed at 4% while the dashed lines represent the ratios for various values of c when q is fixed at 60%. Not surprisingly, the presence of an activist has the greatest impact on discounts when the cost of activism is low and the liquidation probability is high. If the liquidation probability is very low then discounts are unaffected by the presence of an activist since a liquidation is not attempted. Furthermore, changes in the probability of liquidation appear to have a larger impact, *ceteris paribus*, on discounts than changes in the cost of activism.

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[15]Since the potential for activism affects the discount but the discount itself influences the probability of an attack, within a subset of parameter values it is possible that there is no value for the discount such that the probability of activism and the discount are in equilibrium.

Table 2.I: Liquidations. For various liquidation probabilities, q, and ability levels, Π, the number of liquidations per 1,000 simulations is reported in Panel A, the mean survival time of prematurely liquidated funds is reported in Panel B, the mean excess change in discount upon a new attack is reported in Panel C, and the mean excess change in discount upon a liquidation is reported in Panel D. The cost, c, is fixed at 4%.

q	Π											
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	All
Panel A: Number of Liquidations												
0.3	42	22	13	3	0	1	0	1	0	0	0	82
0.4	205	91	47	15	11	3	1	0	0	0	0	373
0.5	389	194	106	54	22	12	1	0	0	0	0	778
0.6	630	324	184	102	50	23	8	2	1	0	0	1324
0.7	781	495	278	156	100	50	28	2	2	0	0	1892
0.8	904	643	395	257	175	92	42	11	3	0	0	2522
0.9	989	800	553	371	236	144	66	13	5	1	0	3178
Panel B: Mean Survival Time												
0.3	11.3	11.5	10.8	11.3	-	11.0	-	9.0	-	-	-	11.2
0.4	12.2	11.4	10.9	11.4	10.3	10.7	11.0	-	-	-	-	11.7
0.5	12.5	11.7	10.9	10.8	10.0	9.7	9.0	-	-	-	-	11.9
0.6	12.9	11.9	11.5	10.6	10.8	9.6	10.0	8.0	12.0	-	-	12.1
0.7	12.6	12.3	12.1	11.8	11.0	10.7	9.2	11.0	8.5	-	-	12.2
0.8	12.0	12.4	11.9	11.7	11.7	11.1	10.4	8.9	7.7	-	-	11.9
0.9	11.2	11.9	12.0	12.2	11.7	11.4	11.0	8.4	8.2	8.0	-	11.7
Panel C: Mean Excess Change in Discount upon Attack												
0.3	4.6	5.0	5.0	4.6	7.3	6.8	-	11.6	-	-	-	4.9
0.4	5.4	5.5	5.9	6.0	7.2	5.7	5.0	-	-	-	-	5.6
0.5	5.8	5.9	6.3	6.4	6.0	6.8	7.1	-	7.5	-	-	6.1
0.6	6.0	6.1	6.0	6.2	6.3	6.3	7.0	8.3	5.7	-	-	6.2
0.7	5.8	5.7	5.8	5.8	5.9	6.0	5.6	5.5	6.1	-	-	5.8
0.8	5.3	5.3	5.3	5.2	5.3	5.3	5.3	5.6	5.2	-	-	5.3
0.9	4.5	4.4	4.5	4.5	4.6	4.6	4.7	4.9	4.7	4.6	-	4.5
Panel D: Mean Excess Change in Discount upon Liquidation												
0.3	12.0	11.0	11.7	11.9	-	12.5	-	5.0	-	-	-	11.8
0.4	9.4	9.5	8.8	8.4	8.1	9.2	9.3	-	-	-	-	9.5
0.5	7.2	7.0	6.8	6.6	6.4	5.1	3.6	-	-	-	-	7.2
0.6	5.2	5.1	5.0	4.6	4.4	4.5	3.4	3.0	4.0	-	-	5.4
0.7	3.5	3.6	3.4	3.3	3.2	3.1	3.1	3.1	3.5	-	-	3.8
0.8	2.1	2.2	2.3	2.1	2.1	2.1	2.0	1.6	1.9	-	-	2.6
0.9	1.0	1.2	1.3	1.3	1.2	1.1	1.0	0.7	1.1	0.8	-	1.6

The influence of the cost of activism, liquidation probability, and managerial ability level on closed-end funds is not limited to the discount. These parameters affect several other fund features, including the ex ante likelihood of premature liquidation, survival time, excess discount changes

upon attacks and liquidations, and the expected wealth of investors and managers. Tables 2.I, 2.II, and 2.III demonstrate the effects of different parameter values on these attributes. Data for probabilities of liquidation less than 0.3 are omitted since the presence of an activist arbitrageur has no impact on funds in these cases because the discount never reaches the attack threshold.

Panel A in Table 2.I, which displays the number of liquidations per 1,000 simulated funds, reveals that the ex ante probability of a premature liquidation is increasing in q but decreasing in Π. Evidently, funds with lower management quality are much more likely to be prematurely liquidated. Panel A in Table 2.II shows that a larger cost of activism also results in fewer liquidations. As Panel B in both Tables demonstrates, however, the mean survival time of prematurely liquidated funds is not dramatically affected by either the liquidation probability, managerial ability, or cost.

Prior empirical studies have observed that discounts tend to shrink upon both the initiation of an activist attack and the announcement of a restructuring. Our sample of simulated funds also experiences discount changes when an activist attacks and when a liquidation takes place, as shown in Panels C and D, respectively, of both Tables 2.I and 2.II. To calculate the excess discount change upon a liquidation, we take the difference between the mean discount change for funds that liquidate at a particular date and the mean discount change for funds that do not liquidate at that date and then compute the average of these differences over time. We perform a similar calculation to find the excess discount change upon an attack, but in computing the excess change at time t we exclude funds that are under attack at $t-1$ in order to focus on the impact of a "new" attack as well as eliminate shifts in the discount that occur following an unsuccessful attempt. Our simulation results are similar to empirical estimates in the literature. Bradley et al. (2010) report that the discount shrinks between 5% and 6% when a restructuring attempt is initiated while Del Guercio, Dann, and Partch (2003) observe that the discount shrinks by about 8.5% upon a restructuring announcement. Moreover, we find that the liquidation probability has an immense effect on excess discount changes which occur upon a liquidation but a much smaller impact on those changes which occur upon an attack. Conversely, the cost structure seems to affect the discount changes which occur upon an attack to a greater extent than those which occur upon a liquidation. We also observe that the excess change upon both an attack and a liquidation is relatively stable across ability levels. This is a consequence of the manager's perceived ability, which is manifested through the discount, being the basis for activism rather than actual ability.

Activist arbitrage also has a dramatic effect on wealth. Panels E and F in Table 2.II display the percentage increase in the expected present value of terminal NAV and management fees, respectively, relative to the benchmark case. Terminal NAV is defined as NAV at the time of liquidation regardless of the liquidation date, and management fees include all fees paid during the life of the fund plus any issue premium. In computing these values, we set $\tilde{r}_{t+1}$ equal to μ for all t in order to eliminate unnecessary noise. The only sources of variability are with respect to $\tilde{\alpha}_{t+1}$, the activist's decision whether to initiate a liquidation attempt, and whether the shareholders approve the attempt. Cash flows are discounted at rate μ. Since Table 2.II lists the results over the entire distribution of managerial ability for each c-q pair, the data represents the ex ante expected increase in value of terminal NAV and management fees. Panel E indicates that the expected present value of terminal NAV is not substantially different than in the benchmark case,[16] but Panel F shows that the expected present value of management fees in the activist setting is less than in the benchmark case whenever c is small or q is large. Not surprisingly, the value of the management fees is inversely related to the ex ante probability of liquidation.

Table 2.III provides the effects on wealth for individual ability levels and liquidation probabili-

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[16]We attribute the difference to "rounding error," or a lack of precision when numerically solving the discount trees.

Table 2.II: Impact of Cost Structure. Data for 11,000 simulations over the entire distribution of managerial ability are reported for various liquidation probabilities, q, and costs, c. The content of each panel is as described in Tables 2.I and 2.III. The return from the fund's portfolio, $\tilde{r}_{t+1}$, is equal to μ for all t.

	q						
c	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Panel A: Number of Liquidations							
0.02	224	652	1121	1830	2511	3267	4192
0.04	82	373	778	1324	1892	2522	3178
0.06	4	203	521	981	1381	1908	2385
0.08	0	57	276	557	975	1388	1775
Panel B: Mean Survival Time							
0.02	11.4	11.8	11.8	11.9	11.9	11.5	11.0
0.04	11.2	11.7	11.9	12.1	12.2	11.9	11.7
0.06	10.8	11.4	11.8	12.0	12.1	12.2	12.3
0.08	-	11.0	11.9	12.0	12.2	12.3	12.6
Panel C: Discount Change upon Attack							
0.02	4.7	5.2	5.4	5.2	4.9	4.2	3.1
0.04	4.9	5.6	6.1	6.2	5.8	5.3	4.5
0.06	4.9	6.1	6.8	7.0	6.9	6.6	6.0
0.08	-	6.4	7.5	7.9	7.9	7.9	7.5
Panel D: Discount Change upon Liquidation							
0.02	11.1	8.7	6.6	4.7	3.3	2.2	1.3
0.04	11.8	9.5	7.2	5.4	3.8	2.6	1.6
0.06	12.8	10.1	7.9	5.9	4.3	3.0	1.9
0.08	-	10.8	8.0	6.4	4.7	3.2	2.1
Panel E: Value of Terminal NAV							
0.02	0.1	0.3	0.4	0.5	0.6	0.7	0.7
0.04	0.0	0.1	0.3	0.4	0.5	0.6	0.6
0.06	0.0	0.1	0.2	0.4	0.5	0.5	0.6
0.08	-	0.0	0.1	0.2	0.4	0.5	0.5
Panel F: Value of Management Fees							
0.02	-0.5	-1.4	-2.3	-4.0	-5.5	-7.7	-11.1
0.04	-0.2	-0.7	-1.5	-2.6	-3.7	-5.3	-7.1
0.06	0.0	-0.4	-1.0	-2.0	-2.7	-3.7	-4.5
0.08	-	-0.1	-0.5	-1.0	-1.9	-2.6	-3.2

ties. Decomposing the results in this manner reveals that, on average, the expected present value of terminal NAV is greater than in the benchmark case when the fund manager has a low ability level but less than in the benchmark case when managerial ability is high. The opposite applies to the expected value of management fees. Since premature liquidation reduces the amount of fees

Table 2.III: Activism and Value. For various liquidation probabilities, q, and ability levels, Π, the percentage increase in the expected present value of terminal NAV relative to the benchmark case is reported in Panel A, and the percentage increase in the expected present value of management fees relative to the benchmark case is reported in Panel B. Terminal NAV is defined as NAV at the time of liquidation regardless of the liquidation date. The cost of activism, c, is fixed at 4%, and the return from the fund's portfolio, $\tilde{r}_{t+1}$, is equal to μ for all t.

						Π						
q	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	All
			Panel A: Expected Present Value of Terminal NAV									
0.3	1.2	0.3	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
0.4	5.4	1.2	0.1	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	0.1
0.5	9.8	2.7	0.4	-0.5	-0.6	-0.7	-0.7	-0.6	-0.6	-0.6	-0.6	0.3
0.6	15.4	4.5	0.8	-0.9	-1.0	-1.1	-1.1	-1.0	-1.0	-0.9	-0.9	0.4
0.7	19.3	6.7	1.2	-1.2	-1.5	-1.6	-1.7	-1.5	-1.4	-1.4	-1.3	0.5
0.8	23.3	8.7	2.1	-1.1	-1.8	-2.3	-2.2	-2.0	-1.9	-1.8	-1.8	0.6
0.9	26.6	11.2	3.2	-1.2	-2.1	-2.8	-2.8	-2.6	-2.4	-2.3	-2.2	0.6
			Panel B: Expected Present Value of Management Fees									
0.3	-2.0	-0.9	-0.5	0.0	0.2	0.1	0.2	0.1	0.1	0.1	0.1	-0.1
0.4	-8.9	-3.8	-1.7	0.0	0.1	0.5	0.6	0.7	0.6	0.6	0.6	-0.7
0.5	-16.2	-7.9	-4.0	-1.4	0.2	0.7	1.3	1.4	1.3	1.3	1.3	-1.5
0.6	-25.4	-13.1	-6.8	-3.2	-0.3	0.9	1.8	2.1	2.1	2.1	2.1	-2.6
0.7	-31.9	-19.7	-9.8	-4.3	-2.0	0.6	1.5	3.1	3.0	3.1	3.0	-3.7
0.8	-38.5	-25.3	-14.8	-8.4	-4.4	-0.5	2.0	3.6	4.0	4.1	4.0	-5.3
0.9	-44.0	-33.1	-21.2	-12.4	-6.4	-1.9	1.9	4.5	5.0	5.2	5.1	-7.1

paid to the manager relative to the benchmark setting and there is a greater ex ante likelihood of early liquidation when managerial ability is low, the aggregate fees received by low-ability managers are expected to be less valuable than in the benchmark case. Furthermore, because a low-ability manager generates a negative expected return net of fees, premature liquidation enhances the expected present value of terminal NAV relative to the benchmark case when managerial ability is low. Conversely, the expected present value of terminal NAV is less than in the benchmark case while the expected value of management fees is greater than in the benchmark case for high levels of managerial ability because there is little chance of liquidation and the fund issues at a premium, which is captured by the manager, when an activist arbitrageur exists.

Taken together, the effects on wealth provided in Table 2.III and Panels E and F of Table 2.II illustrate an important consequence of activist arbitrage. While an actual liquidation event effectuates a wealth transfer from management to investors, the existence of an activist arbitrageur results in an ex ante transfer of wealth from low-ability managers to those with high ability. The possibility of activist arbitrage does not result in greater wealth for investors ex ante because any increase in the present value of terminal NAV is incorporated into the initial fund price in the form of an issue premium. However, the possibility of activist arbitrage reduces the expected value of management fees.

Summary and Implications

As is clear from the simulation results, there are several economic repercussions of activist arbitrage. Akin to an insurance policy against low-quality asset management, the primary consequences of activism are an ex post expected wealth transfer from low-ability fund managers to investors along with an ex ante expected wealth transfer from low-ability to high-ability managers. Investors realize a sizeable gain when a fund is liquidated, but they must pay for this potential windfall at the IPO in the form of an issue premium, thereby offsetting the expected future benefit from liquidation. Since high-ability fund managers are far less likely to experience a premature liquidation, they benefit from the issue premium at the expense of low-ability managers. The possibility of premature liquidation also causes discounts to shrink, even for funds that are never liquidated or attacked, as investors rationally incorporate potential future liquidations into current fund prices.

Since the extent to which a closed-end fund is affected by potential activist arbitrage depends largely on the cost structure and liquidation probability, the governance provisions adopted by a fund's founders have considerable and enduring consequences. For instance, staggered boards, supermajority voting requirements, and the establishment of large blockholders all tend to reduce the likelihood that a liquidation attempt will be successful. In terms of our model, these governance features result in a lower value of q. Other anti-takeover practices, such as credibly signaling to engage in a costly proxy battle, increase the anticipated cost of a liquidation attempt, c. Because low values of q and high values of c discourage activism and consequently diminish the insurance effect that it provides, funds with strong anti-takeover provisions should, *ceteris paribus*, outlast but trade at a lower price than funds with weaker anti-takeover provisions. In extreme cases, a combination of governance provisions could eliminate activism altogether.

Activist arbitrage also gives rise to an interesting tradeoff facing the founders of a closed-end fund. On one hand, anti-takeover provisions decrease the expected present value of terminal NAV but increase the expected value of management fees when managerial ability turns out to be low. The opposite effect materializes when managerial ability happens to be high. Therefore, if managerial ability initially is unknown to both investors and management, fund organizers must find the appropriate balance between a larger issue premium and the potential insurance effects from activism when selecting governance provisions.

Although outside the scope of our model, the potential for activist arbitrage could mitigate some detrimental agency problems due to the varying degrees to which different parameter values affect expected wealth. Our results are based on an assumption that managerial ability is unknown to both the manager and investors at the time of IPO. If, however, the fund manager privately observes his ability level prior to accepting an employment position with a fund, then the potential for activist arbitrage could serve as a mechanism to either screen for higher quality managers or signal the quality of management to investors since activist arbitrage increases the expected wealth for managers with high ability at the expense of low-ability managers. Similarly, the potential for activist arbitrage may entice managers to exert more effort and thereby generate greater excess returns for the fund, as funds with larger returns have narrower discounts and are therefore less likely to undergo a premature termination. We do not address the specific ways in which activist arbitrage can help alleviate adverse selection and moral hazard issues but leave them as topics for future research.

2.3.3   Lifeboat Simulation

We next examine the impact of a lifeboat on closed-end funds. Like in the activist setting, we sometimes analyze how changes in both the dividend rate and lifeboat trigger threshold affect

(a) Ability Levels with a Lifeboat   (b) Lifeboat Trigger and Dividend Rate
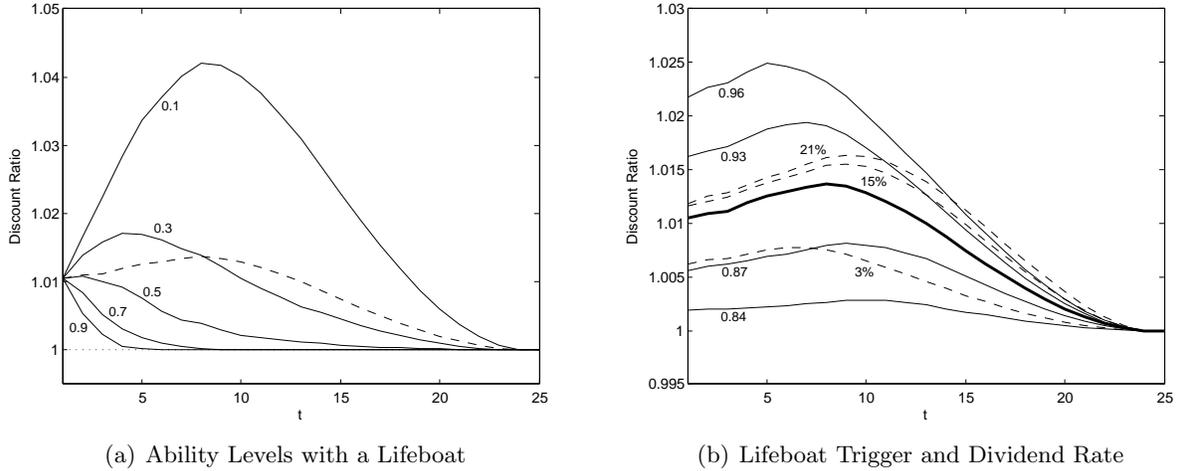
Figure 2.3: Discount Ratios with a Lifeboat. In Figure (a), the solid lines represent the ratio of the mean discount in a lifeboat setting to the mean discount in the benchmark case for various ability levels while the dashed line represents the ratio for the entire sample of 11,000 funds. In Figure (b), the solid lines show the ratio of the mean discount in a lifeboat setting to the mean discount in the benchmark case for various values of λ when δ is fixed at 9%, the dashed lines show the ratio for various values of δ when λ is fixed at 0.90, and the bold solid line shows the ratio when δ is 9% and λ is 0.90.

closed-end funds while other times we find it convenient to study the effects of a single parameter. Unless otherwise noted, we fix the dividend rate, δ, at 9% and the lifeboat trigger, λ, at 90% of NAV. These assumptions are consistent with empirical observations (see, e.g., Johnson, Lin, and Song (2006), Wang and Nanda (2008), and Curtis and Robertson (2008)). To ensure the existence of equilibrium, we also set $\theta_\lambda \equiv \lambda - 0.1$, which means that the probability of MDP implementation increases by 10% when the discount drops by one percentage point within the range defined by θ_λ and λ.

Results

Figure 2.3 compares discounts in the presence of a lifeboat to discounts in the benchmark case and demonstrates the feedback effect from a lifeboat provision. Time series of ratios of mean discounts when a lifeboat exists to mean discounts in the benchmark case for various levels of managerial ability is plotted in Figure 2.3(a). Similar to the activist setting, the existence of a lifeboat leads to approximately a 1.05% increase in the issue premium for all funds. Mean discounts are also milder than in the benchmark case for all levels of ability, but the effects of the lifeboat are more prominent when the fund manager has a low ability level since a low level of ability leads to a deeper discount, which in turn increases the probability of implementing an MDP.

The degree to which a lifeboat affects the discount depends on the dividend rate and lifeboat trigger. Figure 2.3(b) plots time series of ratios of discounts in the presence of a lifeboat provision to discounts in the benchmark case for the entire sample of simulated funds. The solid lines represent the ratios for various values of λ when δ is fixed at 9%, the dashed lines represent the ratios for various values of δ when λ is fixed at 0.90, and the bold solid line depicts the ratios when δ and λ are equal to 9% and 0.90, respectively. Evidently, the effects of the lifeboat provision are largest when the dividend rate is high and the lifeboat trigger is close to one. This result is consistent with Johnson, Lin, and Song (2006), who observe that MDP funds with higher dividend rates have

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Table 2.IV: Lifeboats. For various lifeboat trigger levels, λ, and ability levels, Π, the number of adoptions per 1,000 simulations is reported in Panel A, the mean adoption time is reported in Panel B, the mean excess change in discount upon adoption is reported in Panel C, the percentage increase in the expected present value of all fund distributions relative to the benchmark case is reported in Panel D, and the percentage increase in the expected present value of the management fees is reported in Panel E. Fund distributions include dividend payments plus the terminal liquidation value. The dividend rate, δ, is fixed at 9%, and the return from the fund's portfolio, $\tilde{r}_{t+1}$, is equal to μ for all t.

	Π											
λ	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	All
Panel A: Number of Adoptions												
0.84	259	132	51	26	4	2	0	0	0	0	0	474
0.87	769	340	167	82	26	16	2	0	0	0	0	1402
0.90	971	594	358	197	103	50	22	3	1	1	0	2300
0.93	1000	813	609	420	257	172	73	17	8	0	0	3369
0.96	1000	963	852	692	551	381	229	90	38	6	0	4802
Panel B: Mean Adoption Time												
0.84	10.9	10.7	10.3	10.0	9.8	10.0	-	-	-	-	-	10.7
0.87	11.0	10.4	10.0	9.5	8.9	8.8	9.0	-	-	-	-	10.7
0.90	9.6	9.7	9.6	8.9	9.5	8.9	7.6	6.7	9.0	6.0	-	9.5
0.93	7.7	8.7	8.8	8.8	8.7	8.5	8.1	7.2	7.0	-	-	8.4
0.96	6.0	7.2	7.6	8.0	8.2	8.1	7.8	7.3	6.7	6.2	-	7.4
Panel C: Mean Excess Change in Discount upon Adoption												
0.84	6.4	6.5	7.4	7.2	8.7	9.8	-	-	-	-	-	6.6
0.87	4.4	4.7	5.2	5.6	5.5	6.3	7.5	-	-	-	-	4.7
0.90	2.9	3.2	3.7	3.8	4.3	4.9	4.1	5.5	5.6	6.3	-	3.3
0.93	1.8	2.2	2.5	2.8	3.0	2.9	3.6	3.5	3.4	-	-	2.3
0.96	1.2	1.3	1.4	1.6	1.9	2.0	2.3	2.7	2.6	2.1	-	1.5
Panel D: Expected Present Value of Distributions												
0.84	3.1	0.8	0.0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1	-0.1	0.1
0.87	9.1	2.1	0.2	-0.4	-0.6	-0.6	-0.5	-0.5	-0.5	-0.5	-0.4	0.3
0.90	13.3	4.3	0.8	-0.7	-1.0	-1.1	-1.0	-1.0	-0.9	-0.9	-0.8	0.4
0.93	16.1	6.6	2.0	-0.6	-1.5	-1.8	-1.8	-1.5	-1.4	-1.3	-1.3	0.4
0.96	18.5	9.1	3.6	-0.1	-1.5	-2.5	-2.6	-2.3	-2.1	-1.8	-1.7	0.4
Panel E: Expected Present Value of Management Fees												
0.84	-5.1	-2.4	-0.8	-0.2	0.3	0.3	0.4	0.4	0.3	0.3	0.3	-0.4
0.87	-15.0	-6.4	-2.8	-0.9	0.5	0.7	1.1	1.1	1.1	1.0	1.0	-1.3
0.90	-22.0	-12.5	-7.0	-3.3	-0.5	0.7	1.3	1.9	2.0	1.9	1.9	-2.5
0.93	-26.7	-19.6	-14.1	-8.8	-4.3	-2.0	0.9	2.5	2.8	3.0	3.0	-4.7
0.96	-30.6	-27.2	-23.2	-17.7	-13.2	-7.9	-3.5	1.0	2.7	3.8	4.0	-8.8

much less severe discounts than MDP funds with low dividend rates. A low lifeboat trigger has a negligible impact on discounts since it is unlikely that an MDP will be adopted in such a case while

the marginal impact from raising the dividend rate is much greater for smaller values of δ than for larger values. Overall, changes in the lifeboat trigger appear to have a bigger impact on discounts than changes in the dividend rate, especially when δ is larger than 9%.

In addition to impacting the discount, the dividend rate, lifeboat trigger, and level of managerial ability affect closed-end funds in many other ways, including the incidence of adoptions, the mean time of adoption, excess discount changes upon adoptions, and the expected wealth of investors and managers. Tables 2.IV and 2.V display the effects that different parameter values have on these features.

As shown in Panel A in Table 2.IV, which reports the number of MDP adoptions per 1,000 simulated funds, the ex ante probability of adopting an MDP is increasing in the trigger threshold but decreasing in managerial ability. Panel A in Table 2.V provides the number of adoptions for 11,000 simulated funds over the entire distribution of managerial ability and shows that the likelihood of adopting an MDP is also decreasing with the dividend rate. Furthermore, MDPs tend to be implemented sooner when the trigger threshold is high and the dividend rate is low, as suggested by Panel B in both tables, which display the mean time of adoption. Apparently, MDPs are more likely to be implemented for funds with lower management quality, higher lifeboat triggers, and lower dividend rates, but the primary determinants of how long a fund exists without an MDP appear to be the trigger threshold and dividend rate.

In both Tables 2.IV and 2.V, Panel C displays the mean excess discount change upon the adoption of an MDP for our simulated sample of funds. Analogous to the activist setting, to compute the excess change upon adoption, we first take the difference between the mean discount change for funds that implement an MDP at a particular date and the mean discount change for funds that do not, and we then calculate the average of these differences over time. We find that adopting funds, on average, experience a greater convergence of the discount toward NAV whenever managerial ability is high, the lifeboat trigger is low, and the dividend rate is high. Our simulated discount changes are comparable to an empirical finding by Johnson, Lin, and Song (2006) who report a mean excess discount change of roughly 4% upon adoption of an MDP.

Perhaps the most notable consequence of a lifeboat provision is its impact on wealth, as demonstrated by Panels D and E in Tables 2.IV and 2.V, which display the percentage increase in the expected present value of all fund distributions and management fees relative to the benchmark case. In computing these values, we set $\tilde{r}_{t+1}$ equal to μ for all t in order to eliminate unnecessary noise. The only sources of variability are with respect to $\tilde{\alpha}_{t+1}$ and the shareholders' decision whether to approve adoption of an MDP. Cash flows are discounted at rate μ. Table 2.V shows that the ex ante expected present value of fund distributions, which consists of terminal NAV plus dividends, in the lifeboat setting does not differ much from the benchmark case but that the expected value of management fees is less than in the benchmark setting, especially when λ is high.

The effects on wealth for individual ability levels and lifeboat triggers are reported in Table 2.IV. On average, the expected present value of distributions is greater than in the benchmark case when managerial ability is low but less than in the benchmark case when the manager has a high ability level. The converse is true for management fees. The rationale for this observation is the same as in the case of activist arbitrage. Because an MDP reduces the amount of fees paid to the manager relative to the benchmark setting and there is a greater ex ante likelihood of adoption when managerial ability is low, the aggregate fees received by low-ability managers are expected to be less valuable than in the benchmark case when a lifeboat exists. A lifeboat also provides a boost to the expected present value of distributions relative to the benchmark case when managerial ability is low since a low-ability manager generates a negative return net of fees. On the other hand, a lifeboat decreases (increases) the expected present value of distributions (management fees) for high levels of managerial ability because there is little chance of adoption and the fund issues at a

Table 2.V: Impact of Dividend Rate. Data for 11,000 simulations over the entire distribution of managerial ability are reported for various lifeboat trigger thresholds, λ, and dividend rates, δ. The content of each panel is as described in Table 2.IV. The return form the fund's portfolio, $\tilde{r}_{t+1}$, is equal to μ for all t.

λ	δ						
	0.03	0.06	0.09	0.12	0.15	0.18	0.21
Panel A: Number of Adoptions							
0.84	739	564	474	397	379	349	312
0.87	1900	1627	1402	1255	1155	1106	1028
0.90	2879	2523	2300	2126	2030	1896	1861
0.93	4146	3681	3369	3145	3035	2935	2848
0.96	5593	5097	4802	4639	4426	4295	4198
Panel B: Mean Adoption Time							
0.84	10.2	10.6	10.7	10.9	10.9	11.1	11.0
0.87	9.3	10.1	10.6	10.8	11.1	11.2	11.3
0.90	7.8	8.8	9.5	9.9	10.3	10.7	10.7
0.93	6.8	7.8	8.4	8.9	9.3	9.8	10.0
0.96	6.0	6.8	7.4	7.8	8.3	8.5	8.8
Panel C: Discount Change upon Adoption							
0.84	2.9	4.9	6.6	7.8	9.4	9.8	10.7
0.87	1.9	3.4	4.7	5.8	6.7	7.5	8.1
0.90	1.5	2.4	3.3	4.0	4.7	5.3	5.9
0.93	1.2	1.8	2.3	2.8	3.3	3.7	4.1
0.96	0.8	1.1	1.5	1.8	2.1	2.4	2.6
Panel D: Value of Distributions							
0.84	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.87	0.2	0.2	0.3	0.3	0.3	0.3	0.3
0.90	0.2	0.3	0.4	0.4	0.4	0.4	0.4
0.93	0.2	0.3	0.4	0.5	0.5	0.5	0.5
0.96	0.2	0.4	0.4	0.5	0.5	0.6	0.6
Panel E: Value of Management Fees							
0.84	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
0.87	-0.9	-1.2	-1.3	-1.3	-1.3	-1.4	-1.3
0.90	-1.8	-2.3	-2.5	-2.6	-2.7	-2.5	-2.7
0.93	-3.4	-4.4	-4.7	-4.8	-4.8	-4.7	-4.8
0.96	-5.8	-7.8	-8.8	-9.5	-9.3	-9.4	-9.5

larger premium when it contains a lifeboat provision.

Panels D and E in Tables 2.IV and 2.V reveal that the effects on wealth brought about by a lifeboat provision are qualitatively similar to those caused by activist arbitrage. An MDP can effectuate an ex post transfer of wealth from management to investors, but the existence of a lifeboat results in an ex ante transfer of wealth from low-ability managers to managers with high ability. A lifeboat provision does not lead to greater expected wealth for investors since any increase in

the present value of distributions is incorporated into the initial fund price in the form of an issue premium. A lifeboat does, however, reduce the expected value of management fees.

Summary and Implications

Similar to activist arbitrage, the primary function of a lifeboat is to serve as an insurance policy against low realizations of managerial ability. Conditional on low-quality management, lifeboats cause an ex post expected wealth transfer from managers to investors. However, lifeboats produce an ex ante expected wealth transfer from low-ability to high-ability managers because high-ability managers capture an issue premium but rarely distribute assets via an MDP. Additionally, discounts tend to remain closer to NAV when a lifeboat exists, even for funds where an MDP is never adopted.

The extent of a lifeboat's impact depends on the trigger threshold and dividend rate. As the preceding simulation results demonstrate, higher values of λ and δ permit a lifeboat to exert a greater influence over funds. Moreover, changes in the lifeboat trigger threshold seem to have a greater effect on discounts and other fund attributes than do changes in the dividend rate, especially when δ is already relatively high (such as around $10-15\%$). Because the effects of a lifeboat depend on λ and δ, selecting an appropriate trigger threshold and dividend rate at inception could allow a lifeboat to function as either a screening or signaling device if the fund manager privately observes his ability level before he accepts an employment position. A lifeboat could also help to alleviate agency costs associated with moral hazard. Like with activist arbitrage, we leave effects of a lifeboat on these agency issues for future research.

2.3.4 Combined Simulation

In this section, we explore the interplay between activist arbitrage, lifeboat provisions, and closed-end funds. As we demonstrate below, the existence of a lifeboat impacts the extent and consequences of activist arbitrage, and vice versa. To streamline the computations, we focus on how changes in the parameters that have the largest impact in the individual cases—the probability of liquidation and the lifeboat trigger threshold—affect funds when activists and lifeboats coexist. The cost of activism, c, is fixed at 4%, and the dividend rate, δ, is set at 9%. The values for σ, η, and θ_λ remain unchanged.
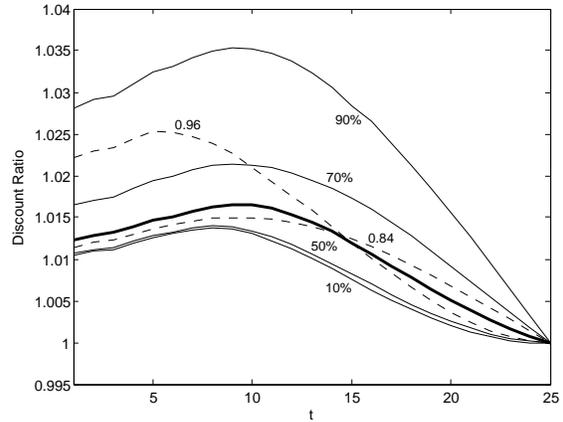
As we alluded to in Section 2.2.4, it is possible that more than one equilibrium may exist since in some cases (to wit, when the lifeboat is triggered at t and there is uncertainty regarding the possibility of both an adoption and a liquidation attempt at $t+1$) the expression for the discount is quadratic. However, the situation arises only when D_t is within the bounds defined by both (θ_κ, κ) and $(\theta_\lambda, \lambda)$. We deal with this quandary by obtaining both solutions and then choosing the value for D_t that is still within the specified bounds. Fortunately, only unique solutions exist when this procedure is followed.

Results

A comparison of discounts in a combined setting to discounts in the benchmark case is presented in Figure 2.4. Time series of ratios of mean discounts when an activist and a lifeboat coexist to mean discounts in the benchmark case for various levels of managerial ability is plotted in Figure 2.4(a). When the liquidation probability is 60% and the trigger threshold in 0.90, funds issue at a premium of 1.22%, which is about 7% greater than in an activist environment and 16% greater than in a lifeboat setting. Figure 2.4(b) plots time series of similar ratios for various values of q and λ. The solid lines represent ratios for several values of q when λ is equal to 0.90, the dashed lines depict ratios for a range of λ values when q is fixed at 60%, and the bold solid line shows the
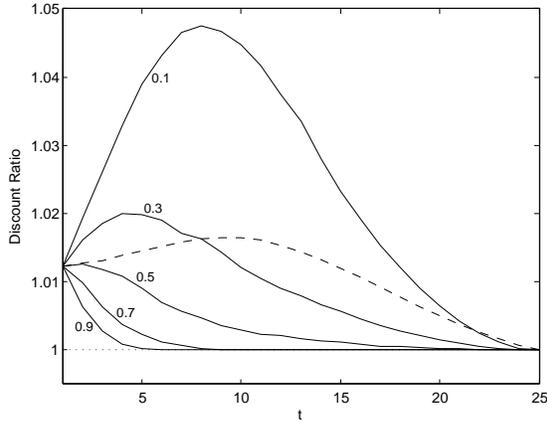
(a) Ability Levels with an Activist and Lifeboat   (b) Liquidation Probability and Lifeboat Trigger

Figure 2.4: Discount Ratios with an Activist and Lifeboat. In Figure (a), the solid lines represent the ratio of the mean discount where both an activist arbitrageur and lifeboat provision exist to the mean discount in the benchmark case for various ability levels while the dashed line represents the ratio for the entire sample of 11,000 funds. In Figure (b), the solid lines show the ratio of the mean discount in a combined setting to the mean discount in the benchmark case for various values of q when λ is fixed at 0.90, the dashed lines show the ratio for various values of λ when q is fixed at 60%, and the bold solid line shows the ratio when q is 60% and λ is 0.90.

ratio when $q = 60\%$ and $\lambda = 0.90$. The addition of a lifeboat causes discounts to be less severe than the case where only an activist is present for relatively small liquidation probabilities, but a lifeboat has little effect on discounts when the liquidation probability is large. Similarly, permitting an activist to operate when a lifeboat exists causes discounts to converge toward NAV when the lifeboat trigger is relatively low, but it has little effect on discounts when the trigger is high.

Like in the other simulations, funds are affected by the liquidation probability and trigger threshold in several ways besides the discount. Comparing Panel A in Table 2.VI with the last column of Panel A in Table 2.I, we observe that, for the most part, there are fewer liquidations when a lifeboat exists, though the degree to which a lifeboat reduces the number of liquidations depends on the trigger threshold. A lifeboat with a low trigger cuts the number of liquidations only when the liquidation probability is relatively small. For large values of q, lifeboats with low triggers are ineffective at decreasing the number of liquidations. As λ increases, however, lifeboats are able to reduce the number of liquidations for large values of q and eliminate them altogether for small values. Our findings are consistent those of Johnson, Lin, and Song (2006), who find that the survival rate for funds with an MDP is greater than the survival rate for funds without an MDP.[17] A quick glance at Panel B suggests that lifeboats do not dramatically affect the average survival time for funds that are prematurely liquidated.

At the same time, a comparison of Panel C in Table 2.VI with the last column of Panel A in Table 2.IV reveals that the potential for activism results in fewer MDP adoptions for moderate and high probabilities of liquidation but has little effect on adoptions when the liquidation probability is small. The potential for activism actually precludes adoptions for funds with low trigger levels when q is relatively high. Furthermore, Panel D shows that the presence of an activist leads to

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[17]Although we do not report the results for attempts, we find that a lifeboat also reduces the number of restructuring attempts. This is consistent with Cherkes, Sagi, and Wang (2009), who find that funds with MDPs in place are attacked less frequently than funds without an MDP.

Table 2.VI: Liquidations and Lifeboats. Data for 11,000 simulations over the entire distribution of managerial ability are reported for various liquidation probabilities, q, and lifeboat trigger thresholds, λ. The content of each panel is as described in Tables 2.I and 2.IV.

	q								
λ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Panel A: Number of Liquidations									
0.84	0	0	35	386	829	1335	1882	2530	3165
0.87	0	0	0	108	611	1320	1879	2495	3175
0.90	0	0	0	0	136	819	1790	2516	3139
0.93	0	0	0	0	15	266	1071	2259	3156
0.96	0	0	0	0	1	163	743	1579	2720
Panel B: Mean Survival Time									
0.84	-	-	12.2	11.9	11.9	12.1	12.1	11.9	11.7
0.87	-	-	-	11.5	11.5	12.0	12.1	12.0	11.8
0.90	-	-	-	-	11.1	11.3	11.9	11.9	11.7
0.93	-	-	-	-	11.5	12.1	11.7	11.6	11.7
0.96	-	-	-	-	12.0	13.5	13.2	12.5	11.4
Panel C: Number of Adoptions									
0.84	462	490	425	26	0	0	0	0	0
0.87	1383	1380	1406	1255	706	0	0	0	0
0.90	2314	2296	2307	2338	2126	1517	396	0	0
0.93	3368	3373	3331	3353	3371	3255	2681	1343	0
0.96	4809	4836	4795	4816	4831	4834	4709	4320	3119
Panel D: Mean Adoption Time									
0.84	10.8	10.8	10.7	10.9	-	-	-	-	-
0.87	10.5	10.7	10.6	10.8	11.2	-	-	-	-
0.90	9.4	9.4	9.5	9.5	9.6	10.2	12.1	-	-
0.93	8.4	8.4	8.4	8.4	8.3	8.5	9.0	10.1	-
0.96	7.3	7.3	7.3	7.4	7.4	7.4	7.5	7.9	8.5

later adoption times whenever q is large relative to λ.

In addition to affecting the incidence of liquidations and adoptions, a combination of activism and a lifeboat also impacts the excess changes in the discount that occur upon attacks, liquidations, and adoptions. A comparison of Panels A and B in Table 2.VII with the last column of Panels C and D in Table 2.I shows that a lifeboat diminishes the excess changes in the discount that occur upon both an attack and a liquidation when the trigger threshold is high relative to the liquidation probability. Either a low trigger threshold or a small probability of liquidation insulates the excess discount changes from the effects of a lifeboat provision. In contrast, the existence of an activist arbitrageur augments the average excess discount change upon an adoption when q is sufficiently large, as demonstrated by comparing Panel C in Table 2.VII with the last column of Panel C in Table 2.IV, but has no effect when the liquidation probability is small.

The expected wealth transfers described in the previous subsections also show up in the combined setting. As a point of reference for comparing the wealth of investors and managers in the

Table 2.VII: Discount Changes and Value. Data for 11,000 simulations over the entire distribution of managerial ability are reported for various liquidation probabilities, q, and lifeboat trigger thresholds, λ. The content of Panels A, B, and C is as described in Tables 2.I and 2.IV. Panels D and E display the percentage increase in the expected present value of all fund distributions and management fees, respectively, relative to the activist setting. The cost, c, is fixed at 4%, the dividend rate, δ, is fixed at 9%, and the return from the fund's portfolio is equal to μ for all t.

	q								
λ	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Panel A: Discount Change upon Attack									
0.84	-	-	4.8	5.7	6.1	6.1	5.8	5.3	4.5
0.87	-	-	-	5.2	5.9	6.1	5.9	5.4	4.5
0.90	-	-	-	-	5.8	5.9	5.8	5.4	4.5
0.93	-	-	-	-	5.4	5.5	5.4	5.2	4.5
0.96	-	-	-	-	4.8	5.3	5.2	4.9	4.4
Panel B: Discount Change upon Liquidation									
0.84	-	-	11.6	9.5	7.2	5.4	3.8	2.6	1.6
0.87	-	-	-	8.9	7.0	5.5	3.9	2.6	1.6
0.90	-	-	-	-	6.5	5.0	3.8	2.6	1.6
0.93	-	-	-	-	6.6	4.7	3.6	2.5	1.6
0.96	-	-	-	-	6.8	4.7	3.5	2.5	1.7
Panel C: Discount Change upon Adoption									
0.84	6.6	6.7	6.6	6.2	-	-	-	-	-
0.87	4.7	4.7	4.7	4.6	4.9	-	-	-	-
0.90	3.3	3.2	3.3	3.3	3.3	3.6	4.1	-	-
0.93	2.3	2.3	2.3	2.3	2.3	2.6	3.1	3.8	-
0.96	1.5	1.5	1.5	1.5	1.5	1.6	2.0	2.5	3.2
Panel D: Value of Distributions									
0.84	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.1
0.87	0.3	0.3	0.3	0.2	0.2	0.0	0.1	0.0	-0.1
0.90	0.4	0.4	0.3	0.2	0.1	0.2	0.2	0.1	0.0
0.93	0.4	0.4	0.4	0.2	0.1	0.1	0.4	0.5	0.0
0.96	0.5	0.5	0.4	0.3	0.2	0.1	0.4	0.7	1.0
Panel E: Value of Management Fees									
0.84	-0.4	-0.4	-0.3	-0.1	-0.2	0.0	0.0	0.0	0.1
0.87	-1.2	-1.2	-1.1	-0.6	-0.4	0.0	0.0	0.2	0.1
0.90	-2.6	-2.5	-2.4	-1.9	-1.1	-0.7	-0.1	0.1	0.3
0.93	-4.7	-4.7	-4.4	-4.0	-3.3	-2.3	-1.7	-0.7	0.2
0.96	-8.8	-8.9	-8.7	-8.2	-7.5	-6.6	-5.7	-4.3	-3.1

combined setting, we use the wealth of the respective parties in the environment with an activist but not a lifeboat (Section 2.3.2) rather than the wealth of the parties in the benchmark case (Section 2.3.1) because we wish to understand the marginal impact of a lifeboat. Our underlying rationale

Table 2.VIII: Activism, Lifeboats, Ability, and Value. For various liquidation probabilities, q, and ability levels, Π, the percentage increase in the expected present value of all fund distributions relative to the activist setting is reported in Panel A, and the percentage increase in the expected present value of management fees relative to the activist setting is reported in Panel B. Fund distributions include dividend payments plus NAV at the time of liquidation regardless of the liquidation date. The cost of activism, c, is fixed at 4%, the lifeboat trigger threshold, λ, is fixed at 0.90, the dividend rate, δ, is fixed at 9%, and the return from the fund's portfolio is equal to μ for all t.

	Π										
q	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
	Panel A: Expected Present Value of Distributions										
0.1	13.6	4.2	0.9	-0.7	-1.0	-1.1	-1.0	-1.0	-0.9	-0.9	-0.8
0.2	13.5	4.3	0.7	-0.7	-1.0	-1.1	-1.0	-0.9	-0.9	-0.9	-0.8
0.3	11.8	4.0	0.7	-0.6	-1.0	-1.0	-1.0	-0.8	-0.8	-0.8	-0.8
0.4	7.5	3.1	0.7	-0.4	-0.6	-0.8	-0.8	-0.7	-0.6	-0.6	-0.6
0.5	4.3	1.9	0.2	-0.2	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.3
0.6	2.2	1.4	0.4	0.1	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1
0.7	1.0	0.4	0.5	0.1	-0.1	0.1	0.1	0.0	0.0	0.0	0.0
0.8	0.3	0.3	0.2	-0.1	-0.1	0.2	-0.1	0.0	0.0	0.0	0.0
0.9	0.1	-0.2	-0.5	0.4	-0.3	-0.1	0.1	0.0	0.0	0.0	0.0
	Panel B: Expected Present Value of Management Fees										
0.1	-22.5	-12.5	-7.3	-3.3	-0.6	0.4	1.4	1.9	1.8	1.9	1.9
0.2	-22.4	-12.5	-6.6	-3.4	-0.6	0.5	1.5	2.0	2.0	1.9	1.9
0.3	-20.1	-11.8	-6.3	-3.5	-1.2	0.4	1.4	1.8	1.8	1.8	1.8
0.4	-14.3	-9.4	-5.3	-3.1	-1.2	-0.2	0.8	1.2	1.2	1.3	1.3
0.5	-8.9	-5.9	-2.4	-1.3	-0.4	-0.4	0.3	0.6	0.6	0.7	0.7
0.6	-3.8	-4.5	-1.8	-0.8	-0.5	-0.5	0.0	0.3	0.1	0.2	0.2
0.7	-1.5	-0.6	-1.2	-1.1	0.6	0.3	1.0	-0.1	-0.1	0.0	0.0
0.8	-1.0	-2.0	-0.4	-0.1	1.7	0.8	0.1	0.0	0.1	0.0	0.0
0.9	-0.3	0.3	1.4	-1.6	1.8	0.1	1.0	0.1	0.1	0.1	0.0

for this decision is that a fund's founders are able to precisely define the parameters of a lifeboat provision in the prospectus but only indirectly affect the prevalence of activism through various governance provisions. The numbers we report are the percentage increase in the expected present value of distributions and management fees in an environment with both an activist arbitrageur and a lifeboat provision relative to a setting with an activist but without a lifeboat.

Panels D and E in Table 2.VII show that introducing a lifeboat does not affect investor wealth, but it does decrease the value of management fees when either the trigger threshold is high or the liquidation probability is low. Table 2.VIII decomposes the impact of a lifeboat over the aggregate distribution of managerial ability into the effects it has on individual ability levels when λ is 0.90. When the liquidation probability is small, the addition of a lifeboat results in a substantial increase in the expected present value of NAV, and an even larger fall in the expected present value of management fees, for low-ability management while the expected value of fees rises for high-ability managers. This finding is similar to what we observe when either an activist or lifeboat exists independently. When the liquidation probability is large, however, a lifeboat's marginal impact on wealth is negligible.

Summary and Implications

The simulation results clearly demonstrate that lifeboat provisions can be effective at warding off activist arbitrageurs. Indeed, the existence of a lifeboat reduces the number of liquidations as well as the excess changes in the discount that occur upon both an attack and a liquidation. Despite limiting activism, however, the results also show that introducing a lifeboat to an environment that already permits activism further decreases the expected value of management fees, at least when the manager's ability level is initially unknown. Hence, our results indicate that lifeboats are not a suitable means for enhancing managerial wealth, even though they may discourage activist arbitrageurs from initiating restructuring attempts.

On the contrary, activist arbitrage and lifeboat provisions serve as substitutes for one another. A lifeboat provides additional insurance against low realizations of managerial ability when the liquidation probability is small relative to the lifeboat trigger. While the existence of both a lifeboat and an activist arbitrageur leads to narrower average discounts than when only an activist exists, the addition of a lifeboat really only affects discounts over the long term for funds with low-quality management. Furthermore, lifeboats have a bigger effect on the discount when the liquidation probability is small. Overall, lifeboats are most effective at providing insurance and shrinking the discount when a fund has strong defensive governance provisions, which may help to explain the conflicting empirical findings regarding the effect of lifeboat provisions on discounts.[18]

2.4   Conclusion

Despite a vast amount of academic research on closed-end funds, very few models incorporate the impact of activist arbitrage or lifeboat provisions. To better appreciate the equilibrium implications of activist arbitrage and lifeboats, we construct a dynamic rational expectations model of closed-end fund discounts that encompasses their feedback effects. We find that both lifeboats and activism cause fund prices to rise and discounts to shrink. We also demonstrate that lifeboats and activist arbitrageurs effectuate an ex post wealth transfer from managers to investors but an ex ante transfer of wealth from low-ability managers to high-ability managers. Investors, on average, neither profit nor suffer from the existence of activist arbitrageurs or lifeboat provisions because their potential benefits are incorporated into higher fund prices. When lifeboats and arbitrageurs coexist, fewer reorganizations occur, and MDPs are adopted less often.

Our current research is an initial inquiry into the equilibrium consequences of lifeboats and activist arbitrage. While exploratory in nature, it opens up some interesting avenues for future research. Due to their effects on wealth, lifeboats or activism could potentially help to mitigate harmful adverse selection or moral hazard problems in the closed-end fund sector.

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[18]Del Guercio, Dann, and Partch (2003) report that lifeboats do not significantly affect discounts, but Bradley et al. (2010) find that lifeboats cause discounts to shrink.

Chapter 3

Advance Disclosure of Insider Trading

We present a noisy rational expectations equilibrium model in which agents who possess private information regarding the profitability of a firm are required to provide advance disclosure of their trading activity. We analytically characterize an equilibrium and conduct a numerical analysis to evaluate the implications of advance disclosure relative to a market in which informed agents trade without providing advance disclosure. By altering the information environment along with managerial incentives, advance disclosure increases risk in the financial market while reducing risk in the real economy. We also find that advance disclosure has implications for equilibrium prices and allocations, managerial compensation contracts, investor welfare, and market liquidity.

3.1   Introduction

Insider trading regulations are one of the most contested issues surrounding financial markets. Advocates of insider trading argue that the information content of informed trades leads to more efficient markets and that it provides a source of compensation for corporate executives. Meanwhile, opponents of insider trading contend that it skews managerial incentives by encouraging overly risky projects, reduces liquidity, decreases profits earned by ordinary investors, and is simply unfair. While there is some merit to these arguments, the overarching question of whether insider trading is ultimately desirable in a general equilibrium context remains unanswered.

Regardless of the desirability of prohibiting insider trading, most commentators agree that the current approaches to regulating insider trading are largely ineffective.[1] This has led authors in both scholarly journals and the popular press to suggest new regulations requiring insiders to provide advance disclosure of their trading activity, which is a departure from current laws that require certain insiders to disclose their trading activity within two business days following a trade.[2] Advance disclosure, it is thought, will increase investor welfare by reducing insider trading profits. Most of the existing research on this subject, however, is based predominantly on intuition rather than sound economic analysis.

To understand the economic implications of potential advance disclosure regulations, we con-

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[1]The two primary legal mechanisms used to combat insider trading are SEC Rule 10b-5 and §16(b) of the Securities Exchange Act of 1934. Rule 10b-5 prohibits trading on material non-public information, but such trading is extremely difficult to detect and prove. Furthermore, this rule does not prevent insiders from trading on private information that is not "material." Section 16(b) prevents corporate executives and directors from earning a profit on any combined purchase and sale of stock in their corporation that occurs within a six month period. Although this law can prevent short-swing profits, it fails to prevent insiders from profiting over a longer time horizon. See Fried (1998) for a thorough discussion of these and other means of restricting insider trading.

[2]See, e.g., Klein (1983), Samuelson (1988), Fried (2006), and Bebchuk and Fried (2009).

struct a competitive rational expectations equilibrium model in which informed insiders are required to provide advance public disclosure of their trading activity. Investors, who are uninformed, learn about the insiders' private information from these disclosures. While the general framework of our model can be applied to a wide variety of circumstances, we focus on a special case where a corporate manager and other insiders—who could be, for example, corporate board members, other employees, or independent accountants or attorneys—obtain private information regarding the profitability of a firm. These insiders can then trade on the basis of their private information to earn insider trading profits. In the benchmark case, insiders trade without providing advance disclosure, and the stock price serves as a noisy signal of the insiders' private information. Conversely, when insiders disclose their trading activity in advance, their disclosures serve as a noisy signal of their private information. Because these two signals are generally distinct, an equilibrium with advance disclosure can differ dramatically from an equilibrium without advance disclosure.

Currently, little is understood about the full spectrum of equilibrium consequences arising out of an advance disclosure requirement. In this article, we attempt to shed some light on this inherently complex issue. Since advance disclosure affects the quantity of the insiders' private information that is revealed to the rest of the market, equilibrium prices and allocations must adjust in response to the new information environment. This in turn impacts the amount of insider trading profits that accrue to insiders. Furthermore, because managers are indirectly compensated by means of insider trading profits, an advance disclosure requirement affects the value and composition of managerial compensation packages and, as a byproduct, the incentives for managers to undertake individually costly actions that enhance firm value. Precisely how advance disclosure affects these and many other equilibrium attributes are important questions that are largely unexplored in the extant literature on insider trading and disclosure.

We find that the equilibrium characteristics of a market in which informed insiders trade without providing advance disclosure and investors learn from prices differ across many dimensions from the equilibrium characteristics of a market in which investors learn from insiders' advance disclosures of trades.[3] In particular, we find that advance disclosure mitigates many of the perceived drawbacks of insider trading while maintaining the benefits, though we refrain from taking a strict stance on the ultimate desirability of advance disclosure regulations. First and foremost, advance disclosure gives rise to markets that are informationally more efficient. This enhanced efficiency has far-reaching consequences and impacts many other equilibrium attributes. Since greater market efficiency means that there is less uncertainty surrounding the intrinsic value of assets, prices are higher and risk premiums are smaller, on average, in a market with advance disclosure. At the same time, prices are more volatile because a greater amount of information is conveyed to the market and incorporated into prices. Markets also tend to be more liquid with advance disclosure since the increased efficiency makes stock prices less susceptible to fluctuations in liquidity trades.

Additionally, the enhanced efficiency brought about by advance disclosure impacts the extent to which insiders can profit by trading on the basis of their private information, which in turn has a few ramifications of its own. Since the manager of the firm is indirectly compensated through her insider trading profits, altering the regulatory environment to require advance disclosure necessitates an adjustment to the manager's compensation package if her ex ante level of expected utility is to be maintained. We therefore endogenize the manager's compensation package and find that it has a higher market value in equilibrium with advance disclosure, which suggests that insider trading profits comprise a substantial portion of managerial compensation. Moreover, changing the manager's compensation package affects her incentives to undertake individually costly actions that enhance firm value. In equilibrium, we observe that advance disclosure results in a lower level of

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[3] Our results should be viewed with the caveat that we analyze only a linear equilibrium in a static environment.

managerial effort, on average, but gives rise to larger effort Sharpe ratios. The diminished ability of the manager to earn insider trading profits also lowers her incentive to undertake excessively risky projects. Without advance disclosure, the manager may find it beneficial to take on overly risky projects for the purpose of creating additional private information on which she can trade. However, advance disclosure severely reduces the incentive to do so because far less profit is earned by trading on the private information.

Furthermore, advance disclosure affects the equilibrium allocations and welfare of insiders as well as individual investors. We find that investors tend to hold more stock in equilibrium while insiders tend to hold less. We also observe that advance disclosure leads to greater ex ante expected utility for investors but reduced ex ante expected utility for insiders other than the manager. The manager's expected utility is unaltered in equilibrium because her compensation package is adjusted.[4] Lastly, we find that insiders will not voluntarily commit to provide advance disclosure of their trading activity.

Our model differs from many of the extant models in the disclosure literature which utilize a framework similar to that of Kyle (1985). In a typical Kyle model, there is an insider who possesses private information, liquidity traders, and a market maker who infers a portion of the insider's private information after observing order quantities submitted by both the insider and liquidity traders. Since these types of models do not include a rational counter-party with whom the insider trades, they tend to focus on prices, liquidity, and the insider's trading profits. For example, in the only other existing economic model of advance disclosure of an informed insider's trades,[5] to the best of our knowledge, Huddart, Hughes, and Williams (2010) examine the impact of pre-announcement of an insider's trades in a Kyle environment. Like us, they find that markets are more efficient with advance disclosure, that insiders' welfare falls when they must provide advance disclosure, and that insiders will not voluntarily commit to provide advance disclosure of their trading activity. Their model, however, is silent regarding many of the equilibrium attributes that we study, including investor welfare, asset allocations, managerial compensation, managerial effort, and the incentive for managers to undertake risky projects. In related work, Huddart, Hughes, and Levine (2001) evaluate the effect of current regulations that require certain insiders to disclose their trades within a short period of time after any transactions occur. Over a longer time horizon, the authors find that post-announcement leads to more efficient prices, greater liquidity, and smaller insider trading profits relative to a setting where insiders trade without any disclosure. Empirically, Cohen, Malloy, and Pomorski (2012) report that insiders do in fact opportunistically trade on private information.

While not all models in the insider trading literature utilize a Kyle framework, most assume that insiders trade strategically rather than competitively (e.g., Bhattacharya and Spiegel (1991), Leland (1992), and Spiegel and Subrahmanyam (1992), but cf. Ausubel (1990)). This approach undoubtedly is appropriate for situations where a single insider possesses private information, but there are liable to be many cases where several individuals possess private information. After all, business is not conducted in a vacuum. When there are a handful of insiders, they lose their ability to strategically control prices and the amount of information conveyed to the rest of the market

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[4]Since we do not adjust the endowment of the other insiders in response to an advance disclosure requirement, we are able to evaluate the impact of advance disclosure on insiders whose utility is permitted to vary under different regulatory regimes. In reality, there are likely to be many cases where altering an insider's compensation package is either impracticable or, if the insider lacks sufficient bargaining power, unnecessary. For example, Babenko and Sen (2011) document that non-executive employees are able to profit from information that they possess about the firms by which they are employed.

[5]There are other models that explore the pre-announcement of trade by an uninformed investor. These include, for example, sunshine trading where uninformed liquidity traders pre-announce their trades (Admati and Pfleiderer (1991)) and trades conducted under SEC Rule 10b5-1 (Jagolinzer (2009)).

through their trades. That is, they must behave like price-takers as well as information-takers. Our model explores this understudied perspective and assumes that insiders behave competitively.

The remainder of the paper is organized as follows. In Section 3.2, we derive analytical solutions for equilibrium prices and allocations in two separate regulatory environments—one in which insiders must provide advance disclosure of their trading activity and one in which they trade without disclosure. We also obtain analytical expressions for an optimal compensation package in these two settings, thereby providing some insights into how advance disclosure may indirectly impact firm value through changes in the incentive structure. Unfortunately, our solutions are not readily interpretable, so we resort to a numerical analysis, which we present in Section 3.3. Finally, Section 3.4 concludes.

3.2   Model

Time is discrete and indexed by $t \in \{0, 1, 2\}$. For convenience, we sometimes refer to the interval between $t = 0$ and $t = 1$ as the first period and the interval between $t = 1$ and $t = 2$ as the second period. The economy is comprised of a single firm and three types of rational agents—a single firm manager, a continuum of identical investors with mass N_i, and a continuum of identical directors with mass N_d—plus liquidity traders. Along with the manager, directors are considered "insiders" because they are privy to information that is unobservable to investors, and their presence ensures the equilibrium will be competitive in nature.[6] At $t = 0$, the manager is hired to run the firm for two periods until $t = 2$, at which time the firm liquidates and distributes its assets to its shareholders.

There are two types of financial assets in the economy—a risky stock and a sequence of one-period riskless bonds. Each one-period bond, which is in elastic supply, has an exogenous interest rate equal to zero. Thus, a bond purchased at time t pays one unit at $t+1$.[7] The stock, which is in unit supply, represents a claim on equity in the firm. The manager can influence the profitability of the firm, and hence the stock payoff, by undertaking some action $A_t \in \mathbb{R}^+$, which is unobservable to the other agents, during each of the two periods. The stock does not pay any dividends, but it provides a terminal payoff, $\tilde{Y}$, at $t = 2$ that depends linearly on managerial action and two independent and normally distributed random variables, $\tilde{X}_t \sim \mathcal{N}(\mu_t, \sigma_t^2)$ for $t = 1, 2$. Specifically,

$$\tilde{Y} \equiv \theta(A_1 + A_2) + \tilde{X}_1 + \tilde{X}_2, \tag{3.1}$$

where $\theta \in \left[0, \sqrt{\gamma \sigma_2^2}\right)$ is an exogenous parameter that affects the impact of managerial action. The restriction on the admissible values for θ ensures that managerial action neither destroys firm value nor trivializes the risk associated with holding the stock. The equilibrium price of the stock at $t = 1$ is endogenous and denoted by P.

All agents obtain utility solely from the consumption of the payoff from financial assets. Consumption occurs at $t = 1, 2$, and agents exhibit identical time-additive-separable preferences characterized by constant absolute risk aversion, with γ denoting the coefficient of risk aversion. Additionally, the manager incurs a cost $\psi(A_t)$ at time t for undertaking action A_t, where for simplicity we define

$$\psi(A_t) \equiv \tfrac{1}{2} A_t^2. \tag{3.2}$$

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[6]We use the term "director" to include members of the board of directors as well as other members of senior management who possess private information. Since their existence means that there is a continuum of individuals who possess private information, all insiders must behave competitively rather than strategically when trading.

[7]While in principle the model can accommodate a non-zero interest, this assumption greatly enhances the tractability and computational efficiency of the model.

This cost is modeled as a monetary cost and is incorporated into the manager's utility function. We further assume that the preferences and cost function are common knowledge.

Each director receives an identical exogenous endowment of stock and bonds at $t = 0$, which we denote by S_0^d and B_0^d, respectively. Similarly, each investor receives an identical exogenous endowment of stock, $S_e^i \equiv \left(1 - N_d S_0^d\right)/N_i$, and bonds, B_e^i. A portion of each investor's endowment is assigned to the manager as compensation while the remaining amount is retained in a personal portfolio until trading occurs at $t = 1$. The manager, on the other hand, is not endowed with any financial assets. Instead, she obtains her wealth by managing the firm and is compensated with a mixture of stock and bonds pursuant to a management contract, the details of which are discussed below. The quantity of stock and bonds held by an agent of type ℓ from time t to $t + 1$ is denoted by S_t^ℓ and B_t^ℓ, respectively, for $\ell \in \{m, d, i\}$, where m denotes the manager, d denotes directors, and i denotes investors.

Under the management contract, the manager is granted S_0^m shares of stock and B_0^m bonds at time zero. The parameters of the contract—S_0^m and B_0^m—are endogenously chosen by investors, but the contract must satisfy the manager's reservation utility, U, which represents an outside option for the manager.[8] The manager is free to trade both assets in the financial market at $t = 1$. Later in this section, we consider two different regulatory schemes—one in which the manager and directors must provide advance disclosure of their trading activity and one in which they trade without disclosure. When advance disclosure is required, prior to observing the stock price the manager and directors must commit to a particular stock trading activity, i.e., submit a non-cancellable "market order," that they are obliged to disclose to the market before trading occurs at $t = 1$. Conversely, in the absence of advance disclosure, the manager and directors determine their trading strategies after observing the stock price a la Grossman and Stiglitz (1980). In either case, neither the manager nor directors can both purchase and sell stock at $t = 1$.[9] Note that the optimal choice for the parameters of the management contract will depend on whether advance disclosure is required.

At the end of the first period, the manager and directors acquire an information advantage over investors that stems from their relationships with the firm. In particular, they observe the realization of $\tilde{X}_1$ while investors do not. By permitting the manager and directors to trade at $t = 1$, however, investors can infer a conditional distribution of $\tilde{X}_1$ from either the equilibrium stock price or the advance disclosure of the insiders' trading activity. To avoid fully revealing equilibria, we assume that at $t = 1$ liquidity traders demand a stochastic and unobservable quantity of stock, $\tilde{k} \sim \mathcal{N}\left(0, \sigma_k^2\right)$. Furthermore, during the first period the manager and directors receive a private signal of these liquidity trades,[10]

$$\tilde{h}_m \equiv \tilde{k} + \tilde{\varepsilon}_m, \tag{3.3}$$

while investors observe a different private signal,

$$\tilde{h}_i \equiv \tilde{k} + \tilde{\varepsilon}_i, \tag{3.4}$$

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[8]For simplicity, we assume that the manager cannot retire after one period and that the contract cannot be renegotiated.

[9]Pursuant to §16 of the Securities Exchange Act of 1934, corporate executives and directors must disclose to the SEC all personal trading of stock in their firm and may be required to forfeit any profit earned as a result of a combined purchase and sale within a six month period.

[10]All insiders receive an identical signal distinct from the signal observed by investors. The difference between the observed signals could arise from, for example, access to information within the firm that foreshadows macroeconomic conditions but does not affect firm profitability. While this assumption conveniently adds an additional layer of noise which prevents the equilibrium with advance disclosure from being fully revealing, it is not required for our analysis. Alternatively, the additional layer of noise could arise from, say, endowment shocks or perquisites that are correlated with the profitability of the firm.

where $\tilde{\varepsilon}_m$ and $\tilde{\varepsilon}_i$ are independent and identically normally distributed with zero mean and variance σ_ε^2. Conditional on their noisy signals, agents revise their beliefs about the extent of liquidity trading and arrive at a posterior distribution of liquidity trades equal to

$$\tilde{k}|h_\ell \sim \mathcal{N}\left(\frac{h_\ell \sigma_k^2}{\sigma_k^2 + \sigma_\varepsilon^2},\ \frac{\sigma_k^2 \sigma_\varepsilon^2}{\sigma_k^2 + \sigma_\varepsilon^2}\right) \tag{3.5}$$

for $\ell \in \{m, i\}$, which follows from Bayesian updating. Finally, we assume that $\tilde{X}_1$, $\tilde{X}_2$, $\tilde{k}$, $\tilde{\varepsilon}_m$, and $\tilde{\varepsilon}_i$ are mutually independent.

The sequence of events is as follows. At $t = 0$, investors receive their endowments. They then offer a management contract to the manager, and we assume that the manager will accept provided that her reservation utility is satisfied. Directors also disclose their stock holdings at this time, as required by current law.[11] During the first period, the manager undertakes action A_1, for which she incurs a cost, $\psi(A_1)$, and the values of the first random component of the stock payoff, X_1, and the signal of the liquidity trades, h_m, are realized, at which time they are observed by the manager and directors but not by investors. At the same time, investors privately observe h_i. At $t = 1$, trading in the financial market occurs. If advance disclosure is required, the manager and directors must commit to and disclose their stock trading activity before trading takes place. The parties then consume a portion of their wealth. During the second period, the manager undertakes action A_2, for which she incurs a cost, $\psi(A_2)$. Finally, at $t = 2$, the second random component of the stock payoff, X_2, is realized, the portfolios are liquidated, and the agents consume their remaining wealth.

3.2.1 No Advance Disclosure of Trading

We first derive an equilibrium in the absence of advance disclosure. Although trading on the basis of material non-public information is illegal in some cases, we feel that a market in which insiders trade freely on their private information is an appropriate benchmark because: (i) insider trading restrictions are notoriously difficult to enforce; (ii) insiders can legally trade on private information that is not material; and (iii) according to DeMarzo, Fishman, and Hagerty (1998), legalizing a limited amount of insider trading is socially optimal. Without advance disclosure, the model is akin to Grossman and Stiglitz (1980) except that we incorporate a signal of the liquidity trades and the effects of managerial action on firm value. Nevertheless, characterizing an equilibrium and optimal compensation contract in this setting provides a useful point of reference for evaluating the impact of advance disclosure.

Equilibrium Without Advance Disclosure of Trading

To maintain tractability, we assume that the stock price is a linear function of the manager's private information, X_1, and the stochastic liquidity trades, k. The following theorem characterizes an equilibrium in the absence of advance disclosure.

Theorem 1. *Without advance disclosure of trading, there exists a partially revealing rational ex-*

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[11]Section 16 of the Securities Exchange Act of 1934, as amended by the Sarbanes-Oxley Act of 2002, mandates that directors and officers disclose any changes in their stock ownership within two business days.

pectations equilibrium in which the stock price and allocations are given by

$$P = \lambda_1 + \lambda_2(X_1 + \omega k) + \lambda_3 h_i \tag{3.6}$$

$$S_1^i = \frac{1}{\Gamma_6}\left[-(1 + N_d)\Gamma_2\left(\omega(X_1 + \omega k - \mu_1) - \frac{\sigma_1^2}{\sigma_\varepsilon^2}h_i\right) + \Gamma_3\right] \tag{3.7}$$

$$S_1^m = \frac{1}{\Gamma_6}\left[N_i\Gamma_2\left(\omega(X_1 - \mu_1) + \frac{\sigma_1^2}{\sigma_\varepsilon^2}h_i\right) - \Gamma_5 k + \Gamma_4\right] \tag{3.8}$$

$$S_1^d = S_1^m, \tag{3.9}$$

where

$$\lambda_1 \equiv \theta A_1 + \mu_2 + \frac{1}{\Gamma_6}(N_i\Gamma_2\omega\mu_1 + \Gamma_4)\left(\gamma\sigma_2^2 - \theta\right)$$

$$\lambda_2 \equiv \frac{\Gamma_5}{\Gamma_6}(1 + N_d)$$

$$\lambda_3 \equiv -\frac{N_i\Gamma_2\sigma_1^2\left(\gamma\sigma_2^2 - \theta^2\right)}{\Gamma_6\sigma_\varepsilon^2}$$

$$\omega \equiv \frac{\gamma\sigma_2^2 - \theta^2}{1 + N_d} \tag{3.10}$$

$$\begin{array}{ll}
\Gamma_1 \equiv \sigma_1^2\left(\sigma_k^2 + \sigma_\varepsilon^2\right)\left(\gamma\sigma_2^2 - \theta^2\right) & \Gamma_4 \equiv \Gamma_3 + \omega^2\gamma^2\sigma_1^2\sigma_2^2\sigma_k^2\sigma_\varepsilon^2 \\
\Gamma_2 \equiv \omega\sigma_k^2\sigma_\varepsilon^2\left(\gamma\sigma_2^2 - \theta^2\right) & \Gamma_5 \equiv N_i\omega\Gamma_1 + \Gamma_4 \\
\Gamma_3 \equiv (\Gamma_1 + \omega\Gamma_2)\left(\gamma\sigma_2^2 - \theta^2\right) & \Gamma_6 \equiv (1 + N_d)\Gamma_4 + N_i\Gamma_3.
\end{array}$$

The remaining portion of this subsection describes the derivation of the equilibrium, which results from the utility-maximizing objectives of the agents. Note that all agents behave like price-takers because there is a continuum of both outsiders (investors) and insiders (the manager and directors). Consequently, the equilibrium is competitive. We proceed by first deriving the stock demand functions for the manager, directors, and investors. We then aggregate these demands with liquidity trades to obtain an equilibrium price.

The manager's problem at $t = 1$ is fairly standard. She observes the first component of the stock payoff, X_1, as well as the stock price, P, and she chooses her portfolio composition and level of action, A_2. The liquidity trades, k, and the private signals, h_m and h_i, are not pertinent to her decisions because the manager need not make any inferences about unobservable variables. As a result, the only relevant uncertainty she faces is with respect to $\tilde{X}_2$. The manager's objective, therefore, is to maximize her expected utility from consumption, C_t^m for $t = 1, 2$, by selecting a portfolio and action level:

$$\max_{A_2, S_1^m, B_1^m} \quad \mathbb{E}\left[u\left(C_1^m\right) + \beta u\left(\tilde{C}_2^m\right) \mid X_1\right] \tag{3.11}$$

subject to

$$C_1^m = S_0^m P + B_0^m - \left(S_1^m P + B_1^m\right) - \psi(A_1) \tag{3.12}$$

$$\tilde{C}_2^m = S_1^m \tilde{Y} + B_1^m - \psi(A_2), \tag{3.13}$$

where $\mathbb{E}$ is the expectation operator, $u(\cdot)$ is the utility function, and β is a time preference parameter.[12] Equating the manager's expected marginal utility from consumption across dates by adjusting her bond holdings allows her objective function to be rewritten in closed form as

$$\max_{A_2, S_1^m} \quad -2\sqrt{\beta}\exp\Big[-\tfrac{1}{2}\gamma\Big(S_1^m\big(\theta(A_1 + A_2) + X_1 + \mu_2 - P\big)$$
$$+ S_0^m P + B_0^m - \tfrac{1}{2}\big(A_1^2 + A_2^2 + \gamma(S_1^m)^2\sigma_2^2\big)\Big)\Big] \quad (3.14)$$

after substituting (3.1), (3.2), (3.12), and (3.13) into (3.11) and integrating with respect to $\tilde{X}_2$. Then, the first-order conditions can be solved to obtain the manager's optimal action strategy,

$$A_2 = \theta S_1^m, \quad (3.15)$$

and demand function,

$$S_1^m = \frac{\theta A_1 + X_1 + \mu_2 - P}{\gamma\sigma_2^2 - \theta^2}, \quad (3.16)$$

which depends on her private information.

Directors face a problem similar to that of the manager because they also observe the first component of the stock payoff in addition to the stock price. However, directors do not undertake any actions to influence firm value. Since preferences are common knowledge, though, directors can deduce the manager's action strategy and demand function, which they take into account when selecting a portfolio to maximize their expected utility from consumption, C_t^d for $t = 1, 2$. It follows that each director's objective is:

$$\max_{S_1^d, B_1^d} \quad \mathbb{E}\big[u\big(C_1^d\big) + \beta u\big(\tilde{C}_2^d\big) \mid X_1\big] \quad (3.17)$$

subject to

$$C_1^d = S_0^d P + B_0^d - \big(S_1^d P + B_1^d\big) \quad (3.18)$$
$$\tilde{C}_2^d = S_1^d \tilde{Y} + B_1^d \quad (3.19)$$

and (3.15) and (3.16). Substituting (3.1), (3.15), (3.18), and (3.19) into (3.17), integrating the resulting expression with respect to $\tilde{X}_2$, and equating marginal utility from consumption across dates by adjusting the bond holdings, the objective function can be rewritten in closed form as

$$\max_{S_1^d} -2\sqrt{\beta}\exp\Big[-\tfrac{1}{2}\gamma\Big(S_1^d\big(\theta A_1 + \theta^2 S_1^m + X_1 + \mu_2 - P\big) + S_0^d P + B_0^d - \tfrac{1}{2}\gamma\big(S_1^d\big)^2\sigma_2^2\Big)\Big]. \quad (3.20)$$

Substituting the manager's demand function, (3.16), into the first-order condition of this expression provides the director's demand function,

$$S_1^d = \frac{\theta A_1 + X_1 + \mu_2 - P}{\gamma\sigma_2^2 - \theta^2}, \quad (3.21)$$

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[12]Section 16 of the Securities Exchange Act of 1934 prohibits corporate executives and directors from taking a short position in any security issued by the firm that they manage. As a consequence, the manager technically should face an additional constraint when choosing her optimal portfolio: $S_1^m \geq 0$. However, we ignore this constraint to maintain tractability and calibrate the model so that the manager never actually takes a short position in the simulation in Section 3.3. This qualification applies to all of the manager's and directors' optimization problems contained in this article, but it does not pertain to investors.

which is identical to that of the manager. This equivalence results from the identical preferences and information sets of the agents.

While the optimization problems for the manager and directors are fairly straightforward, investors face a more intricate problem because they do not directly observe the private information, although they can deduce the manager's action strategy and demand function since preferences are common knowledge. However, because investors do not directly observe X_1, they cannot deduce the precise level of action that the manager will undertake during the second period. Given a price, though, they can infer a distribution of that action level. As mentioned above, we restrict the stock price to be a linear function of X_1 and k. Specifically, we assume that P is a linear function of

$$q \equiv X_1 + \omega k,$$

where ω is given by (3.10). Because k is unobservable, the stock price serves as a noisy signal of X_1 but does not fully reveal its value. Nonetheless, after observing q through P, investors can update their beliefs about $\tilde{X}_1$ in a Bayesian fashion to form a posterior distribution of the private information,

$$\tilde{X}_1 | P \sim \mathcal{N}\left(\frac{\left(\omega \mu_1 \sigma_\varepsilon^2 - h_i \sigma_1^2\right) \omega \sigma_k^2 + q \sigma_1^2 \left(\sigma_k^2 + \sigma_\varepsilon^2\right)}{\omega^2 \sigma_k^2 \sigma_\varepsilon^2 + \sigma_1^2 \left(\sigma_k^2 + \sigma_\varepsilon^2\right)} , \frac{\omega^2 \sigma_1^2 \sigma_k^2 \sigma_\varepsilon^2}{\omega^2 \sigma_k^2 \sigma_\varepsilon^2 + \sigma_1^2 \left(\sigma_k^2 + \sigma_\varepsilon^2\right)} \right). \tag{3.22}$$

Given their updated beliefs about $\tilde{X}_1$, investors can infer a conditional distribution of A_2. As a result, each investor faces uncertainty with respect to $\tilde{X}_1$ and $\tilde{X}_2$, and their objective is to maximize expected utility from consumption, C_t^i for $t = 1, 2$, by choosing a portfolio of stock and bonds:

$$\max_{S_1^i, B_1^i} \quad \mathbb{E}\left[u\left(C_1^i\right) + \beta u\left(\tilde{C}_2^i\right) \mid P \right] \tag{3.23}$$

subject to

$$C_1^i = S_0^i P + B_0^i - \left(S_1^i P + B_1^i\right) \tag{3.24}$$

$$\tilde{C}_2^i = S_1^i \tilde{Y} + B_1^i \tag{3.25}$$

as well as (3.15) and (3.16). Since $\tilde{X}_2$ and $\tilde{X}_1 | P$ are both normally distributed, the objective function can be rewritten in closed form as

$$\max_{S_1^i} \quad -2\sqrt{\beta} \exp\left[-\frac{1}{2}\gamma \left(\frac{S_1^i \left(\theta A_1 + \mathbb{E}\left[\tilde{X}_1 | P\right] + \mu_2 - P\right) \gamma \sigma_2^2}{\gamma \sigma_2^2 - \theta^2} \right. \right.$$

$$\left. \left. + S_0^i P + B_0^i - \frac{1}{2}\gamma \left(S_1^i\right)^2 \sigma_2^2 \left(1 + \frac{\gamma^2 \mathbb{V}\left[\tilde{X}_1 | P\right] \sigma_2^2}{\left(\gamma \sigma_2^2 - \theta^2\right)^2}\right)\right)\right], \tag{3.26}$$

where $\mathbb{V}$ is the variance operator, after substituting (3.1), (3.15), (3.16), (3.24), and (3.25) into (3.23), integrating with respect to $\tilde{X}_1$ and $\tilde{X}_2$, and adjusting the investor's bond holdings so that his expected marginal utility is constant over time. Each investor's demand function then is obtained by solving the first-order condition of his maximization problem, yielding

$$S_1^i = \frac{\left(\theta A_1 + \mathbb{E}\left[\tilde{X}_1 | P\right] + \mu_2 - P\right)\left(\gamma \sigma_2^2 - \theta^2\right)}{\gamma^2 \mathbb{V}\left[\tilde{X}_1 | P\right] \sigma_2^2 + \left(\gamma \sigma_2^2 - \theta^2\right)^2}. \tag{3.27}$$

The market-clearing condition requires that aggregate demand equals supply: $S_1^m + N_d S_1^d + N_i S_1^i + k = 1$. Enforcing this condition provides the equilibrium stock price, which is given by

(3.6) in Theorem 1. A quick glance at the stock price confirms our assumption that it is a linear function of q. Finally, substituting the appropriate expressions for $\mathbb{E}[\tilde{X}_1|P]$, $\mathbb{V}[\tilde{X}_1|P]$, and (3.6) into (3.27) as well as (3.6) into (3.16) and (3.21) provides the respective stock holdings for investors, the manager, and directors, which are given by (3.7), (3.8), and (3.9).

Optimal Compensation Without Advance Disclosure of Trading

As mentioned above, the manager is granted a package of stock and bonds as compensation for managing the firm. The parameters of the compensation package—S_0^m and B_0^m—are optimally chosen by investors to maximize their expected utility while providing the manager with her reservation utility. In this section, we describe our derivation of the contract parameters. Although analytical solutions for S_0^m and B_0^m are attainable, they are not readily interpretable. Therefore, we present our results numerically in Section 3.3 instead of reporting analytical expressions for the optimal contract parameters.

Our first step is to determine the manager's expected utility at $t = 0$, conditional on a portfolio and action level, which we find by substituting (3.4), (3.6), and (3.8) into (3.14), yielding

$$\mathbb{E}\left[-\exp\left[-\tfrac{1}{2}\gamma\left(B_0^m + S_0^m\left(\delta_1^m\tilde{X}_1 + \delta_2^m\tilde{k} + \delta_3^m\tilde{\varepsilon}_i + \theta A_1 + \delta_4^m\right) + \delta_5^m\tilde{X}_1^2 + \delta_6^m\tilde{k}^2\right.\right.\right.$$
$$\left.\left.\left. + \delta_7^m\tilde{\varepsilon}_i^2 + \delta_8^m\tilde{X}_1\tilde{k} + \delta_9^m\tilde{X}_1\tilde{\varepsilon}_i + \delta_{10}^m\tilde{k}\tilde{\varepsilon}_i + \delta_{11}^m\tilde{X}_1 + \delta_{12}^m\tilde{k} + \delta_{13}^m\tilde{\varepsilon}_i + \delta_{14}^m - \tfrac{1}{2}A_1^2\right)\right]\right], \quad (3.28)$$

where δ_j^m for $j = 1, \ldots, 14$ are constants.[13] After integrating (3.28) over $\tilde{X}_1$, $\tilde{k}$, and $\tilde{\varepsilon}_i$ using symbolic computational methods,[14] the manager's optimal action strategy is obtained by solving her first-order condition with respect to A_1, giving

$$A_1 = \theta S_0^m. \tag{3.29}$$

Substituting this action strategy back into the integrated expression provides the manager's expected utility at $t = 0$, which also serves as her participation constraint in the contracting problem and is displayed on the left hand side of (3.32) below.

The ex ante expected utility for an investor is derived in a similar fashion. We first substitute (3.4), (3.6), (3.7), and (3.29) into (3.26). Because the stock price depends on S_0^m, we also substitute the market-clearing condition, $S_0^m = 1 - N_d S_0^d - N_i S_0^i$, so that the investor's expected utility can be written independently of the manager's initial stock allocation. This gives

$$\mathbb{E}\left[-\exp\left[-\tfrac{1}{2}\gamma\left(B_0^i + S_0^i\left(\delta_1^i\tilde{X}_1 + \delta_2^i\tilde{k} + \delta_3^i\tilde{\varepsilon}_i + \delta_4^i S_0^i + \delta_5^i\right) + \delta_6^i\tilde{X}_1^2 + \delta_7^i\tilde{k}^2\right.\right.\right.$$
$$\left.\left.\left. + \delta_8^i\tilde{\varepsilon}_i^2 + \delta_9^i\tilde{X}_1\tilde{k} + \delta_{10}^i\tilde{X}_1\tilde{\varepsilon}_i + \delta_{11}^i\tilde{k}\tilde{\varepsilon}_i + \delta_{12}^i\tilde{X}_1 + \delta_{13}^i\tilde{k} + \delta_{14}^i\tilde{\varepsilon}_i + \delta_{15}^m\right)\right]\right], \quad (3.30)$$

where δ_j^i for $j = 1, \ldots, 15$ are constants. We then integrate over $\tilde{X}_1$, $\tilde{k}$, and $\tilde{\varepsilon}_i$ to obtain a closed-form expression for the investor's expected utility, which serves as the investor's objective function in the contracting problem and is displayed in (3.31) below.

The contracting problem is relatively simple. Investors select a portfolio of stock and bonds to maximize their expected utility subject to satisfying the manager's reservation utility:

$$\max_{S_0^i, B_0^i} \quad -\exp\left[-\tfrac{1}{2}\gamma\left(B_0^i + \varphi_1^i\left(S_0^i\right)^2 + \varphi_2^i S_0^i + \varphi_3^i\right)\right] \tag{3.31}$$

---

[13] The expressions for these coefficients, as well as the analogous coefficients in equations (3.30), (3.31), (3.32), (3.59), (3.61), (3.62), and (3.63), are not reported but are available upon request.

[14] $\int_{-\infty}^{\infty} e^{-ax^2 - 2bx} dx = \sqrt{\tfrac{\pi}{a}} e^{\frac{b^2}{a}}$ if $a > 0$. The restriction on the admissible values for θ is a sufficient condition to satisfy this inequality.

subject to

$$-\exp\left[-\tfrac{1}{2}\gamma\left(B_0^m + \varphi_1^m\left(S_0^m\right)^2 + \varphi_2^m S_0^m + \varphi_3^m\right)\right] \geq U, \tag{3.32}$$

where φ_j^i and φ_j^m for $j = 1, \ldots, 3$ are constants. To solve this problem we invoke the asset supply constraints. Since the aggregate stock holdings at $t = 0$ must sum to one and the number of bonds held by the manager and investors must equal $N_i B_e^i$, we can substitute $S_0^m = 1 - N_d S_0^d - N_i S_0^i$ and $B_0^m = N_i(B_e - B_0^i)$ into (3.32), which provides an expression for B_0^i after a bit of algebra. Substituting this expression for B_0^i into (3.31) and solving the corresponding first-order condition provides an investor's utility-maximizing choice of S_0^i. Finally, plugging this value back into the manager's participation constraint gives an investor's utility-maximizing choice of B_0^i. The contract parameter—S_0^m and B_0^m—follow immediately from the asset supply constraints. We present numerical results in Section 3.3.

3.2.2 Advance Disclosure of Trading

We now investigate the impact of advance disclosure. With advance disclosure, investors can infer a noisy signal of X_1 based on the disclosed stock trading activity of the manager and directors. Unlike the case without advance disclosure, the stock price is determined by investors and contains no additional information about X_1. In this section, we derive an equilibrium price and allocations when advance disclosure is required. The notation is the same as above, except that a circumflex (^) is added to some variables to distinguish them from the setting without advance disclosure.

Equilibrium With Advance Disclosure of Trading

To maintain tractability, we assume that the equilibrium stock price is a linear function of the first random component of the stock payoff, X_1, the stochastic liquidity trades, k, and the insiders' private signal of the liquidity trades, h_m. The following theorem characterizes an equilibrium when advance disclosure is required.

Theorem 2. *With advance disclosure of trading, there exists a partially revealing rational expectations equilibrium in which the stock price and allocations are given by*

$$\hat{P} = \hat{\lambda}_1 + \hat{\lambda}_2(X_1 + \rho h_m) + \hat{\lambda}_3 k \tag{3.33}$$

$$\hat{S}_1^i = \frac{1}{\hat{\Gamma}_2}\left[\left(\sigma_1^2 + \rho^2\sigma_\varepsilon^2\right)\left(\theta\hat{A}_1 + \hat{S}_1^m\theta^2 + \mu_2 - \hat{P}\right) + \sigma_1^2\left(X_1 + \rho(h_m - k)\right) + \mu_1\rho^2\sigma_\varepsilon^2\right], \tag{3.34}$$

$$\hat{S}_1^m = \frac{2}{\hat{\Gamma}_3}\left[\left(\sigma_k^2 + \sigma_\varepsilon^2\right)\left(\theta\hat{A}_1 + \left(1 - \hat{\lambda}_2\right)(X_1 + \rho h_m) + \mu_2 - \hat{\lambda}_1\right) + \tfrac{1}{2}\gamma\hat{\lambda}_3^2\sigma_k^2\sigma_\varepsilon^2\hat{S}_0^m\right] \tag{3.35}$$

$$\hat{S}_1^d = \hat{S}_1^m + \frac{1}{\hat{\Gamma}_1}\left[\left(\hat{S}_0^d - \hat{S}_0^m\right)\hat{\lambda}_3^2\sigma_k^2\sigma_\varepsilon^2\right] \tag{3.36}$$

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where

$$\hat{\lambda}_1 \equiv \theta \hat{A}_1 + \mu_2 + \frac{1}{\hat{\Gamma}_1 \hat{\Gamma}_4} \Big[\hat{\lambda}_3^2 \sigma_k^2 \sigma_\varepsilon^2 \big((\hat{\Gamma}_4 - 2(\sigma_k^2 + \sigma_\varepsilon^2) \hat{\Gamma}_2) \theta^2 + \gamma \hat{\Gamma}_1 \hat{\Gamma}_2 \big) \hat{S}_0^m$$

$$+ N_i \hat{\Gamma}_1 \hat{\Gamma}_3 \rho^2 \sigma_\varepsilon^2 \mu_1 - \hat{\Gamma}_2 \hat{\Gamma}_3 \big(1 - N_d \hat{\lambda}_3^2 \sigma_k^2 \sigma_\varepsilon^2 \hat{S}_0^d \big) \Big]$$

$$\hat{\lambda}_2 \equiv \frac{2}{\hat{\Gamma}_4} \Big[\tfrac{1}{2} \gamma N_i \sigma_1^2 \hat{\Gamma}_1 + N_i \rho^2 \sigma_\varepsilon^2 (\sigma_k^2 + \sigma_\varepsilon^2) \theta^2 + (1 + N_d)(\sigma_k^2 + \sigma_\varepsilon^2) \hat{\Gamma}_2 \Big]$$

$$\hat{\lambda}_3 \equiv \frac{\hat{\Gamma}_2 - N_i \rho \sigma_1^2}{N_i (\sigma_1^2 + \rho^2 \sigma_\varepsilon^2)}$$

$$\rho \equiv -\frac{\hat{\lambda}_3 \sigma_k^2}{\sigma_k^2 + \sigma_\varepsilon^2} \tag{3.37}$$

$$\hat{\Gamma}_1 \equiv \hat{\lambda}_3^2 \sigma_k^2 \sigma_\varepsilon^2 + 2(\sigma_k^2 + \sigma_\varepsilon^2) \sigma_2^2 \qquad\qquad \hat{\Gamma}_3 \equiv \gamma \hat{\Gamma}_1 - 2(\sigma_k^2 + \sigma_\varepsilon^2) \theta^2$$

$$\hat{\Gamma}_2 \equiv \gamma \big(\sigma_1^2 \sigma_2^2 + \rho^2 (\sigma_1^2 + \sigma_2^2) \sigma_\varepsilon^2 \big) \qquad \hat{\Gamma}_4 \equiv \gamma N_i (\sigma_1^2 + \rho^2 \sigma_\varepsilon^2) \hat{\Gamma}_1 + 2(1 + N_d)(\sigma_k^2 + \sigma_\varepsilon^2) \hat{\Gamma}_2.$$

The equilibrium derivation is described in the remaining portion of this subsection. As in the case without advance disclosure, all agents behave competitively. When advance disclosure is required, the manager and directors must commit to a particular stock trading activity prior to observing the stock price, but they need not determine their bond holdings or consumption pattern until after the stock price is observed. Thus, the manager and directors face a sequence of maximization problems, which we now proceed to solve recursively.

Subsequent to observing the stock price, the manager's objective is to maximize her expected utility from consumption by selecting an action level and the quantity of bonds to hold in her portfolio:

$$\max_{\hat{A}_2, \hat{B}_1^m} \quad \mathbb{E}\big[u(\hat{C}_1^m) + \beta u(\tilde{\hat{C}}_2^m) \mid X_1 \big] \tag{3.38}$$

subject to

$$\hat{C}_1^m = \hat{S}_0^m \hat{P} + \hat{B}_0^m - \big(\hat{S}_1^m \hat{P} + \hat{B}_1^m \big) - \psi(\hat{A}_1) \tag{3.39}$$

$$\tilde{\hat{C}}_2^m = \hat{S}_1^m \tilde{\hat{Y}} + \hat{B}_1^m - \psi(\hat{A}_2). \tag{3.40}$$

At this point in time, the only uncertainty the manager faces is with respect to $\tilde{X}_2$. Accordingly, she optimally chooses her bond holdings to equate her expected marginal utility from consumption across dates after substituting (3.1), (3.2), (3.39), and (3.40) into (3.38) and integrating with respect to $\tilde{X}_2$. Carrying out this procedure, her objective function, conditional on $\hat{P}$, can be rewritten in closed form as

$$\max_{\hat{A}_2} \quad -2\sqrt{\beta} \exp\Big[-\tfrac{1}{2}\gamma \Big(\hat{S}_1^m \big(\theta(\hat{A}_1 + \hat{A}_2) + X_1 + \mu_2 - \hat{P} \big)$$

$$+ \hat{S}_0^m \hat{P} + \hat{B}_0^m - \tfrac{1}{2}\big(\hat{A}_1^2 + \hat{A}_2^2 + \gamma (\hat{S}_1^m)^2 \sigma_2^2 \big) \Big) \Big]. \tag{3.41}$$

Solving the first-order condition of this maximization problem gives the manager's optimal action strategy,

$$\hat{A}_2 = \theta \hat{S}_1^m. \tag{3.42}$$

Additionally, directors and investors can deduce this action strategy since preferences are common knowledge.

Because the manager does not observe the stock price before committing to a particular stock trading activity, she must determine her optimal stock holdings based on her beliefs about the distribution of $\hat{P}$. Since the manager observes X_1 and h_m, it follows immediately from (3.5) and (3.33) that, from the manager's perspective,

$$\tilde{\hat{P}}|X_1, h_m \sim \mathcal{N}\left(\hat{\lambda}_1 + \hat{\lambda}_2(X_1 + \rho h_m) + \frac{\hat{\lambda}_3 \sigma_k^2 h_m}{\sigma_k^2 + \sigma_\varepsilon^2}, \frac{\hat{\lambda}_3^2 \sigma_k^2 \sigma_\varepsilon^2}{\sigma_k^2 + \sigma_\varepsilon^2}\right). \tag{3.43}$$

Consequently, the manager's utility is log-normally distributed prior to observing the stock price, and (3.41) can easily be integrated with respect to $\tilde{\hat{P}}$ after substituting (3.42) to obtain a new objective function,

$$\max_{\hat{S}_1^m} \quad -2\sqrt{\beta}\exp\left[-\tfrac{1}{2}\gamma\left(\hat{S}_1^m\left(\theta\hat{A}_1 + \theta^2\hat{S}_1^m + X_1 + \mu_2 - \mathbb{E}\big[\tilde{\hat{P}}|X_1, h_m\big]\right) + \hat{S}_0^m\mathbb{E}\big[\tilde{\hat{P}}|X_1, h_m\big]\right.\right.$$
$$\left.\left. + \hat{B}_0^m - \tfrac{1}{2}\left(\hat{A}_1^2 + \gamma\left(\hat{S}_1^m\right)^2\sigma_2^2 + \tfrac{1}{2}\gamma\left(\hat{S}_1^m - \hat{S}_0^m\right)^2\mathbb{V}\big[\tilde{\hat{P}}|X_1, h_m\big]\right)\right)\right]. \tag{3.44}$$

Finally, solving the first-order condition of this optimization problem provides the manager's stock demand function,

$$\hat{S}_1^m = \frac{\theta\hat{A}_1 + X_1 + \mu_2 - \mathbb{E}\big[\tilde{\hat{P}}|X_1, h_m\big] + \tfrac{1}{2}\gamma\hat{S}_0^m\mathbb{V}\big[\tilde{\hat{P}}|X_1, h_m\big]}{\gamma\left(\sigma_2^2 + \tfrac{1}{2}\mathbb{V}\big[\tilde{\hat{P}}|X_1, h_m\big]\right) - \theta^2}, \tag{3.45}$$

which is similar to her demand function without advance disclosure, except that with advance disclosure her stock demand incorporates the uncertainty surrounding the stock price and depends on her stock holdings during the previous period. Interestingly, the manager's stock demand at $t = 1$, *ceteris paribus*, is proportional to the amount of stock she receives under the management contract at $t = 0$.

The maximization problem for directors is similar to that of the manager. After observing the stock price, each director must choose the quantity of bonds to hold in his portfolio to maximize his expected utility from consumption:

$$\max_{\hat{B}_1^d} \quad \mathbb{E}\big[u\big(\hat{C}_1^d\big) + \beta u\big(\tilde{\hat{C}}_2^d\big) \,|\, X_1\big] \tag{3.46}$$

subject to

$$\hat{C}_1^d = \hat{S}_0^d\hat{P} + \hat{B}_0^d - \big(\hat{S}_1^d\hat{P} + \hat{B}_1^d\big) \tag{3.47}$$

$$\tilde{\hat{C}}_2^d = \hat{S}_1^d\tilde{\hat{Y}} + \hat{B}_1^d. \tag{3.48}$$

In solving this problem, each director equates his expected marginal utility across dates by appropriately choosing his bond holdings after substituting (3.1), (3.42), (3.47), and (3.48) into (3.38) and integrating with respect to $\tilde{X}_2$. Like the manager, directors must determine their optimal stock holdings based on their beliefs about the distribution of $\hat{P}$ since they do not observe the stock price before committing to a particular stock trading activity. Because directors and managers both observe X_1 and h_m, they share the same beliefs about $\tilde{\hat{P}}$, the distribution of which is given by

(3.43). Integrating over $\hat{\tilde{P}}$, the objective function can be rewritten as

$$\max_{\hat{S}_1^d} \quad -2\sqrt{\beta}\exp\Big[-\tfrac{1}{2}\gamma\Big(\hat{S}_1^d\big(\theta\hat{A}_1 + \theta^2\hat{S}_1^m + X_1 + \mu_2 - \mathbb{E}\big[\hat{\tilde{P}}|X_1, h_m\big]\big)$$

$$+ \hat{S}_0^d\mathbb{E}\big[\hat{\tilde{P}}|X_1, h_m\big] + \hat{B}_0^d - \tfrac{1}{2}\gamma\big((\hat{S}_1^d)^2\sigma_2^2 + \tfrac{1}{2}(\hat{S}_1^d - \hat{S}_0^d)^2\mathbb{V}\big[\hat{\tilde{P}}|X_1, h_m\big]\big)\Big)\Big]. \quad (3.49)$$

The demand function for directors,

$$\hat{S}_1^d = \frac{\theta\hat{A}_1 + X_1 + \mu_2 - \mathbb{E}\big[\hat{\tilde{P}}|X_1, h\big] + \tfrac{1}{2}\gamma\hat{S}_0^m\mathbb{V}\big[\hat{\tilde{P}}|X_1, h_m\big]}{\gamma\big(\sigma_2^2 + \tfrac{1}{2}\mathbb{V}\big[\hat{\tilde{P}}|X_1, h_m\big]\big) - \theta^2} + \frac{\tfrac{1}{2}\big(\hat{S}_0^d - \hat{S}_0^m\big)\mathbb{V}\big[\hat{\tilde{P}}|X_1, h\big]}{\sigma_2^2 + \tfrac{1}{2}\mathbb{V}\big[\hat{\tilde{P}}|X_1, h_m\big]}, \quad (3.50)$$

is then derived by substituting the manager's demand function, (3.45), into the corresponding first-order condition, and it equals the manager's demand function plus a term that adjusts for the disparity in price risk faced by the manager and directors. Note that this additional term, conditional on the portfolio holdings at $t = 0$, is constant and independent of X_1, k, and h_m, which means that directors' disclosures do not contain any information in addition to that conveyed by the manager's disclosure.

We now turn to the investors. Although investors do not observe the realization of $\tilde{X}_1$, they are able to infer a conditional distribution of $\tilde{X}_1$ from the insiders' stock trading disclosures, and the mechanism by which this occurs is analogous to their inferences from the equilibrium stock price in the case without advance disclosure. First, note that $\mathbb{E}\big[\hat{\tilde{P}}|X_1, h_m\big]$ is linear in X_1 and h_m, while $\mathbb{V}\big[\hat{\tilde{P}}|X_1, h_m\big]$ is independent of X_1 and h_m. Then, since the insiders' demand functions are linear in X_1 and $\mathbb{E}\big[\hat{\tilde{P}}|X_1, h_m\big]$, it follows that their demand functions are linear in X_1 and h_m. Hence, $\hat{S}_1^m$ and $\hat{S}_1^d$ serve as identical noisy signals of X_1 and can be written as linear functions of

$$r \equiv X_1 + \rho h_m, \quad (3.51)$$

where ρ is a constant whose expression is given by (3.37). After observing r through the insiders' disclosures, investors can use Bayesian updating to revise their beliefs, leading to the following posterior distribution of $\tilde{X}_1$:[15]

$$\tilde{X}_1|k, r \sim \mathcal{N}\left(\frac{\rho^2\mu_1\sigma_\varepsilon^2 + (r - \rho k)\sigma_1^2}{\sigma_1^2 + \rho^2\sigma_\varepsilon^2}, \frac{\rho^2\sigma_1^2\sigma_\varepsilon^2}{\sigma_1^2 + \rho^2\sigma_\varepsilon^2}\right). \quad (3.52)$$

Since preferences are common knowledge and the manager discloses her trading activity, investors can infer the precise value of $\hat{A}_2$, which is given by (3.42). Consequently, similar to the case without advance disclosure, investors face uncertainty only with respect to $\tilde{X}_1$ and $\tilde{X}_2$ at $t = 1$. Hence, each investor's objective is to maximize his expected utility from consumption by selecting a portfolio of stock and bonds:

$$\max_{\hat{S}_1^i, \hat{B}_1^i} \quad \mathbb{E}\big[u\big(\hat{C}_1^i\big) + \beta u\big(\hat{\tilde{C}}_2^i\big) \,|\, k, \hat{S}_1^m\big] \quad (3.53)$$

subject to

$$\hat{C}_1^i = \hat{S}_0^i\hat{P} + \hat{B}_0^i - \big(\hat{S}_1^i\hat{P} + \hat{B}_1^i\big) \quad (3.54)$$

$$\hat{\tilde{C}}_2^i = \hat{S}_1^i\tilde{\tilde{Y}} + \hat{B}_1^i \quad (3.55)$$

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[15]In equilibrium, investors can infer the value of k from the insiders' disclosures and their own demand.

in addition to (3.42) and (3.45). Substituting (3.1), (3.42), (3.54), and (3.55) into (3.53), integrating with respect to $\tilde{X}_1$ and $\tilde{X}_2$, and equating expected marginal utility across dates by adjusting bond holdings allows this objective to be rewritten as

$$\max_{\hat{S}_1^i} \quad -2\sqrt{\beta}\exp\left[-\tfrac{1}{2}\gamma\left(\hat{S}_1^i\left(\theta\hat{A}_1 + \theta^2\hat{S}_1^m + \mathbb{E}\big[\tilde{X}_1|k,\hat{S}_1^m\big] + \mu_2 - \hat{P}\right)\right.\right.$$
$$\left.\left. + \hat{S}_0^i\hat{P} + \hat{B}_0^i - \tfrac{1}{2}\gamma\big(\hat{S}_1^i\big)^2\big(\sigma_2^2 + \mathbb{V}\big[\tilde{X}_1|k,\hat{S}_1^m\big]\big)\right)\right]. \quad (3.56)$$

Solving the first-order condition of this maximization problem provides the demand function for investors,

$$\hat{S}_1^i = \frac{\theta\hat{A}_1 + \theta^2\hat{S}_1^m + \mathbb{E}\big[\tilde{X}_1|k,\hat{S}_1^m\big] + \mu_2 - \hat{P}}{\gamma\big(\sigma_2^2 + \mathbb{V}\big[\tilde{X}_1|k,\hat{S}_1^m\big]\big)}, \quad (3.57)$$

from which the equilibrium stock price is derived.

Since aggregate demand must equal supply and insiders pre-commit to a particular trading activity, the market-clearing condition requires that $N_i\hat{S}_1^i = 1 - \hat{S}_1^m - N_d\hat{S}_1^d - k$. Imposing this condition results in the following expression for the equilibrium stock price:

$$\hat{P} = \theta\hat{A}_1 + \theta^2\hat{S}_1^m + \mathbb{E}\big[\tilde{X}_1|k,\hat{S}_1^m\big] + \mu_2 - \frac{\gamma}{N_i}\big(\sigma_2^2 + \mathbb{V}\big[\tilde{X}_1|k,\hat{S}_1^m\big]\big)\big(1 - \hat{S}_1^m - N_d\hat{S}_1^d - k\big). \quad (3.58)$$

To verify our initial assumption that $\hat{P}$ is linear in X_1, h_m, and k, note that since $\mathbb{V}\big[\tilde{X}_1|k,\hat{S}_1^m\big]$ is independent of X_1, h_m, and k, the stock price is a linear function of $\mathbb{E}\big[\tilde{X}_1|k,\hat{S}_1^m\big]$, $\hat{S}_1^m$, and k. As we argued above, $\hat{S}_1^m$ is a linear function X_1 and h_m, and (3.52) combined with (3.51) demonstrates that $\mathbb{E}\big[\tilde{X}_1|k,\hat{S}_1^m\big]$ is linear in X_1, h_m, and k. Thus, $\hat{P}$ is a linear function of X_1, h_m, and k. The precise values for the coefficients on these parameters are reported in Theorem 2. Only $\hat{\lambda}_1$ is influenced by endogenous variables, $\hat{A}_1$ and $\hat{S}_0^m$. The remaining expressions depend on exogenous parameters, and ρ is the solution to a cubic polynomial.[16] Equilibrium allocations, which are given by (3.35), (3.36), and (3.34), are derived by substituting (3.33) into the respective demand functions.

Optimal Compensation With Advance Disclosure of Trading

Since advance disclosure influences equilibrium prices and allocations as well as the amount of the manager's private information conveyed to the rest of the market, it also affects the extent to which the manager can profit from her private information and hence the distribution of the her utility. As a consequence, the optimal compensation package in the absence of advance disclosure generally will be suboptimal when advance disclosure is required. We therefore derive an optimal compensation package when advance disclosure is required. Like without advance disclosure, the solutions for the optimal contract parameters with advance disclosure are not readily interpretable, so we present our results numerically in Section 3.3.

Derivation of the optimal contract with advance disclosure closely follows the process used to derive the optimal compensation package without advance disclosure. First, the manager's expected utility at $t = 0$, conditional on a portfolio and action level, is found by substituting (3.3), (3.33), (3.42), (3.45), and the appropriate expressions for $\mathbb{E}\big[\tilde{\hat{P}}|X_1,h\big]$ and $\mathbb{V}\big[\tilde{\hat{P}}|X_1,h\big]$ into (3.41), resulting

---

[16]There exists a unique real solution for ρ given our calibration is Section 3.3.

in

$$\mathbb{E}\Big[-\exp\Big[-\tfrac{1}{2}\gamma\Big(\hat{B}_0^m + \hat{S}_0^m\big(\hat{\delta}_1^m \tilde{X}_1 + \hat{\delta}_2^m \tilde{k} + \hat{\delta}_3^m \tilde{\varepsilon}_m + \theta A_1 + \hat{\delta}_4^m \hat{S}_0^m + \hat{\delta}_5^m\big) + \hat{\delta}_6^m \tilde{X}_1^2 + \hat{\delta}_7^m \tilde{k}^2$$
$$+\, \hat{\delta}_8^m \tilde{\varepsilon}_m^2 + \hat{\delta}_9^m \tilde{X}_1 \tilde{k} + \hat{\delta}_{10}^m \tilde{X}_1 \tilde{\varepsilon}_m + \hat{\delta}_{11}^m \tilde{k}\tilde{\varepsilon}_m + \hat{\delta}_{12}^m \tilde{X}_1 + \hat{\delta}_{13}^m \tilde{k} + \hat{\delta}_{14}^m \tilde{\varepsilon}_i + \hat{\delta}_{15}^m - \tfrac{1}{2}A_1^2\Big)\Big]\Big], \quad (3.59)$$

where $\hat{\delta}_j^m$ for $j = 1, \ldots, 15$ are constants. After integrating (3.59) over $\tilde{X}_1$, $\tilde{h}_m$, and $\tilde{k}$, the manager's optimal action strategy is derived by solving the first-order condition with respect to $\hat{A}_1$, resulting in

$$\hat{A}_1 = \theta \hat{S}_0^m. \qquad (3.60)$$

Then, substituting this expression back into the integrated expression gives the manager's expected utility at $t = 0$, which is displayed on the left hand side of (3.63) below.

Similarly, an investor's expected utility at $t = 0$, conditional on a portfolio and the manager's action strategy, which investors can deduce because preferences are common knowledge, is derived by substituting (3.3), (3.33), (3.35), (3.36), (3.34), (3.60), the expressions for $\mathbb{E}\big[\tilde{X}_1|k, \hat{S}_1^m\big]$ and $\mathbb{V}\big[\tilde{X}_1|k, \hat{S}_1^m\big]$, and the stock supply constraint, $\hat{S}_0^m = 1 - N_d \hat{S}_0^d - N_i \hat{S}_0^i$, into (3.56), yielding

$$\mathbb{E}\Big[-\exp\Big[-\tfrac{1}{2}\gamma\Big(\hat{B}_0^i + \hat{S}_0^i\big(\hat{\delta}_1^i \tilde{X}_1 + \hat{\delta}_2^i \tilde{k} + \hat{\delta}_3^i \tilde{\varepsilon}_m + \hat{\delta}_4^i \hat{S}_0^i + \hat{\delta}_5^i\big) + \hat{\delta}_6^i \tilde{X}_1^2 + \hat{\delta}_7^i \tilde{k}^2$$
$$+\, \hat{\delta}_8^i \tilde{\varepsilon}_m^2 + \hat{\delta}_9^i \tilde{X}_1 \tilde{k} + \hat{\delta}_{10}^i \tilde{X}_1 \tilde{\varepsilon}_m + \hat{\delta}_{11}^i \tilde{k}\tilde{\varepsilon}_m + \hat{\delta}_{12}^i \tilde{X}_1 + \hat{\delta}_{13}^i \tilde{k} + \hat{\delta}_{14}^i \tilde{\varepsilon}_i + \hat{\delta}_{15}^i\Big)\Big]\Big], \quad (3.61)$$

where $\hat{\delta}_j^i$ for $j = 1, \ldots, 15$ are constants. We then integrate over $\tilde{X}_1$, $\tilde{h}_m$, and $\tilde{k}$ to obtain a closed-form expression of the investor's expected utility. The resulting contracting problem is:

$$\max_{\hat{S}_0^i, \hat{B}_0^i} \quad -\exp\Big[-\tfrac{1}{2}\gamma\Big(\hat{B}_0^i + \hat{\varphi}_1^i\big(\hat{S}_0^i\big)^2 + \hat{\varphi}_2^i \hat{S}_0^i + \hat{\varphi}_3^i\Big)\Big] \qquad (3.62)$$

subject to

$$-\exp\Big[-\tfrac{1}{2}\gamma\Big(\hat{B}_0^m + \hat{\varphi}_1^m\big(\hat{S}_0^m\big)^2 + \hat{\varphi}_2^m \hat{S}_0^m + \hat{\varphi}_3^m\Big)\Big] \geq U, \qquad (3.63)$$

where $\hat{\varphi}_j^i$ and $\hat{\varphi}_j^m$ for $j = 1, \ldots, 3$ are constants. The optimal contract parameters are derived in a similar fashion as when there is no advance disclosure in Section 3.2.1. Numerical results are presented in Section 3.3.

3.3 Simulation

In the previous section, we characterize two distinct equilibria—one in which agents who possess private information are required to provide advance disclosure of their trading activity and one in which they trade without providing advance disclosure. Although analytical expressions for prices and allocations in these equilibria are attainable, they are not readily interpretable. Therefore, we conduct a numerical analysis to better understand and compare several characteristics of the equilibria. We first examine macroeconomic features such as market efficiency, prices, risk premiums, and liquidity. We then investigate the effects of advance disclosure on individuals, including portfolio allocations, insider trading profits, welfare, and the optimal management contract. Lastly, we explore the impact of advance disclosure at the firm level by studying managerial effort levels and the propensity for managers to undertake excessively risky projects.

As part of the numerical analysis, we examine how the quantity of private information affects the equilibrium outcomes. In furtherance of this objective, we define $\tilde{Z} \equiv \tilde{X}_1 + \tilde{X}_2$, where

Table 3.I: Parameter Values.

Variable	Symbol	#1	#2	#3	#4
Mean of $\tilde{Z}$	μ_z	100	100	1000	1000
Variance of $\tilde{Z}$	σ_z^2	64	64	6400	6400
Impact of managerial action	θ	0	3	0	12
Variance of liquidity trades	σ_k^2	0.01	0.01	0.01	0.01
Variance of signal of liquidity trades	σ_ε^2	0.01	0.01	0.01	0.01
Mass of investors	N_i	15	15	150	150
Mass of directors	N_d	4	4	5	5
Investors' bond endowment	B_e^i	1	1	1	1
Director's bond endowment	B_0^d	1	1	1	1
Directors' stock endowment	S_0^d	0.05	0.05	0.0065	0.0065
Manager's reservation utility	U	-10^{-7}	-10^{-7}	-10^{-11}	-10^{-11}
Risk aversion coefficient	γ	6	6	7	7
Time preference parameter	β	1	1	1	1

$\tilde{Z} \sim \mathcal{N}\left(\mu_z, \sigma_z^2\right)$, and let $\alpha \in (0,1)$ denote the quantity of private information observed by the manager. We also assume that the respective distributions of $\tilde{X}_1$ and $\tilde{X}_2$ are $\tilde{X}_1 \sim \mathcal{N}\left(\alpha \mu_z, \alpha \sigma_z^2\right)$ and $\tilde{X}_2 \sim \mathcal{N}\left((1-\alpha)\mu_z, (1-\alpha)\sigma_z^2\right)$. Under this specification, the sum of the random components of the stock payoff, $\tilde{X}_1$ and $\tilde{X}_2$, is unaffected by the quantity of private information, but a larger α gives rise to more private information.

Although most of the qualitative results are robust to various calibrations, we simulate data using four distinct calibrations because the quantitative impact of advance disclosure depends on the particular parameter values assumed. The parameter values for these calibrations are listed in Table 3.I. The major differences between the calibrations are the parameter values for the mass of investors, N_i, and the effect of managerial action, θ. These calibrations highlight how both the manager's contribution and the relative "size" of the insiders influence the impact of advance disclosure. The mean and variance of the stock payoff (without managerial action), μ_z and σ_z^2, are chosen so that 99% of payoff realizations are within roughly 25% of the mean, which helps ensure that insiders do not take a short position in the stock since current laws prohibit corporate executives and directors from taking a short position in any security issued by their firm. The impact of managerial action, θ, is then selected so that the manager adds approximately 1% to the value of the firm in equilibrium. The variance of the liquidity trades, σ_k^2, and the noise component of the agents' signals of the liquidity trades, σ_ε^2, are both set at 0.01, which means that the noise component of the investors' signal of the insiders' private information is not predisposed to be either smaller or larger with advance disclosure. In two of the calibrations insiders comprise a quarter of the market, and in the other two calibrations they comprise only 4% of the market. The manager's reservation utility, U, and the directors' stock endowment, S_0^d, are adjusted in order that the ex ante expected utility is of the same order of magnitude for all agents within a particular calibration.

We simulate 10,000 realizations of $\tilde{X}_1$, $\tilde{k}$, $\tilde{h}_i$, and $\tilde{h}_m$ for several values of α ranging from 0.03 to 0.70. This range of α seems realistic and ensures that both the manager's stock holdings and the stock price are always positive. For consistency, we use the same realizations of the simulated variables for each calibration and level of α.
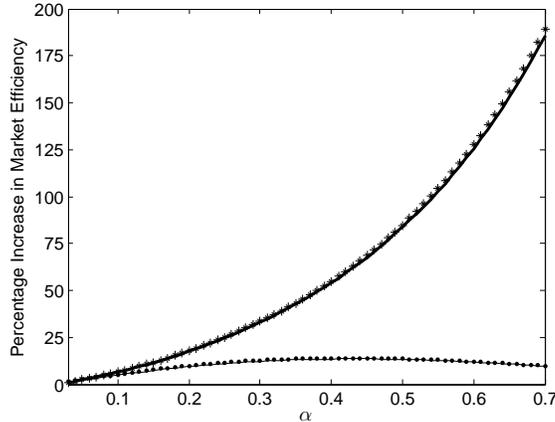
Figure 3.1: Efficiency. The percentage increase in market efficiency resulting from advance disclosure, measured as $(\hat{\Sigma}/\Sigma - 1) \times 100$, is plotted for various values of α and multiple calibrations. The thin solid line represents calibration #1, the dots represent calibration #2, the bold solid line represents calibration #3, and the asterisks represent calibration #4. Table 3.I lists parameter values for these calibrations.

3.3.1 Market Efficiency

We first discuss market efficiency because it forms a basis for much of our subsequent analysis. Following Spiegel and Subrahmanyam (1992), we measure efficiency, which is denoted by Σ, as the inverse of the variance of the stock payoff, conditional on the information available to the market (i.e., investors) at $t = 1$. A higher level of efficiency means that there is less uncertainty regarding the stock payoff. The following corollary provides expressions for market efficiency.

Corollary 1. *Market efficiency without advance disclosure of trading is given by*

$$\Sigma = \frac{\Gamma_3}{\Gamma_4 \sigma_2^2} \tag{3.64}$$

while market efficiency with advance disclosure of trading is given by

$$\hat{\Sigma} = \frac{\sigma_1^2 + \rho^2 \sigma_\varepsilon^2}{\rho^2 \sigma_1^2 \sigma_\varepsilon^2 + \left(\sigma_1^2 + \rho^2 \sigma_\varepsilon^2\right)\sigma_2^2}. \tag{3.65}$$

Proof. See Appendix.

While these analytical expressions for efficiency are easily derived, we resort to a numerical comparison because the presence of ρ, which is a solution to a cubic polynomial, makes an analytical comparison infeasible. Figure 3.1, which plots the percentage increase in market efficiency resulting from advance disclosure of trading, indicates that advance disclosure gives rise to markets that are more efficient. This result is consistent with Huddart, Hughes, and Levine (2001) as well as Huddart, Hughes, and Williams (2010), who find that market efficiency increases with both pre- and post-disclosure of insider trading.

The degree to which managerial action affects the stock payoff, θ, appears to have a negligible impact on efficiency, likely because managerial action comprises only a small fraction of total firm value. The mass of investors relative to that of insiders, however, seems to dramatically affect efficiency, especially when insiders possess a great deal of private information. This latter effect on efficiency is related to the liquidity of the market. When the mass of investors is large, the price

|	
(a) Average Price	(b) Volatility
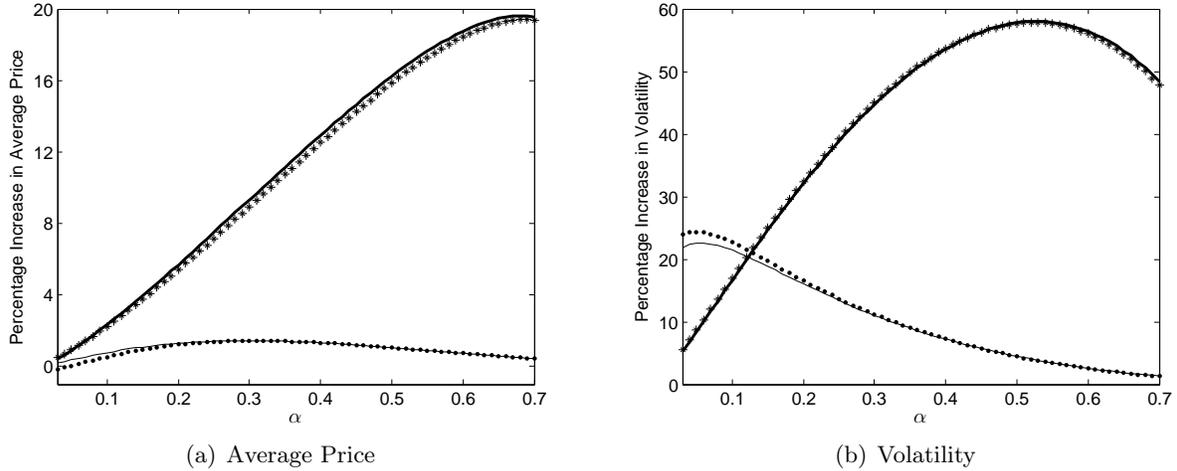
Figure 3.2: Price. The percentage increase in the mean price and the volatility of price resulting from advance disclosure, $(\mathbb{E}[\hat{P}]/\mathbb{E}[P] - 1) \times 100$ and $(\mathbb{V}[\hat{P}]^{1/2}/\mathbb{V}[P]^{1/2} - 1) \times 100$, is plotted for various levels of α and multiple calibrations. The thin solid line represents calibration #1, the dots represent calibration #2, the bold solid line represents calibration #3, and the asterisks represent calibration #4. Table 3.I lists parameter values for these calibrations.

reacts to a lesser extent in response to a liquidity trade, *ceteris paribus*, because there are more investors to absorb fluctuations in supply. That is, without advance disclosure insiders are able to adjust their demand in response to liquidity shocks. As a consequence, both the liquidity trades and the manager's signal of the liquidity trades exert a smaller influence over the stock price. Yet, the mass of investors only affects the investors' signal of the insiders' private information with advance disclosure, as a marginal increase in N_i causes the magnitude of ρ to decrease but does not affect ω. This means that the insiders' disclosures become more informative as N_i increases while the informativeness of the price without advance disclosure remains constant. Hence, the increase in market efficiency that results from the advance disclosure of trading is more pronounced whenever the mass of insiders is relatively small.

3.3.2 Price

We next evaluate the effect of advance disclosure on price. Figures 3.2(a) and 3.2(b) plot the percentage increase in average price and volatility, respectively, in a market with advance disclosure relative to a market without advance disclosure. These figures indicate that advance disclosure leads to higher average prices and greater volatility. Both of these results are largely attributable to the enhanced market efficiency generated by advance disclosure. On average, the stock price will be higher with advance disclosure since there is less uncertainty regarding the stock payoff. At the same time, there is a greater degree of variability in the private information made available to the market with advance disclosure because a larger portion of the insiders' private information is revealed. Since the private information revealed to the market is incorporated into the stock price, the increased variability of information gives rise to greater price volatility. Thus, advance disclosure "accelerates the resolution of uncertainty" and appears to exacerbate the increased volatility caused by insider trading, as documented by Leland (1992).
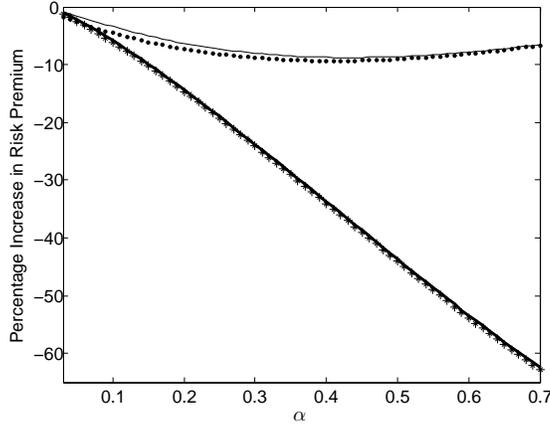
Figure 3.3: Risk Premium. The percentage increase in the average risk premium resulting from advance disclosure, measured as $(\hat{\Pi}/\Pi - 1) \times 100$, is plotted for various levels of α. The thin solid line represents calibration #1, the dots represent calibration #2, the bold solid line represents calibration #3, and the asterisks represent calibration #4. Table 3.I lists parameter values for these calibrations.

3.3.3 Risk Premium

The risk premium, which is denoted by Π, is calculated as the difference between the stock's expected payoff and its price.[17] Both with and without advance disclosure, the risk premium is a function of the insiders' private information, the liquidity trades, and the private signals of the liquidity trades. Consequently, the risk premium is stochastic. For the sake of comparison, we therefore derive expressions for the average risk premium.

Corollary 2. *The average risk premium without advance disclosure of trading is given by*

$$\Pi = \gamma \sigma_2^2 \frac{\Gamma_4}{\Gamma_6} \tag{3.66}$$

while the average risk premium with advance disclosure of trading is given by

$$\hat{\Pi} = \frac{1}{\hat{\Gamma}_3}\left[\gamma\big(\hat{\Gamma}_1\big(\theta\hat{A}_1 + \big(1 - \hat{\lambda}_2\big)\mu_1 + \mu_2 - \hat{\lambda}_1\big) + \hat{\lambda}_3^2 \sigma_k^2 \sigma_\varepsilon^2 \theta^2 \hat{S}_0^m\big)\right]. \tag{3.67}$$

Proof. See Appendix.

Figure 3.3 depicts the percentage increase in average risk premiums for various levels of α. Evidently, advance disclosure gives rise to a smaller average risk premium. Along with the impact on price, the effect on the risk premium is attributable to enhanced efficiency—investors command a smaller risk premium when there is less uncertainty surrounding the stock payoff.

3.3.4 Liquidity

Similar to Leland (1992), we measure liquidity, which is denoted by Λ, as the inverse impact on price from a marginal increase in the quantity of liquidity trades: $(\partial P/\partial k)^{-1}$. A market that

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[17]Defining the risk premium as the percentage difference between the stock's expected payoff and its price produces quantitative results almost identical to the ones presented in Figure 3.3 but generates more complicated analytical expressions.
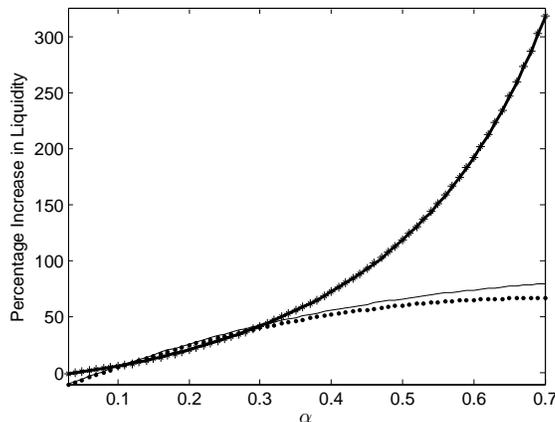
Figure 3.4: Liquidity. The percentage increase in liquidity resulting from advance disclosure, measured as $(\hat{\Lambda}/\Lambda - 1) \times 100$, is plotted. The thin solid line represents calibration #1, the dots represent calibration #2, the bold solid line represents calibration #3, and the asterisks represent calibration #4. Table 3.I lists parameter values for these calibrations.

experiences a smaller price change in response to a marginal change in the amount of liquidity trades is considered to be more liquid than a market that experiences a larger price change. The following corollary provides expressions for liquidity.

Corollary 3. *Liquidity without advance disclosure of trading is given by*

$$\Lambda = \frac{\Gamma_6 \sigma_\varepsilon^2}{\left(\Gamma_5 \sigma_\varepsilon^2 - N_i \Gamma_2 \sigma_1^2\right)\left(\gamma \sigma_2^2 - \theta^2\right)} \tag{3.68}$$

while liquidity with advance disclosure of trading is given by

$$\hat{\Lambda} = \left(\rho \hat{\lambda}_2 + \hat{\lambda}_3\right)^{-1}. \tag{3.69}$$

Proof. See Appendix.

Figure 3.4, which plots the percentage increase in liquidity arising from advance disclosure, indicates that a market with advance disclosure is more liquid than a market without advance disclosure except when insiders possess very little private information. On one hand, the increased efficiency in a market with advance disclosure makes stock prices less susceptible to liquidity trades. On the other hand, advance disclosure precludes insiders from adjusting their demand in response to a liquidity shock, thereby making prices more susceptible to liquidity trades. Thus, a market with advance disclosure will be more (less) liquid whenever the former (latter) effect dominates. As Figure 3.4 demonstrates, the gain from enhanced efficiency outweighs the loss from the inflexibility of the insiders' demand except when improved efficiency is of little value because the insiders possess only a small amount of private information. Thus, advance disclsoure may help to mitigate any reduction in liquidity caused by insider trading (see, e.g., Kyle (1985) and Leland (1992)). Note that our results are consistent with Huddart, Hughes, and Levine (2001), who find that post-trading disclosure enhances liquidity, but conflict with Huddart, Hughes, and Williams (2010), who find that pre-announcement leads to a loss of liquidity.

(a) Total Compensation

(b) Bond Compensation

(c) Stock Compensation

(d) Value of Stock Compensation
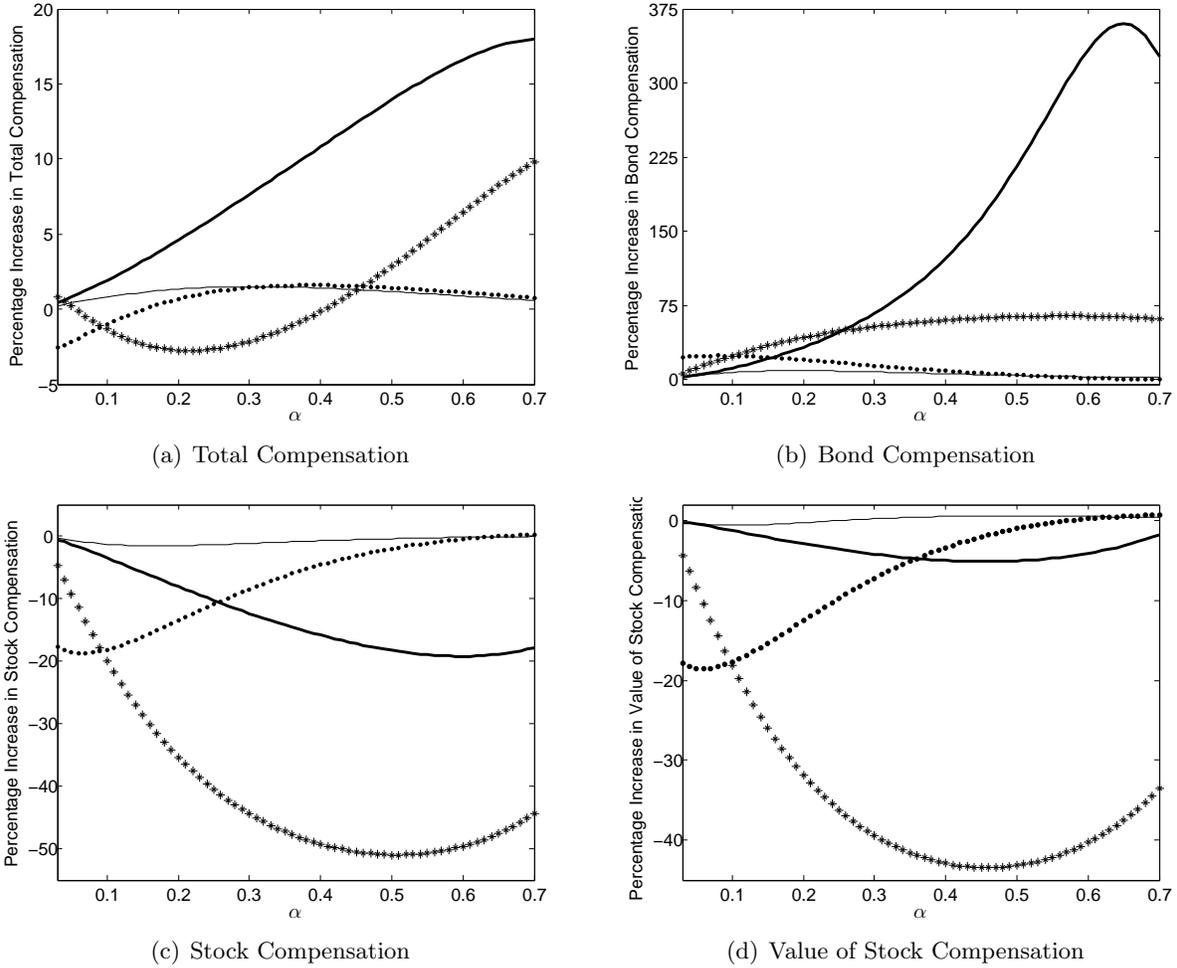
Figure 3.5: Compensation Contract. For various levels of α and multiple calibrations, (a) plots the percentage increase in the expected market value of the total compensation package $((\mathbb{E}[\hat{P}]\hat{S}_0^m + \hat{B}_0^m)/(\mathbb{E}[P]S_0^m + B_0^m) - 1) \times 100$, (b) plots the percentage increase in bond compensation $(\hat{B}_0^m/B_0^m - 1) \times 100$, (c) plots the the percentage increase in stock compensation $(\hat{S}_0^m/S_0^m - 1) \times 100$, and (c) plots the percentage increase in the expected value of stock compensation $((\mathbb{E}[\hat{P}]\hat{S}_0^m)/(\mathbb{E}[P]S_0^m) - 1) \times 100$ as a consequence of advance disclosure. The thin solid line represents calibration #1, the dots represent calibration #2, the bold solid line represents calibration #3, and the asterisks represent calibration #4. Table 3.I lists parameter values for these calibrations.

3.3.5 Allocations

Figure 3.5 illustrates the effect of advance disclosure on the parameters of the management contract—S_0^m and B_0^m—which are the solutions to the contracting problems described in Sections 3.2.1 and 3.2.2. Figures 3.5(b) and 3.5(c) plot the respective percentage increases in bond and stock compensation (quantity of bonds and number of shares) with advance disclosure relative to a setting without advance disclosure. These figures indicate that the manager receives more bonds and less stock when she must provide advance disclosure of her trading activity. Furthermore, Figures 3.5(a) and 3.5(d) indicate that the expected value of the total compensation package, $\mathbb{E}[P]S_0^m + B_0^m$, is for the most part higher with advance disclosure while the expected value of the stock compensation, $\mathbb{E}[P]S_0^m$, tends to be lower with advance disclosure. The fact that managers receive more
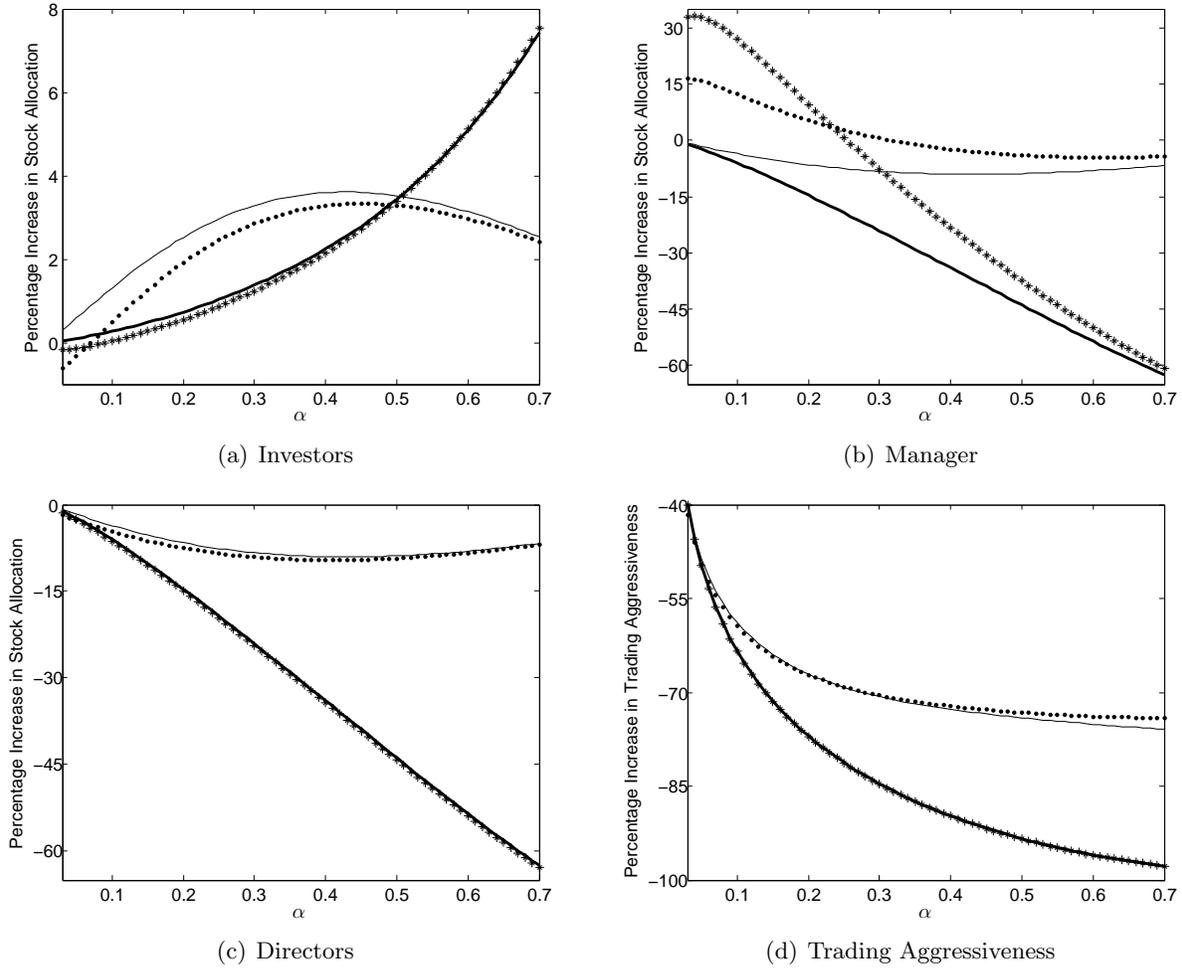
Figure 3.6: Equilibrium Allocations. The percentage increase in the mean equilibrium stock allocations resulting from advance disclosure are plotted in Figures (a)-(c). Figure (d) plots the relative aggressiveness with which insiders trade on their private information, measured as $((\partial \hat{S}_1^m/\partial X_1)/(\partial S_1^m/\partial X_1) - 1) \times 100$, with advance disclosure. The thin solid line represents calibration #1, the dots represent calibration #2, the bold solid line represents calibration #3, and the asterisks represent calibration #4. Table 3.I lists parameter values for these calibrations.

valuable compensation packages with advance disclosure suggests that insider trading profits without advance disclosure comprise a substantial portion of managerial compensation. This result is consistent with previous findings that managerial compensation is weakly increasing in the amount of mandated disclosure (Hermalin and Weisbach (2012)) and that firms that restrict insider trading tend to provide more valuable managerial compensation packages (Roulstone (2001)).

Market efficiency, the distribution of the future stock price, and managerial action all influence the composition of the optimal compensation package. Overall, larger variations in both the composition and expected value of the compensation package occur when advance disclosure leads to a bigger increase in market efficiency and greater volatility. Because greater efficiency leads to a stock price that more accurately reflects the insiders' private information, the manager cannot gain as much from purchasing undervalued shares or selling overvalued ones, which means that she earns smaller profits from insider trading. Consequently, the market value of her compensation package
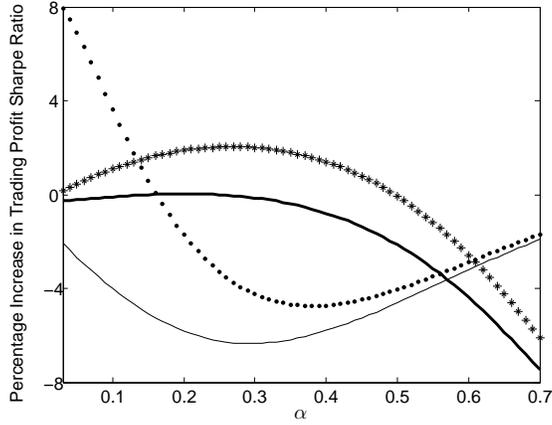
(a) Investors
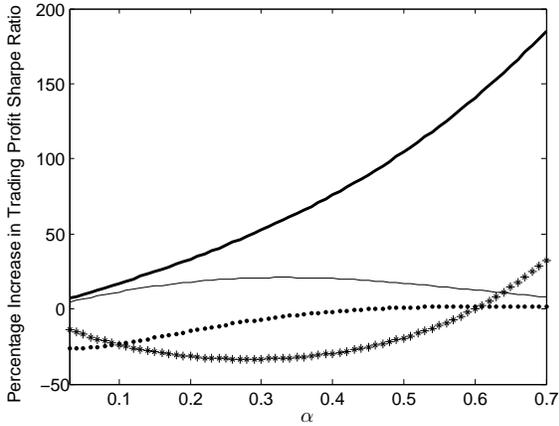
(b) Manager
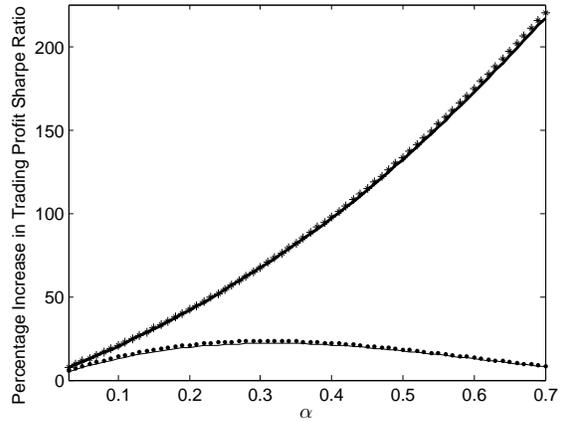
(c) Directors

Figure 3.7: Trading Profit. The percentage increase in the Sharpe ratio of trading profits resulting from advance disclosure, $((\mathbb{E}[\hat{\pi}_\ell]/\mathbb{V}[\hat{\pi}_\ell]^{1/2})/(\mathbb{E}[\pi_\ell]/\mathbb{V}[\pi_\ell]^{1/2}) - 1) \times 100$, is plotted. The thin solid line represents calibration #1, the dots represent calibration #2, the bold solid line represents calibration #3, and the asterisks represent calibration #4. Table 3.I lists parameter values for these calibrations.

increases in order to satisfy her reservation utility. Furthermore, with higher stock price volatility, each share of stock provides a lower amount of expected utility, so a portion of the manager's stock compensation is replaced with bonds.

In addition to receiving less stock pursuant to the management contract, the manager also tends to hold less stock at $t = 1$, on average, when she provides advance disclosure of her trading activity, as demonstrated by Figure 3.6, which displays the percentage increase in the average equilibrium stock allocations at $t = 1$ brought about by advance disclosure. Directors also tend to hold fewer shares in a market with advance disclosure, but investors hold a greater amount of stock. By removing more of the information asymmetries from the market, advance disclosure induces investors to hold more stock. Finally, Figure 3.6(d) reveals that insiders trade much less aggressively on their private information when they must provide advance disclosure.

(a) Investors	(b) Directors
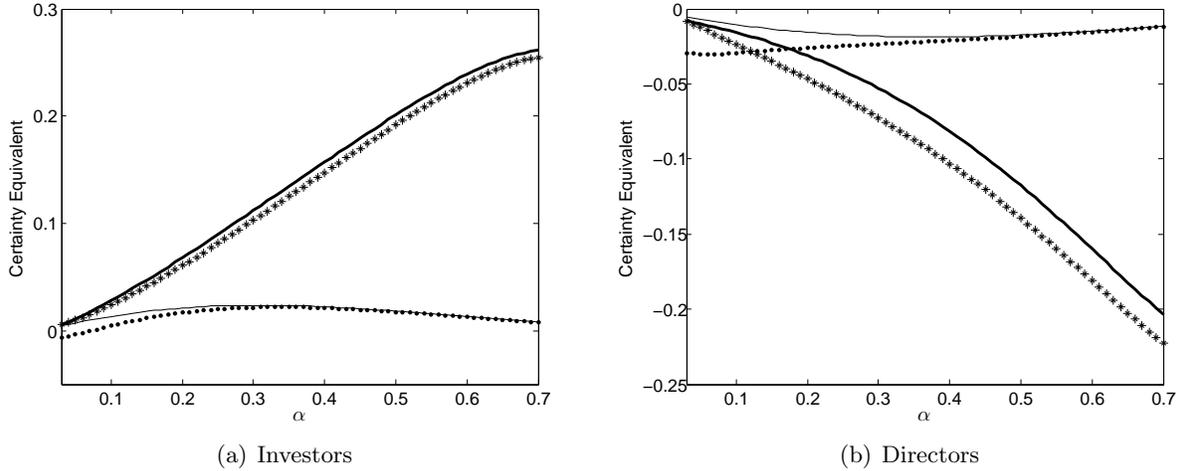
Figure 3.8: Welfare. The certainty equivalent of additional consumption without advance disclosure that is necessary to provide the agents with the same ex ante expected utility that is obtained with advance disclosure is plotted for various levels of α and multiple calibrations. The thin solid line represents calibration #1, the dots represent calibration #2, the bold solid line represents calibration #3, and the asterisks represent calibration #4. Table 3.I lists parameter values for these calibrations.

3.3.6 Trading Profits

Differences in the stock allocations and the aggressiveness with which insiders trade are both significant factors in the amount of trading profits earned by the agents. We measure trading profits as the gain in wealth directly attributable to stock ownership, and it consists of the amount received from the terminal payoff at $t = 2$ plus (minus) any sales (purchases) at $t = 1$. The trading profit for an investor of type ℓ, which is denoted by π_ℓ, is given by

$$\pi_\ell \equiv S_1^\ell Y + \left(S_0^\ell - S_1^\ell\right)P \tag{3.70}$$

for $\ell \in \{m, d, i\}$.

Since trading profits are stochastic, it seems natural to evaluate the impact of advance disclosure on these profits by comparing a Sharpe ratio of trading profits. Specifically, we compute the ratio of expected trading profits to the standard deviation of trading profits both with and without advance disclosure. We then divide this Sharpe ratio with advance disclosure by its counterpart without advance disclosure and subtract one from the resulting fraction. Agents can expect to earn larger trading profits per unit of risk when this metric, which is plotted in Figure 3.7, is positive. For the most part, advance disclosure leads to a lower Sharpe ratio of trading profits for investors but a higher Sharpe ratio of trading profits for the manager and directors. However, if we look only at the expected trading profits, which are unreported, we observe that the trading profits for the manager and directors fall, on average, with advance disclosure. This finding is consistent with the post- and pre-announcement results of Huddart, Hughes, and Williams (2010) and Huddart, Hughes, and Levine (2001). We also observe a corresponding rise in the expected trading profits for investors.

3.3.7 Welfare

Interestingly, the effect of advance disclosure on the Sharpe ratio of trading profits does not seem to correlate with its effect on welfare. Figure 3.8 measures the change in welfare resulting from
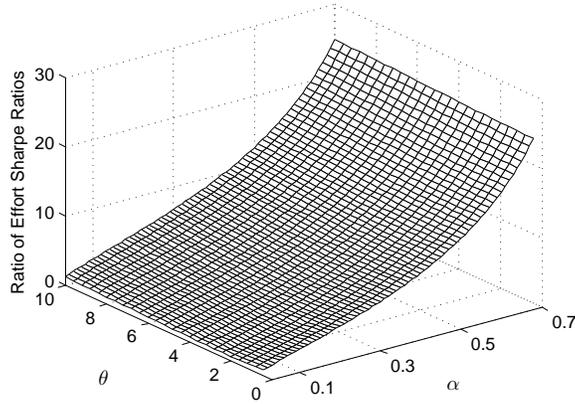
Figure 3.9: Managerial Effort. The increase in the Sharpe ratio of managerial effort resulting from advance disclosure, $(\mathbb{E}[(\hat{S}_0^m + \hat{S}_1^m)\theta^2]/\mathbb{V}[(\hat{S}_0^m + \hat{S}_1^m)\theta^2]^{1/2})/(\mathbb{E}[(S_0^m + S_1^m)\theta^2]/\mathbb{V}[(S_0^m + S_1^m)\theta^2]^{1/2}) - 1$, is plotted for various values of α and θ. The remaining parameter values are listed in Table 3.I under calibration #1.

advance disclosure. It depicts the certainty equivalent of additional consumption without advance disclosure necessary to provide the investors and directors with the same ex ante expected utility that they obtain with advance disclosure. The manager always receives her reservation expected utility. Figure 3.8 shows that investors' ex ante expected utility rises but that directors' ex ante expected utility falls with advance disclosure.

3.3.8 Managerial Effort

Advance disclosure can also indirectly affect the manager's incentives to undertake individually costly actions that enhance firm value. Since the manager's action strategies derived in Section 3.2 depend on her stock holdings, it follows that managerial effort itself depends on the manager's stock holdings. Accordingly, the aggregate effort levels with and without advance disclosure are $(\hat{S}_0^m + \hat{S}_1^m)\theta^2$ and $(S_0^m + S_1^m)\theta^2$, respectively. Provided that $\theta \neq 0$, advance disclosure results in greater effort when the manager holds more stock. Firm value is never destroyed through negative effort since the manager always holds a non-negative amount of stock.

Because the manager's stock allocation at $t = 1$, and hence her effort level, is stochastic and depends on the realizations of several random variables, we compare effort with advance disclosure to effort without advance disclosure by examining a Sharpe ratio of managerial effort. Figure 3.9 plots the percentage increase in the Sharpe ratio of managerial effort resulting from advance disclosure for various values of α and θ. The figure clearly indicates that the average amount of effort per unit of risk increases with advance disclosure, and this increase is more pronounced when the insiders possess a great deal of private information. However, the expected effort level falls with advance disclosure because the manager is granted less stock pursuant the management contract and holds less stock on average after trading at $t = 1$.

3.3.9 Incentive to Undertake Excessive Risk

Next, we investigate how advance disclosure affects the manager's incentive to undertake excessive risk for the purpose of generating additional private information. We consider a slight modification of the model outlined in Section 3.2 that permits the manager to take on additional risky projects that have a zero expected payoff. These projects generate more private information

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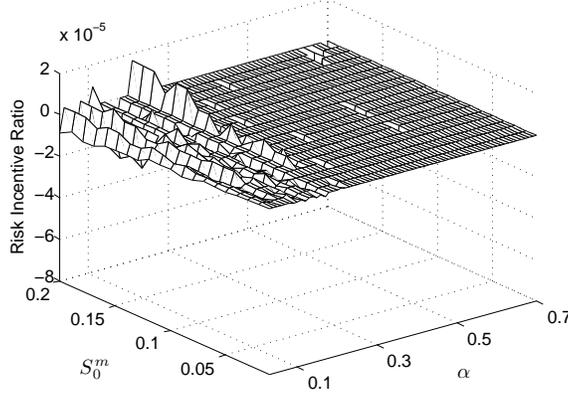
Figure 3.10: Risk Incentive. The ratio of the partial derivative of the manager's ex ante expected utility with respect to J_1 with advance disclosure to the partial derivative without advance disclosure is plotted over a range of values for α and S_0^m. The remaining parameters are listed in Table 3.I under calibration #1.

but do not create any additional value for the firm on average. We denote the quantity of additional risky projects undertaken at time t by J_t and the payoff from these projects by R_t, where $J_t \in \mathbb{R}^+$ and $\tilde{R}_t \sim \mathcal{N}\left(0, \sigma_R^2\right)$ for $t = 1, 2$. We further assume that these projects are linearly incorporated into the stock payoff, which in this setting becomes

$$\tilde{\bar{Y}} \equiv \theta(\bar{A}_1 + \bar{A}_2) + J_1\tilde{R}_1 + J_2\tilde{R}_2 + \tilde{X}_1 + \tilde{X}_2, \tag{3.71}$$

where a macron ($^-$) is added to some variables to distinguish them from versions of the model previously discussed. The manager chooses J_1 at $t = 0$ and, along with directors, observes the realization of $\tilde{R}_1$ before trading occurs at $t = 1$. Investors do not directly observe R_1, but they can use the information available to them in the market to form a conditional distribution of $\tilde{R}_1$. The manager also selects J_2 at $t = 1$, and R_2 is realized at $t = 2$. Furthermore, $\tilde{R}_1$, $\tilde{R}_2$, $\tilde{X}_1$, $\tilde{X}_2$, $\tilde{k}$, $\tilde{\varepsilon}_m$, and $\tilde{\varepsilon}_i$ are mutually independent.

As before, we assume that the stock price and disclosures are linear functions of the insiders' private information, which now includes R_1. Hence, the stock price is a linear function of $\bar{q} \equiv J_1R_1 + X_1 + \bar{\omega}k$ in a market without advance disclosure, and the insiders' trading disclosures are linear functions of $\bar{r} \equiv \hat{J}_1R_1 + X_1 + \bar{\rho}h_m$ in a market with advance disclosure. The equilibria are derived in a similar fashion as in Section 3.2, but for the sake of brevity, we do not report the equilibrium outcomes. We note, however, that the action strategies are the same as in Section 3.2 while the prices and allocations now incorporate the additional risky projects.

Solving a revised maximization problem for the manager that includes the decision to undertake additional risky projects, we find that the manager optimally chooses $J_2 = 0$ both with and without advance disclosure. In both cases, there is no incentive for the manager to create extra risk because she is risk averse and the added uncertainty does not generate more private information on which she can capitalize. Conversely, the optimal choice of J_1 depends on whether she provides advance disclosure of her trading activity since the value of the additional private information can potentially outweigh the added risk. Although we are unable to obtain an analytical solution for J_1, we can numerically compute the change in the manager's ex ante expected utility from a marginal increase in J_1 to gauge the manager's incentive to undertake additional risky projects at $t = 0$. Figure 3.10 plots the ratio of this partial derivative with advance disclosure to the partial derivative without advance disclosure over a range of values for α and S_0^m when $J_1 = 0$. As is evident from the plot,

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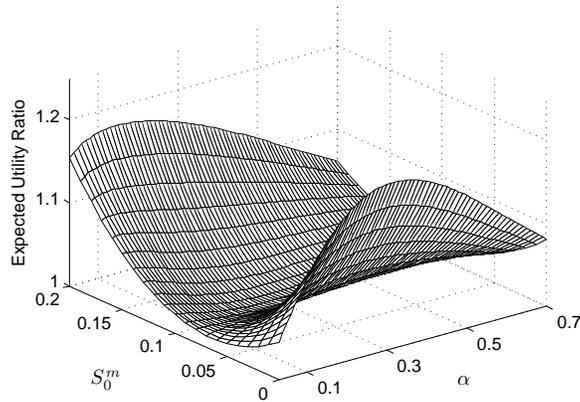
Figure 3.11: Expected Utility Ratio. The ratio of the manager's ex ante expected utility with advance disclosure to her ex ante expected utility without advance disclosure is plotted over a range of α and S_0^m in figure (a). The remaining parameters are listed in Table 3.I under calibration #1.

the value of the aforementioned ratio is close to zero over the entire range of α and S_0^m, which means that the incentive for the manager to undertake excessive risk is dramatically reduced when she must provide advance disclosure of her trading activity.

3.3.10   Voluntary Disclosure

Our final task is to investigate whether the manager would voluntarily commit to provide advance disclosure of her trading activity in the absence of a requirement to do so. Consistent with Huddart, Hughes, and Williams (2010), we find that she will not. Holding her bond compensation constant, we compare the manager's ex ante expected utility with advance disclosure to her ex ante expected utility without advance disclosure over a range of values for S_0^m and α. Figure 3.11 plots a ratio of these utility levels for calibration #1.[18] Since agents exhibit CARA preferences, a ratio greater than one indicates a drop in expected utility, and vice versa. It is clear from the figure that, given a quantity of future private information and an initial portfolio of stock and bonds, the manager's expected utility falls when she must provide advance disclosure of her trading activity. Hence, the manager will prefer to not commit to advance disclosure after receiving her compensation package at $t = 0$, even though she is ex ante indifferent because her compensation package is adjusted so that she always receives her reservation utility.

3.3.11   Sensitivity of Results

In this section, we briefly discuss the sensitivity of our results to the realizations of the simulated variables. As previously mentioned, we simulate 10,000 realizations each of X_1, k, h_i, and h_m. To check whether this number of realizations provides a sufficient amount of data from which to draw reliable inferences, we group the realizations into 10 buckets of 1,000 realizations each and compare the simulation results for each bucket. For brevity, we focus on average prices and allocations because they affect many other equilibrium attributes, such as trading profits, welfare, managerial effort, and the incentive to undertake excessively risky projects. Market-wide equilibrium characteristics like market efficiency and liquidity are unaffected by the realizations.

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[18]The other calibrations lead to identical qualitative conclusions.

(a) Average Price

(b) Investors

(c) Manager

(d) Directors
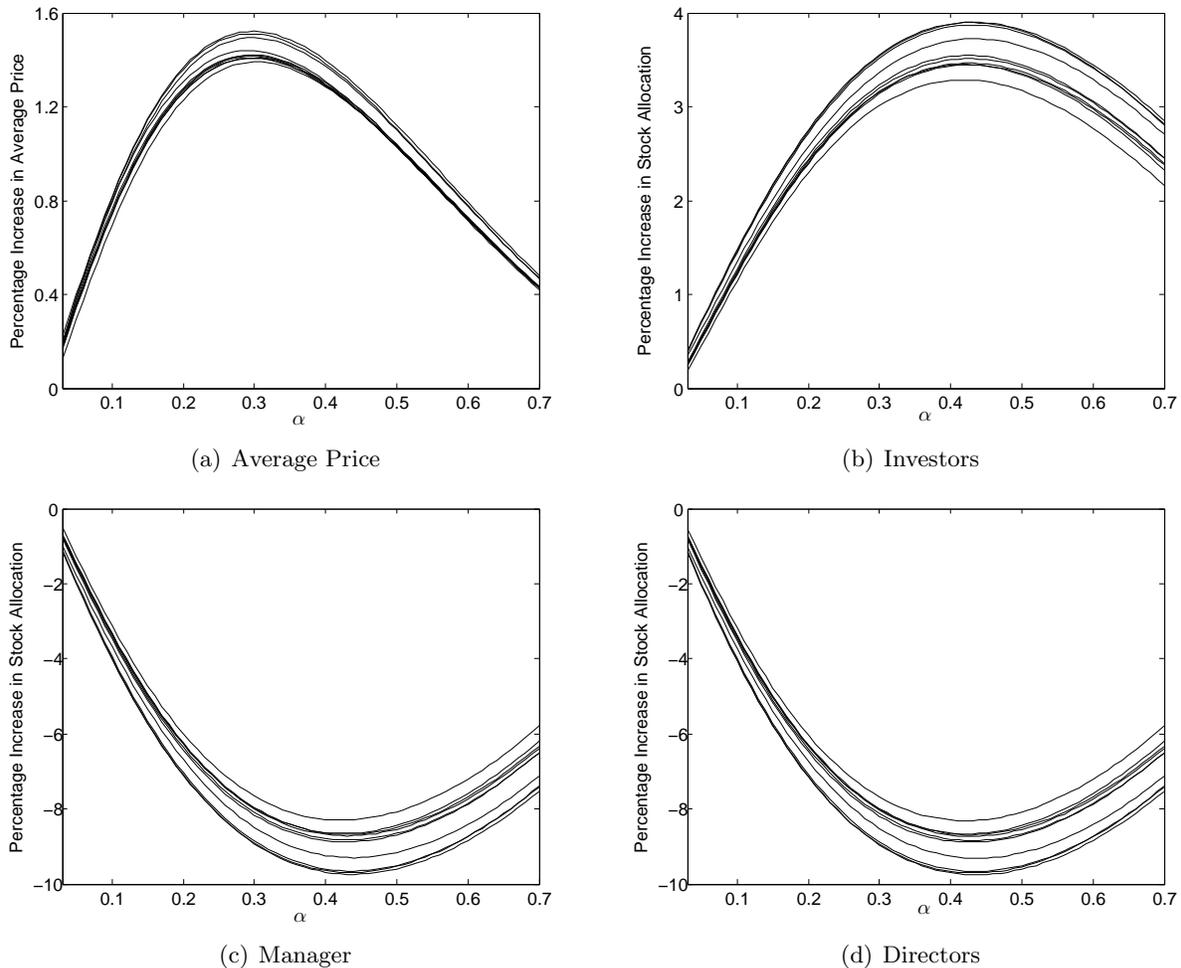
Figure 3.12: Sensitivity. The percentage increase in the mean equilibrium price and stock allocations resulting from advance disclosure is plotted for several simulations of $1,000$ realizations each. The parameter values are listed in Table 3.I under calibration #1.

Figure 3.12(a) plots the average stock price while Figures 3.12(b)-(d) plot the average equilibrium stock allocations for 10 different simulations of 1,000 realizations each. As indicated by the figures, each simulation produces results which are quantitatively similar and qualitatively identical. Therefore, we conclude that 10,000 realizations is a sufficient number to produce reliable solutions.

3.4 Concluding Remarks

We construct a noisy rational expectations equilibrium model in which informed insiders provide advance disclosure of their trading activity. Relative to a market in which informed insiders trade without providing advance disclosure and investors learn from prices, we find that there are several benefits to a market in which investors learn from insiders' advance disclosures of trades. In particular, advance disclosure gives rise to markets that: (i) are informationally more efficient; (ii) are ordinarily more liquid; (iii) have larger managerial effort Sharpe ratios; and (iv) discourage

excessively risky projects. A drawback of advance disclosure, however, is that prices are more volatile. Additionally, there are many consequences of advance disclosure that are neither beneficial nor detrimental. First, prices are higher and risk premiums are smaller, on average, in a market with advance disclosure. Second, investors tend to hold more stock in equilibrium while insiders tend to hold less. Third, the market value of the manager's compensation package is higher. Fourth, the Sharpe ratio of trading profits may either rise or fall. We also observe that advance disclosure leads to greater ex ante expected utility for investors but reduced ex ante expected utility for insiders other than the manager. The manager's expected utility is unaltered in equilibrium because her compensation package is adjusted. Finally, we find that insiders will not voluntarily commit to provide advance disclosure of their trading activity.

Our model also presents several interesting avenues for future research. For instance, one could extend the set of permissible types of trades to include limit orders. The effect of advance disclosure on independent information acquisition, as in Fishman and Hagerty (1992) or McNichols and Trueman (1994), is potentially intriguing, as well.

Appendix A

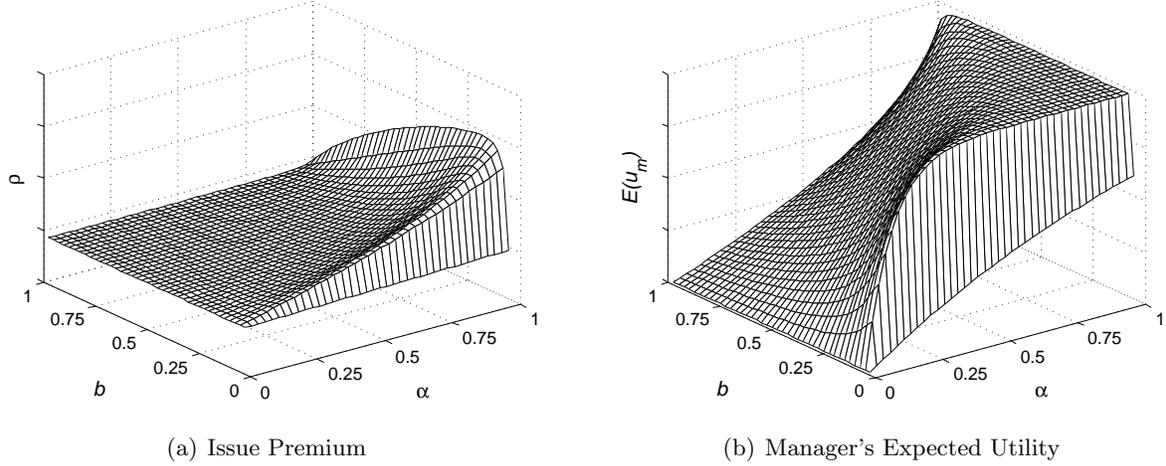# The Closed-End Fund Puzzle: Management Fees and Private Information

A.1 Endogenous Stock Price without Liquidity Traders

In this section, we modify our model to allow for an endogenous stock price. We first describe the modifications to our model and present the new equilibrium. We then verify the robustness of our results.

Modifying our model to allow for an endogenous stock price requires two adjustments to our set of assumptions. First, we eliminate our assumption that the stock price process is exogenously given by (1.44). Second, to overcome a no-trade theorem that otherwise would prevent trade from occurring among the asymmetrically-informed agents, we assume that the investor is slightly unsophisticated in that he is unable to infer the manager's private information from the equilibrium stock price. The investor in the modified version of our model has rational expectations in the sense of Muth (1961) and Lucas and Prescott (1971), as he correctly anticipates the distribution of future asset prices and chooses utility-maximizing portfolios based on his prior information. The only limit to his rationality is that he is unable to "reverse engineer" or invert the price function as in Radner (1979) or Grossman and Stiglitz (1980) to infer the manager's private information. This is arguably a weaker assumption than the device traditionally used by theorists to overcome no-trade theorems in a model like ours; namely, noise traders who provide shocks to supply that are completely random and do not respond in any way to expectations about future prices. Heuristically, this version of our model can be thought of as the limiting case of another variation of our model with an endogenous stock price, fully rational investors, and liquidity traders, which we discuss in Appendix A.2.

Under our new set of assumptions, the endogenously determined equilibrium stock price is equivalent to the exogenous process we assumed for our featured model whenever information is symmetric but not when information is asymmetric. Hence, at the beginning and end of each cycle the stock price is given by (1.44) and the allocations are given by (1.50) and (1.51). At the middle of cycle n, the manager's private information is incorporated into the stock price, which is given by

$$ P_{3n-1}^s = \sum_{\tau=1}^{3n-2} X_\tau + \sum_{\tau=3n}^{T} \left(\mu_\tau - \frac{\gamma_i \gamma_m}{\Gamma} \sigma_\tau^2 \right) + \frac{\gamma_i Z_{n,1} + (1 - \alpha_q) b \left(\Gamma \mu_{3n-1} - \gamma_i \gamma_m \sigma_{3n-1}^2 \right)}{\alpha_q \gamma_i + (1 - \alpha_q) \Gamma b}, \qquad \text{(A.1)} $$

(a) Issue Premium   (b) Manager's Expected Utility

Figure A.1: Issue Premium and Expected Utility.

as well as the stock allocations, which are given by

$$S_{3n-1}^{f} = \frac{(\Gamma b - \gamma_i)(Z_{n,1} - \alpha_q \mu_{3n-1}) + \gamma_i \gamma_m b \sigma_{3n-1}^2}{\gamma_m b (\alpha_q \gamma_i + (1 - \alpha_q)\Gamma b) \sigma_{3n-1}^2} \tag{A.2}$$

and

$$S_{3n-1}^{i} = \frac{(\Gamma b - \gamma_i)(\alpha_q \mu_{3n-1} - Z_{n,1} + (1 - \alpha_q)\gamma_m b \sigma_{3n-1}^2)}{\gamma_m b (\alpha_q \gamma_i + (1 - \alpha_q)\Gamma b) \sigma_{3n-1}^2}. \tag{A.3}$$

Furthermore, since endogenizing the stock price impacts the extent to which the manager can profit from her information advantage, it also affects the discount. The weighted average of the expected benefit of the manager's private information with an endogenous stock price is now given by

$$\hat{\delta} \equiv \frac{\lambda_\ell \Upsilon_\ell \sqrt{1 - \frac{(1-\alpha_h)\alpha_h \gamma_i (\Gamma + \gamma_m)(\Gamma b - \gamma_i)^2}{\left(\gamma_m (\alpha_h \gamma_i + (1-\alpha_h)\Gamma b)\right)^2}} + \lambda_h \Upsilon_h \sqrt{1 - \frac{(1-\alpha_\ell)\alpha_\ell \gamma_i (\Gamma + \gamma_m)(\Gamma b - \gamma_i)^2}{\left(\gamma_m (\alpha_\ell \gamma_i + (1-\alpha_\ell)\Gamma b)\right)^2}}}{\Upsilon_\ell \sqrt{1 - \frac{(1-\alpha_h)\alpha_h \gamma_i (\Gamma + \gamma_m)(\Gamma b - \gamma_i)^2}{\left(\gamma_m (\alpha_h \gamma_i + (1-\alpha_h)\Gamma b)\right)^2}} + \Upsilon_h \sqrt{1 - \frac{(1-\alpha_\ell)\alpha_\ell \gamma_i (\Gamma + \gamma_m)(\Gamma b - \gamma_i)^2}{\left(\gamma_m (\alpha_\ell \gamma_i + (1-\alpha_\ell)\Gamma b)\right)^2}}}. \tag{A.4}$$

Accordingly, equilibrium discounts are now described by (1.54), (1.57), and (1.60) with $\hat{\delta}$ in place of δ.

In summary, the only real difference between the equilibrium in our modified model and in our featured model is the effect of the manager's information advantage on her portfolio choices when information is asymmetric at the middle of every cycle. With an endogenous stock price, there is a price feedback effect that limits the manager's capacity to profit from her information advantage.

We verify the robustness of the results obtained from our featured model in the remaining portion of this appendix. To generate a distribution of discounts that matches empirical observations, we make two minor adjustments to our calibration. First, we set the fixed component of the management contract, a, equal to 0.0185. Second, we set the fund's initial wealth designated for investment, W_f, equal to 1.5, which ensures that the fund price does not turn negative in any of the simulations. All other parameter values remain the same.

Figure A.1 plots the issue premium and the manager's ex ante expected utility for various values of α and b. Similar to our featured model discussed in Section 1.2, the choice of b that maximizes
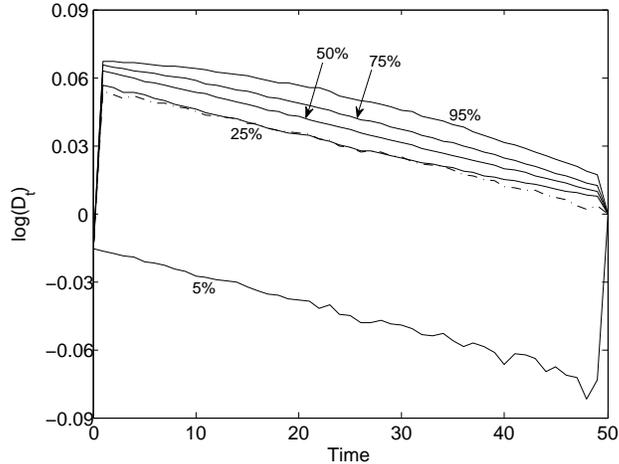
Figure A.2: Distribution of Closed-End Fund Discounts.

the manager's expected utility also maximizes the issue premium for a given level of ability, α, when the stock price is endogenously determined. The other results are also robust to an environment with an endogenous stock price. Figure A.2 plots the discount distribution, which is similar to the distribution of discounts in Figure 1.2. As Table A.I reveals, the time-series correlations between discounts and returns with an endogenous stock price are very similar to those obtained with an exogenous price process. Furthermore, our modified model produces an average correlation between changes in percentage discounts and the returns on the stock held by each fund equal to -0.016. It also yields an average correlation between changes in log premiums and NAV returns of -0.268. Both of these correlations are consistent with those generated by our featured model. Lastly, our modified model produces a log variance ratio of 0.462.

A.2 Endogenous Stock Price with Liquidity Traders

In this section, we evaluate the robustness of our results to a setting with an endogenous stock price and liquidity traders. We first outline our assumptions and present the new equilibrium. We then discuss the robustness of our results.

We make a few modifications to our original set of assumptions. First, we assume that there are $J \in \mathbb{N}$ stocks that each pay a different random amount at $T+1$. For simplicity, we assume that the manager's ability to acquire information is the same for each stock. This could result from, say, knowledge about a particular industry. Including additional risky assets about which the fund manager obtains an information advantage produces discounts that better quantitatively match empirical observations, but the number of assets does not affect the qualitative results. The payoff of each stock consists of the sum of independent and jointly normally distributed random variables; accordingly, the payoff vector[1] is defined as

$$\tilde{\mathbf{Y}} \equiv \sum_{t=1}^{T} \tilde{\mathbf{X}}_t, \tag{A.5}$$

where $\tilde{\mathbf{X}}_t \sim \mathcal{N}(\boldsymbol{\mu}_t, \boldsymbol{\Sigma}_t)$ for all $t \leq T$, $\boldsymbol{\mu}_t$ is a vector of expected payoffs, and $\boldsymbol{\Sigma}_t$ is a diagonal $J \times J$ covariance matrix. We also assume that the stock prices are endogenously determined rather

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[1]Unless otherwise noted, all bold symbols in this appendix denote a $J \times 1$ vector.

Table A.I: Average Correlation Coefficients.

	Premium$_\tau$	Fund Return$_\tau$	NAV Return$_\tau$
Premium$_{\tau-1}$	0.339		
Fund Return$_{\tau-1}$	0.504	-0.133	
Fund Return$_\tau$	-0.200		
Fund Return$_{\tau+1}$	-0.038		
NAV Return$_{\tau-1}$	0.005	-0.020	-0.021
NAV Return$_\tau$	0.345	0.707	
NAV Return$_{\tau+1}$	-0.039	0.238	

exogenously given by (1.44).

Second, to facilitate trade among the rational, asymmetrically informed agents, we assume that at the middle of every cycle liquidity traders demand a stochastic and unobservable amount of each stock denoted by $\tilde{\mathbf{k}}_n \sim \mathcal{N}\left(\mathbf{0}, \boldsymbol{\Sigma}_k\right)$ for all n, where $\mathbf{0}$ is a vector of zeros and $\boldsymbol{\Sigma}_k$ is a diagonal $J \times J$ covariance matrix.[2] The volatility of liquidity trades is constant across stocks, and σ_k^2 denotes this volatility for an individual stock. Furthermore, these liquidity shocks are independent across time and stocks. When solving the model, to maintain tractability we assume that the stock prices at the middle of cycle n are linear functions of

$$\mathbf{r}_n \equiv \mathbf{Z}_{n,1} + (1 - \alpha_q)\gamma_m b \boldsymbol{\Sigma}_{3n-1} \mathbf{k}_n. \tag{A.6}$$

Because $\mathbf{k}_n$ is unobservable, the stock prices serve as a noisy signal of $\mathbf{Z}_{n,1}$ but do not fully reveal its value. However, after observing $\mathbf{r}$ through $\mathbf{P}_{3n-1}^s$, the investor can update his beliefs about $\tilde{\mathbf{Z}}_{n,1}$ in a Bayesian fashion to form a posterior of the manager's private information which is normally distributed with mean

$$\left(\alpha_q \boldsymbol{\Sigma}_{3n-1} + (1 - \alpha_q)^2 \gamma_m^2 b^2 \boldsymbol{\Sigma}_{3n-1}^2 \boldsymbol{\Sigma}_k\right)^{-1} \alpha_q \left((1 - \alpha_q)^2 \gamma_m^2 b^2 \boldsymbol{\Sigma}_{3n-1}^2 \boldsymbol{\Sigma}_k \boldsymbol{\mu}_{3n-1} + \boldsymbol{\Sigma}_{3n-1} \mathbf{r}\right) \tag{A.7}$$

and variance

$$\left(\alpha_q \boldsymbol{\Sigma}_{3n-1} + (1 - \alpha_q)^2 \gamma_m^2 b^2 \boldsymbol{\Sigma}_{3n-1}^2 \boldsymbol{\Sigma}_k\right)^{-1} \alpha_q (1 - \alpha_q)^2 \gamma_m^2 b^2 \boldsymbol{\Sigma}_{3n-1} \boldsymbol{\Sigma}_{3n-1}^2 \boldsymbol{\Sigma}_k. \tag{A.8}$$

Despite the existence of liquidity traders, the basic techniques described in Section 1.2 can be used to solve this modified version of the model. Since information is symmetric and there are no liquidity trades at the end of each cycle, the equilibrium stock prices at the end of cycle n are analogous to the stock price in our original model and are given by

$$\mathbf{P}_{3n}^s = \sum_{\tau=1}^{3n-1} \mathbf{X}_\tau + \sum_{\tau=3n}^{T} \left(\boldsymbol{\mu}_{j,\tau} - \frac{\gamma_i \gamma_m}{\Gamma} \boldsymbol{\Sigma}_\tau \mathbf{1}\right), \tag{A.9}$$

where $\mathbf{1}$ is a vector of ones. Similarly, the stock allocations are given by

$$\mathbf{S}_{3n}^f = \gamma_i (\Gamma b)^{-1} \mathbf{1} \tag{A.10}$$

and

$$\mathbf{S}_{3n}^i = (\Gamma b - \gamma_i)(\Gamma b)^{-1} \mathbf{1}. \tag{A.11}$$

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[2]Since the sole purpose of the liquidity traders is to generate trade in an environment with asymmetric information, we assume that the liquidity traders do not trade when information is symmetric at the beginning and end of each cycle. This assumption eliminates unnecessary liquidity trader risk.

(a) Issue Premium   (b) Manager's Expected Utility
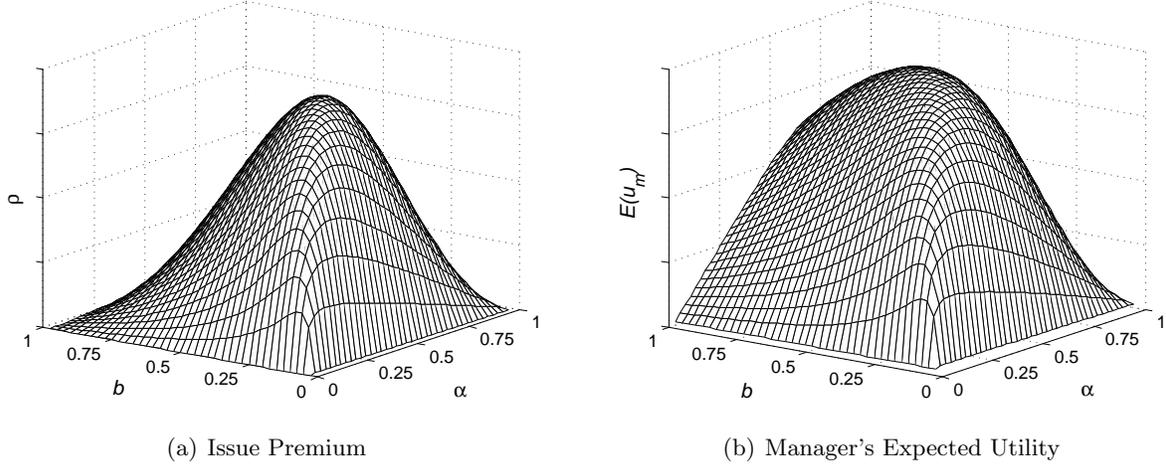
Figure A.3: Issue Premium and Expected Utility.

The future liquidity trades impact the fund price. In this setting, the weighted average of the investor's expected benefit from the manager's private information is given by

$$\bar{\delta} \equiv J \frac{\bar{\lambda}_\ell \Upsilon_\ell \Phi_\ell^{-J/2} + \bar{\lambda}_h \Upsilon_h \Phi_h^{-J/2}}{\Upsilon_\ell \Phi_\ell^{-J/2} + \Upsilon_h \Phi_h^{-J/2}}, \tag{A.12}$$

where

$$\bar{\lambda}_q \equiv \frac{\alpha_q(1-\alpha_q)(1-b)(\Gamma b - \gamma_i)\sigma_{3n-1}^2\sigma_k^2}{\alpha_q + (1-\alpha_q)\big(\alpha_q\gamma_i(1-b)(\Gamma b - \gamma_i + \gamma_m b) + (1-\alpha_q)\gamma_m^2 b^2\big)\sigma_{3n-1}^2\sigma_k^2} \tag{A.13}$$

and

$$
\begin{aligned}
\Phi_q \equiv &\frac{\alpha_q(1-\alpha_q)(1-bt)(\Gamma b - \gamma_i)\sigma_{3n-1}^2\sigma_k^2}{\bar{\lambda}_q\big(\alpha_q\Gamma + (1-\alpha_q)\gamma_m^2 b(\alpha_q\gamma_i + (1-\alpha_q)\Gamma b)\sigma_{3n-1}^2\sigma_k^2\big)^2} \\
&\times \big(\alpha_q\Gamma^2 + (1-\alpha_q)\gamma_m^2 b\big(2\alpha_q\gamma_i\Gamma + (1-\alpha_q)\Gamma^2 b + (1-\alpha_q)\gamma_i^2\gamma_m^2 b\sigma_{3n-1}^2\sigma_k^2\big)\sigma_{3n-1}^2\sigma_k^2\big).
\end{aligned} \tag{A.14}
$$

The discount at the end of cycle n has a similar form as in our original model and is given by

$$D_{3n} = a + b\big(V_{3n} - V_{3n-2}\big) - (N-n)\big(\bar{\delta} - a\big). \tag{A.15}$$

The greatest divergence between our original model and our modified model with liquidity traders occurs at the middle of each cycle. The stock price at the middle of cycle n is given by

$$\mathbf{P}_{3n-1}^s = \sum_{\tau=1}^{3n-2} \mathbf{X}_\tau + \sum_{\tau=3n}^{T} \Big(\boldsymbol{\mu}_\tau - \tfrac{\gamma_i\gamma_m}{\Gamma}\boldsymbol{\Sigma}_\tau\mathbf{1}\Big) + \boldsymbol{\theta}_{q1} + \boldsymbol{\theta}_{q2}\big(\mathbf{Z}_{n,1} + (1-\alpha_q)\gamma_m b\boldsymbol{\Sigma}_{3n-1}\mathbf{k}_n\big), \tag{A.16}$$

where

$$
\begin{aligned}
\boldsymbol{\theta}_{q0} &\equiv \alpha_q\Gamma\mathbf{I} + (1-\alpha_q)\gamma_m^2 b\big(\alpha_q\gamma_i + (1-\alpha_q)\Gamma b\big)\boldsymbol{\Sigma}_{3n-1}\boldsymbol{\Sigma}_k \\
\boldsymbol{\theta}_{q1} &\equiv (1-\alpha_q)\boldsymbol{\theta}_{q0}^{-1}\big(\alpha_q\mathbf{I} + (1-\alpha_q)\gamma_m^2 b^2\boldsymbol{\Sigma}_{3n-1}\boldsymbol{\Sigma}_k\big)\big(\Gamma\boldsymbol{\mu}_{3n-1} - \gamma_i\gamma_m\boldsymbol{\Sigma}_{3n-1}\mathbf{1}\big) \\
\boldsymbol{\theta}_{q2} &\equiv \boldsymbol{\theta}_{q0}^{-1}\big(\alpha_q\Gamma\mathbf{I} + (1-\alpha_q)\gamma_i\gamma_m^2 b\boldsymbol{\Sigma}_{3n-1}\boldsymbol{\Sigma}_k\big)
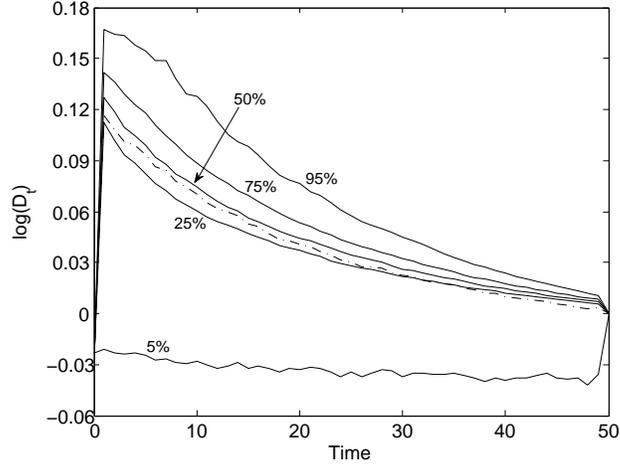\end{aligned}
$$

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Figure A.4: Distribution of Closed-End Fund Discounts.

and $\mathbf{I}$ is the identity matrix. The expressions for the stock allocations at the middle of cycle n are

$$\mathbf{S}^f_{3n-1} = \boldsymbol{\theta}^{-1}_{q0}\big((1-\alpha_q)\gamma_m\boldsymbol{\Sigma}_k\big((\Gamma b - \gamma_i)\big(\mathbf{Z}_{n,1} - \alpha_q\boldsymbol{\mu}_{3n-1}\big) + \gamma_i\gamma_m b\boldsymbol{\Sigma}_{3n-1}\mathbf{1}\big) + \alpha_q\tfrac{\gamma_i}{b}\mathbf{1}\big) - \boldsymbol{\theta}_{q2}\mathbf{k}_n \quad (A.17)$$

and

$$\mathbf{S}^i_{3n-1} = (\Gamma b - \gamma_i)\boldsymbol{\theta}^{-1}_{n0}\big((1-\alpha_q)\gamma_m\boldsymbol{\Sigma}_k\big(\alpha_q\boldsymbol{\mu}_{3n-1} - \mathbf{Z}_{n,1} + (1-\alpha_q)\gamma_m b\boldsymbol{\Sigma}_{3n-1}\big(\mathbf{1} - \mathbf{k}_n\big)\big) + \alpha_q\tfrac{1}{b}\mathbf{1}\big), \quad (A.18)$$

and the discount at the middle of cycle n is

$$D_{3n-1} = a - b(V_{3n-1} - V_{3n-2}) - J\bar{\lambda}_q - (N-n)\big(\bar{\delta} - a\big). \quad (A.19)$$

The expression for the stock prices at the beginning of each cycle are similar to the stock prices at the end of each cycle. At the beginning of cycle n, the equilibrium stock prices are given by

$$\mathbf{P}^s_{3n-2} = \sum_{\tau=1}^{3n-3} \mathbf{X}_\tau + \sum_{\tau=3n-2}^{T} \big(\boldsymbol{\mu}_{j,\tau} - \tfrac{\gamma_i\gamma_m}{\Gamma}\boldsymbol{\Sigma}_\tau\mathbf{1}\big), \quad (A.20)$$

and the stock allocations are given by (A.10) and (A.11). The discount at the beginning of cycle n is

$$D_{3n-2} = a - J\bar{\lambda}_q - (N-n)\big(\bar{\delta} - a\big). \quad (A.21)$$

Since most of the manager's private information about each individual stock is revealed to the investor through the equilibrium stock price, we must recalibrate our model to quantitatively match the distribution of discounts observed empirically. Unless otherwise noted, the parameter values remain the same as in our featured model discussed in Section 1.3.3. In this setting, we assume that the manager obtains private information about twenty stocks, so we set J equal to 20. We also set α_ℓ and α_h equal to 0.02 and 0.50, respectively. Additionally, the fixed component of the management contract, a, now equals 0.06.

Figure A.3 plots the issue premium and the manager's ex ante expected utility for various values of α and b when $J = 1$. For many ability levels, the choice of b that maximizes the manager's expected utility also maximizes the issue premium. For some relatively high levels of α, though, there is no value of b that maximizes both the manager's expected utility and issue

Table A.II: Average Correlation Coefficients.

	Premium$_\tau$	Fund Return$_\tau$	NAV Return$_\tau$
Premium$_{\tau-1}$	0.613		
Fund Return$_{\tau-1}$	0.197	0.016	
Fund Return$_\tau$	−0.152		
Fund Return$_{\tau+1}$	−0.170		
NAV Return$_{\tau-1}$	−0.059	−0.004	0.001
NAV Return$_\tau$	0.152	0.851	
NAV Return$_{\tau+1}$	−0.149	0.196	

premium. However, in these cases the utility-maximizing choice of b still leads to relatively large issue premiums.

The distribution of discounts with liquidity traders is comparable to the distribution from our featured model and is depicted in Figure A.4. Likewise, the time-series correlations between discounts and returns are also robust to an environment with liquidity traders, as evidenced by Table A.II. Moreover, the average correlation between changes in percentage discounts and the returns on the stocks held by a fund is −0.054 while the average correlation between changes in log premiums and NAV returns is −0.199. Finally, the log variance ratio is 0.105.

Appendix B

Activist Arbitrage, Lifeboats, and Closed-End Funds

B.1 Discounts and Parameter Values

Table B.I: Summary of Discounts. The appropriate equation for the discount under a variety of circumstances is listed. The "Substitution" column denotes the proper adjustment to make to the superscript on the $\tilde{D}_{t+1}$ variable.

Scenario	Equation	Substitution	
		Out	In
Panel A: Activist and Lifeboat Absent			
All scenarios	(2.6)	-	-
Panel B: Activist Present and Lifeboat Absent			
Current attempt and $D_t \in (\theta_\kappa, \kappa)$	(2.9)	-	-
Current attempt and $D_t \leq \theta_\kappa$	(2.10)	-	-
Current attempt and $D_t \geq \kappa$	(2.10)	A	$\neg A$
No attempt and $D_t \in (\theta_\kappa, \kappa)$	(2.11)	-	-
No attempt and $D_t \leq \theta_\kappa$	(2.6)	$\emptyset$	A
No attempt and $D_t \geq \kappa$	(2.6)	$\emptyset$	$\neg A$
Panel C: Lifeboat Present and Activist Absent			
MDP adopted	(2.16)	-	-
MDP not adopted and $D_t \in (\theta_\lambda, \lambda)$	(2.17)	-	-
MDP not adopted and $D_t \leq \theta_\lambda$	(2.6)	$\emptyset$	δ
MDP not adopted and $D_t \geq \lambda$	(2.6)	$\emptyset$	$\neg\delta$

Table B.II: Summary of Discounts with Activist and Lifeboat. The appropriate equation for the discount under a variety of circumstances is listed. In general, the "Substitution" column denotes the proper adjustment to make to the superscript on the $\tilde{D}_{t+1}$ variable. For the case where $D_t \in (\theta_\lambda, \kappa)$, the "Substitution" column indicates that q should equal zero.

Scenario	Equation	Substitution Out	Substitution In
Panel A: MDP Previously Adopted			
Current attempt and $D_t \in (\theta_\kappa, \kappa)$	(2.18)	-	-
Current attempt and $D_t \leq \theta_\kappa$	(2.21)	-	-
Current attempt and $D_t \geq \kappa$	(2.21)	δA	$\delta \neg A$
No attempt and $D_t \in (\theta_\kappa, \kappa)$	(2.22)	-	-
No attempt and $D_t \leq \theta_\kappa$	(2.16)	δ	δA
No attempt and $D_t \geq \kappa$	(2.16)	δ	$\delta \neg A$
Panel B: MDP Not Adopted			
Current attempt and $D_t \leq \min\{\theta_\kappa, \theta_\lambda\}$	(2.10)	A	δA
Current attempt and $D_t \in (\theta_\kappa, \theta_\lambda)$	(2.9)	A	δA
		$\neg A$	$\delta \neg A$
Current attempt and $D_t \in (\theta_\lambda, \theta_\kappa)$	(2.19)	$\delta \neg A$	δA
		$\neg \delta A$	$A \neg \delta$
Current attempt and $D_t \in (\kappa, \theta_\lambda)$	(2.10)	A	$\delta \neg A$
Current attempt and $D_t \in (\lambda, \theta_\kappa)$	(2.10)	A	$A \neg \delta$
Current attempt and $D_t \in (\theta_\lambda, \kappa)$	(2.20)	-	-
Current attempt and $D_t \in (\kappa, \lambda)$	(2.19)	-	-
Current attempt and $D_t \in (\lambda, \kappa)$	(2.9)	A	$A \neg \delta$
		$\neg A$	$\neg \delta A$
Current attempt and $D_t \geq \max\{\kappa, \lambda\}$	(2.10)	A	$\neg \delta A$
No attempt and $D_t \leq \min\{\theta_\kappa, \theta_\lambda\}$	(2.6)	$\emptyset$	δA
No attempt and $D_t \in (\theta_\kappa, \theta_\lambda)$	(2.11)	A	δA
		$\neg A$	$\delta \neg A$
No attempt and $D_t \in (\theta_\lambda, \theta_\kappa)$	(2.17)	δ	δA
		$\neg \delta$	$A \neg \delta$
No attempt and $D_t \in (\kappa, \theta_\lambda)$	(2.6)	$\emptyset$	$\delta \neg A$
No attempt and $D_t \in (\lambda, \theta_\kappa)$	(2.6)	$\emptyset$	$A \neg \delta$
No attempt and $D_t \in (\theta_\lambda, \kappa)$	(2.20)	q	0
No attempt and $D_t \in (\kappa, \lambda)$	(2.17)	δ	$\delta \neg A$
		$\neg \delta$	$\neg \delta A$
No attempt and $D_t \in (\lambda, \kappa)$	(2.11)	A	$A \neg \delta$
		$\neg A$	$\neg \delta A$
No attempt and $D_t \geq \max\{\kappa, \lambda\}$	(2.6)	$\emptyset$	$\neg \delta A$

Table B.III: Parameter Values.

Variable	Symbol	Value
Time horizon	T	25
Expected return	μ	0.025
Low excess return	α_ℓ	0
High excess return	α_h	0.1
Prior "success" parameter	a_1	1
Prior "failure" parameter	b_1	1
Excess return scale factor	γ_1	1
Management fee	ϕ	0.02
Excess return adjustment threshold	Υ	0.023775
Cost of attack	c	0.04
Probability of liquidation	q	0.60
Liquidation probability scale factor	σ	1/9
Liquidation probability scale factor	η	2/3
Dividend rate	δ	0.09
Lifeboat trigger	λ	0.90
Approval threshold	θ_λ	0.80

B.2 Proofs

Proof of Proposition 1. At every point in time, the expected return for the fund must equal the market expected rate of return. Therefore,

$$
\begin{aligned}
1 + \mu &= E_t \left[\tilde{R}_{t+1}^f \right] \\
&= E_t \left[\tilde{P}_{t+1} \right] / P_t \\
&= E_t \left[\tilde{D}_{t+1} \tilde{V}_{t+1} \right] / P_t \\
&= E_t \left[\tilde{D}_{t+1} \left(M + \tilde{\alpha}_{t+1} \right) \right] V_t / P_t,
\end{aligned}
$$

which can be solved for D_t to obtain the desired result. The second equality follows from (2.5), the third equality follows from (2.2), and the final equality follows from (2.3) and the lack of serial correlation and cross-correlation between the return on the fund's portfolio and the excess return generated by the fund manager. □

Proof of Proposition 2. At every point in time, the expected return for the fund must equal the market expected rate of return. Therefore,

$$
\begin{aligned}
1 + \mu &= E_t \left[\tilde{R}^f_{t+1} \right] \\
&= E_t \left[\tilde{P}_{t+1} \right] / P_t \\
&= \frac{q}{P_t} E_t \left[\tilde{V}_{t+1} \right] + \frac{1-q}{P_t} \left(\rho_\kappa E_t \left[\tilde{D}^A_{t+1} \tilde{V}_{t+1} \right] + (1 - \rho_\kappa) E_t \left[\tilde{D}^{\neg A}_{t+1} \tilde{V}_{t+1} \right] \right) \\
&= q \frac{V_t}{P_t} E_t \left[M + \gamma_t \tilde{\alpha}_{t+1} \right] + (1 - q) \frac{V_t}{P_t} \left(\frac{\kappa - D_t}{\kappa - \theta_\kappa} E_t \left[\tilde{D}^A_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} \right) \right] \right. \\
&\quad \left. + \frac{D_t - \theta_\kappa}{\kappa - \theta_\kappa} E_t \left[\tilde{D}^{\neg A}_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} \right) \right] \right),
\end{aligned}
\tag{B.1}
$$

which can be solved for D_t to obtain the desired result. The third equality follows from (2.2) while the final equality follows from (2.7), (2.8), and the lack of serial correlation and cross-correlation between the return on the fund's portfolio and the excess return generated by the fund manager. □

Proof of Proposition 3. At every date, the expected return on the fund must equal the market expected rate of return. For (i), this implies

$$
\begin{aligned}
1 + \mu &= E_t \left[\tilde{R}^f_t \right] \\
&= E_t \left[\tilde{P}_{t+1} + d_{t+1} \right] / P_t \\
&= E_t \left[\tilde{D}^\delta_{t+1} \tilde{V}_{t+1} + d_{t+1} \right] / P_t \\
&= \frac{V_t}{P_t} E_t \left[\tilde{D}^\delta_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} - \delta \right) + \delta \right],
\end{aligned}
$$

which can be solved for D_t to obtain the desired result. The second equality follows from (2.15), the third equality follows from (2.2), and the final equality follows from (2.12), (2.13), and the lack of serial correlation and cross-correlation between the return on the fund's portfolio and the excess return generated by the fund manager.

Similarly, the implication for (ii) is

$$
\begin{aligned}
1 + \mu &= E_t \left[\tilde{R}^f_t \right] \\
&= E_t \left[\tilde{P}_{t+1} \right] / P_t \\
&= \frac{\rho_\lambda}{P_t} E_t \left[\tilde{D}^\delta_{t+1} \tilde{V}_{t+1} \right] + \frac{1 - \rho_\lambda}{P_t} E_t \left[\tilde{D}^{\neg \delta}_{t+1} \tilde{V}_{t+1} \right] \\
&= \frac{V_t}{P_t} \left(\frac{\lambda - D_t}{\lambda - \theta_\lambda} E_t \left[\tilde{D}^\delta_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} \right) \right] + \frac{D_t - \theta_\lambda}{\lambda - \theta_\lambda} E_t \left[\tilde{D}^{\neg \delta}_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} \right) \right] \right),
\end{aligned}
\tag{B.2}
$$

which can solved for D_t to obtain the desired result. The third equality follows from (2.2) while the final equality follows from (2.3), (2.14), and the lack of serial correlation and cross-correlation between the return on the fund's portfolio and the excess return generated by the fund manager. □

Proof of Proposition 4. At every date, the expected return for the fund must equal the market expected rate of return. For (i), this implies

$$
\begin{aligned}
1 + \mu &= E_t \left[\tilde{R}^f_{t+1} \right] \\
&= E_t \left[\tilde{P}_{t+1} + d_{t+1} \right] / P_t \\
&= \frac{q}{P_t} E_t \left[\tilde{V}_{t+1} + d_{t+1} \right] + \frac{1-q}{P_t} \left(\rho_\kappa E_t \left[\tilde{D}^{\delta A}_{t+1} \tilde{V}_{t+1} + d_{t+1} \right] + (1 - \rho_\kappa) E_t \left[\tilde{D}^{\delta \neg A}_{t+1} \tilde{V}_{t+1} + d_{t+1} \right] \right)
\end{aligned}
\tag{B.3}
$$

$$
\begin{aligned}
&= \delta \frac{V_t}{P_t} + q \frac{V_t}{P_t} E_t \left[M + \gamma_t \tilde{\alpha}_{t+1} - \delta \right] \\
&\quad + (1-q) \frac{V_t}{P_t} \left(\frac{\kappa - D_t}{\kappa - \theta_\kappa} E_t \left[\tilde{D}^{\delta A}_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} - \delta \right) \right] + \frac{D_t - \theta_\kappa}{\kappa - \theta_\kappa} E_t \left[\tilde{D}^{\delta \neg A}_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} - \delta \right) \right] \right),
\end{aligned}
$$

which can be solved for D_t to obtain the desired result. The second equality follows from (2.15), the third equality follows from (2.2) while the final equality follows from (2.8), (2.12), (2.13) and the lack of serial correlation and cross-correlation between the return on the fund's portfolio and the excess return generated by the fund manager.

The implication for (ii) is

$$
\begin{aligned}
1 + \mu &= E_t \left[\tilde{R}^f_{t+1} \right] \\
&= E_t \left[\tilde{P}_{t+1} \right] / P_t \\
&= \frac{q}{P_t} E_t \left[\tilde{V}_{t+1} \right] + \frac{1-q}{P_t} \left(\rho_\lambda E_t \left[\tilde{D}^{\delta \neg A}_{t+1} \tilde{V}_{t+1} \right] + (1 - \rho_\lambda) E_t \left[\tilde{D}^{\neg \delta A}_{t+1} \tilde{V}_{t+1} \right] \right) \\
&= q \frac{V_t}{P_t} E_t \left[M + \gamma_t \tilde{\alpha}_{t+1} \right] + (1-q) \frac{V_t}{P_t} \left(\frac{\lambda - D_t}{\lambda - \theta_\lambda} E_t \left[\tilde{D}^{\delta \neg A}_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} \right) \right] \right. \\
&\quad \left. + \frac{D_t - \theta_\lambda}{\lambda - \theta_\lambda} E_t \left[\tilde{D}^{\neg \delta A}_{t+1} \left(M + \gamma_t \tilde{\alpha}_{t+1} \right) \right] \right),
\end{aligned}
\tag{B.4}
$$

which can be solved for D_t to obtain the desired result. The second equality follows from (2.5), the third equality follows from (2.2) and (2.7) while the final equality follows from (2.3), (2.14), and the lack of serial correlation and cross-correlation between the return on the fund's portfolio and the excess return generated by the fund manager.

For (iii),

$$
\begin{aligned}
1 + \mu &= E_t\left[\tilde{R}^f_{t+1}\right] \\
&= E_t\left[\tilde{P}_{t+1}\right]/P_t \\
&= \frac{q}{P_t} E_t\left[\tilde{V}_{t+1}\right] + \frac{1-q}{P_t}\left[\rho_\lambda\left(\rho_\kappa E_t\left[\tilde{D}^{\delta A}_{t+1}\tilde{V}_{t+1}\right] + (1-\rho_\kappa) E_t\left[\tilde{D}^{\delta\neg A}_{t+1}\tilde{V}_{t+1}\right]\right)\right. \\
&\qquad \left. + (1-\rho_\lambda)\left(\rho_\kappa E_t\left[\tilde{D}^{A\neg\delta}_{t+1}\tilde{V}_{t+1}\right] + (1-\rho_\kappa) E_t\left[\tilde{D}^{\neg\delta A}_{t+1}\tilde{V}_{t+1}\right]\right)\right] \\
&= q\frac{V_t}{P_t} E_t\left[M + \gamma_t\tilde{\alpha}_{t+1}\right] \\
&\quad + (1-q)\frac{V_t}{P_t}\left[\frac{\lambda - D_t}{\lambda - \theta_\lambda}\left(\frac{\kappa - D_t}{\kappa - \theta_\kappa} E_t\left[\tilde{D}^{\delta A}_{t+1}\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right] + \frac{D_t - \theta_\kappa}{\kappa - \theta_\kappa} E_t\left[\tilde{D}^{\delta\neg A}_{t+1}\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right]\right)\right. \\
&\qquad \left. + \frac{D_t - \theta_\lambda}{\lambda - \theta_\lambda}\left(\frac{\kappa - D_t}{\kappa - \theta_\kappa} E_t\left[\tilde{D}^{A\neg\delta}_{t+1}\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right] + \frac{D_t - \theta_\kappa}{\kappa - \theta_\kappa} E_t\left[\tilde{D}^{\neg\delta A}_{t+1}\left(M + \gamma_t\tilde{\alpha}_{t+1}\right)\right]\right)\right],
\end{aligned}
$$

which can be rearranged to obtain $xD_t^2 + yD_t + z = 0$, where x, y, and z are defined in the Proposition. The second equality follows from (2.5), the third equality follows from (2.2) and (2.7) while the final equality follows from (2.3), (2.8), (2.14), and the lack of serial correlation and cross-correlation between the return on the fund's portfolio and the excess return generated by the fund manager. $\qquad\square$

Appendix C

Advance Disclosure of Insider Trading

Proof of Corollary 1. Without advance disclosure,

$$
\begin{aligned}
\Sigma &= \big(\mathbb{V}\big[\tilde{Y}|P\big]\big)^{-1} \\
&= \big(\mathbb{V}\big[\theta^2 \tilde{S}_1^m + \tilde{X}_1 + \tilde{X}_2|P\big]\big)^{-1} \\
&= \left(\frac{\gamma^2 \sigma_1^2 \sigma_2^4 \sigma_k^2 \sigma_\varepsilon^2}{(1+N_d)^2 \sigma_1^2 \big(\sigma_k^2 + \sigma_\varepsilon^2\big) + \sigma_k^2 \sigma_\varepsilon^2 \big(\gamma \sigma_2^2 - \theta^2\big)^2} + \sigma_2^2 \right)^{-1} \\
&= \frac{\Gamma_3}{\Gamma_4 \sigma_2^2},
\end{aligned}
$$

where the second equality follows from (3.1), (3.15), and the fact that S_1^m is a function of $\tilde{X}_1$, the third equality follows from (3.16) and (3.22), and the last equality is a product of algebra.

On the other hand, with advance disclosure,

$$
\begin{aligned}
\hat{\Sigma} &= \big(\mathbb{V}\big[\tilde{\hat{Y}}|\hat{S}_1^m\big]\big)^{-1} \\
&= \big(\mathbb{V}\big[\tilde{X}_1 + \tilde{X}_2|\hat{S}_1^m\big]\big)^{-1} \\
&= \left(\frac{\rho^2 \sigma_1^2 \sigma_\varepsilon^2}{\sigma_1^2 + \rho^2 \sigma_\varepsilon^2} + \sigma_2^2 \right)^{-1} \\
&= \frac{\sigma_1^2 + \rho^2 \sigma_\varepsilon^2}{\rho^2 \sigma_1^2 \sigma_\varepsilon^2 + \big(\sigma_1^2 + \rho^2 \sigma_\varepsilon^2\big)\sigma_2^2},
\end{aligned}
$$

where the second equality follows from (3.1) and the fact that $\hat{S}_1^m$ is observed by the market, the third equality follows from from (3.52), and the last equality is a consequence of algebra. $\qquad \square$

Proof of Corollary 2. To find the expected payoff without advance disclosure, we substitute the manager's action strategy, (3.15), and stock holdings, (3.8), into the stock payoff, (3.1), and integrate over $\tilde{X}_2$. We then subtract the stock price, (3.6), substitute (3.4) for h_i, and integrate over $\tilde{X}_1$, $\tilde{k}$, and $\tilde{\varepsilon}_i$ to obtain the average risk premium, which is given by (3.66). Likewise, the average risk premium with advance disclosure is derived by first substituting (3.35) and (3.42) into (3.1) and integrating over $\tilde{X}_2$. Then, (3.33) is subtracted, (3.3) is substituted for h_m, and the resulting expression is integrated over $\tilde{X}_1$, $\tilde{k}$, and $\tilde{\varepsilon}_m$, yielding (3.67). $\qquad \square$

Proof of Corollary 3. The expressions follow immediately from substituting $h_i = k + \varepsilon_i$ into (3.6) and $h_m = k + \varepsilon_m$ into (3.33) and differentiating with respect to k. $\qquad \square$

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