Closed-End Funds: A Dynamic Model of Premiums and Discounts

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ABSTRACT

Closed-end funds have been a topic of interest among finance academics and professionals on five counts. First, they tend to sell above their net asset value at their commencement. Second, they start selling at a discount within a year. Third, this discount is volatile but mean-reverting. Fourth, the news of open-ending a fund reduces the discount although some discount persists till the actual event of open-ending. Fifth, the volatility of the return on a fund's price is higher than the volatility of the return on its underlying net asset value. In this paper, we develop a dynamic model that helps explain these empirical regularities. We predict a systematic pattern of premiums and discounts. Using numerical techniques, we approximate the manager's optimal investment strategy in the presence of other informed investors and an extraneous policy restriction. We analyze the effect of this strategy on the fund's discount.

1 Introdution

The life-cycle of a closed-end fund can be characterized by five main empirical regularities. These regularities form the five pieces of the long standing closed-end fund puzzle.

- Closed-end funds start out at a premium of about 10%, when organizers raise money from new investors and use it to purchase securities (Weiss, 1989; Peavy, 1990).
- Although the funds start at a premium, on average they move to a 10% discount within 120 days of the beginning of their trading (Weiss, 1989).
- Discounts to closed-end funds are subject to wide fluctuations that appear to be mean reverting (Thompson, 1978; Richards, Fraser and Groth, 1980; Anderson, 1986; Brauer, 1988).
- When closed-end funds are terminated through either open-ending or liquidation, share prices rise and the discount shrinks (Brauer, 1984; Brickley and Schalheim, 1985). A small discount persists till the final termination.
- The volatility of the return on a fund's price is higher than that on its underlying net asset value (Pontiff, 1997).

The existence of this five-piece puzzle has troubled the finance community for some time. There are six broad lines of explanations for this phenomenon: illiquidity of assets, tax liabilities, market sentiments, finite lived agents and random asset supplies, market segmentation and heterogeneous agents, and agency costs.

The illiquidity of assets explanation is that the calculations of the fund's net asset value (henceforth NAV) ignore the liquidity cost and therefore over-value the worth of the underlying assets. This explanation, in general, has scarce empirical support. In fact it is found that many of the large funds that trade at a discount have only liquid publicly traded securities (Lee, Shleifer, and Thaler, 1991). The proponents of tax liabilities argue that the NAV does not reflect the capital gains tax that must be paid by the fund if the assets in the fund are sold (Bierman and Swaminathan, 2000). This argument may not explain the existence of premiums in some of the funds. The behaviorists support the idea that market sentiment governs the fluctuations in fund discounts. There is mixed evidence for this argument. Lee, Shleifer, and Thaler (1991) find support for it while their arguments are later countered by Chen, Kan, and Miller (1993). Swaminathan (1996) finds that closed-end fund discounts and future excess returns on small firms are positively correlated, thus suggesting that closed-end fund discounts contain information on economic fundamentals.

Chordia and Swaminathan (1996) show the existence of discounts in the presence of market segmentation and information asymmetry. Spiegel (1999) demonstrates that if agents have finite lives and asset supplies are random, then one can have a systematic pattern of discounts as an equilibrium. Although in this model, an initial premium can be attained as a randomly realized state of nature, it is not clear why one should expect it on an *ex ante* basis.[1]

Finally, the existing literature has touched upon the impact of agency problems on fund management (Boudreaux, 1973) without much success. The criticism of this approach has been on three grounds. First, it does not explain why investors buy the fund at a premium. Second, it fails to account for the cross-sectional variation among discounts. Third, it does not explain why there are such wide fluctuations in the discounts.

In this paper, we seek to revive the issue of agency problems in closed-end fund management and address the above criticisms. The agency cost that we discuss is of a very specific nature. A fund manager has an incentive to expand the asset base since his salary is proportional to the NAV. This implies that he would never want to return money to his investors and reduce his NAV. Instead, he would prefer to invest as much as he can, even if it is sub-optimal for the fund performance. This problem is compounded by the policy restrictions that limit his investment opportunities. These fund policies act as contracting mechanisms to prevent a deviation by the manager from the level of risk that the shareholders want him to take.[2] Brown, Harlow, and Starks (1996) and Chevalier and Ellison (1997) show that fund advisors have incentives to affect levels of risk different from investor preferences. Fama and Jensen (1983a, b) argue that contractual constraints can mitigate conflicts between contracting parties. In the context of fund management, contractual limits on the set of allowed investments serve such a purpose. Grinblatt and Titman (1989) argue that when fund advisors have adverse incentives to manipulate risk levels, contracts should include covenants

[1]Some funds like Turkish Investment continue to trade at a premium for long periods of time. In addition, Khorana, Wahal and Zenner (2002) find that closed-end funds announce rights usually when they trade at a premium. Over the course of the offering, this premium turns into a discount.

[2]See Appendix A for examples.

that specify permissible portfolio strategies.

However, limiting the set of manager's investment strategies involves opportunity costs. If there is very good news that calls for a lot of investment, the manager has to miss out some of this opportunity since he can leverage his NAV only to a certain extent. If there is very bad news, he is obligated to invest in some risky stocks due to policy constraints. Usually the management earns a fee of about 1% of the NAV. It is therefore in the best interest of the manager to keep the NAV high. A fund manager would not invest the fund's money exactly as he would if it had been his own money. If it were the case, then the manager, after investing optimally, would return all the uninvested amount to the investors. This would decrease the NAV and therefore hurt his compensation. A similar agency problem in the context of project management has been analyzed extensively by Stulz (1990), Stein (1997), and others. In their context, managers derive extra benefits by investing the money even if they have run out of good projects and have to invest in negative NPV projects. For a fund manager, deviating from the optimal trade or overinvesting due to non-informational reasons such as the fund policy restrictions represents an agency problem. This problem hurts the fund because the manager cannot credibly communicate to the market maker that his overinvestment is due to policy restrictions rather than private information, which adversely affects the stock price. As the NAV grows, the manager's overinvestment increases. The negative effect from the manager's overinvestment might exceed his informational advantage, thereby resulting in a discount. The market is rational in expecting this problem associated with a large NAV. Therefore it offers a smaller NAV to be managed initially. As a result, the policy constraint at this stage is not so binding as to dominate the informational gain of the manager, resulting in a premium in the beginning.

The main objective of this paper is to develop a dynamic model that studies these issues and helps explain the empirical regularities associated with closed-end funds. In order to analyze the cost of non-optimal (over) investments in risky assets, it is important to endogenize the price formation so that the impact of adverse trading can be assessed. Therefore, we formulate a model that is similar to the seminal model developed by Kyle (1985). Our problem is more complicated because the manager has a policy constraint on him. This constraint makes closed-form solutions unobtainable. Without invoking a specific solution form for the model, we first derive some general results that help explain qualitatively most of the aforementioned empirical puzzles. We predict that a closed-end fund starts selling at a premium that can turn into a discount later on. In order to provide a specific resolution, we solve our constrained-Kyle problem numerically using the projection techniques introduced by Judd (1992).

The rest of the paper is arranged as follows. Section 2 presents a two-period one-asset model. Section 3 discusses the general results of the model. Section 4 presents the empirical implications of the model. Section 5 uses a simplifying assumption based on the results of our numerical calculations and obtains some closed-form results. Section 6 assumes a myopic manager and extends the model to incorporate multiple assets. Section 7 concludes. The fund history and the events that led to some strict fund policies that aim to tie down managers' hands are provided in Appendix A. Our main model in the next section does not possess analytical solutions because of the policy constraints on the fund manager. The techniques used to solve the main model numerically are nontrivial and are presented in Appendix B. This appendix also discusses the non-linear equilibria that we attain as our solutions.

2 The Model

In our two-period economy, there exists a fund manager who manages a fund by investing in a risky asset.[3] The risky asset has a payoff $\tilde{v}$ given by the sum of a constant μ and two independent, zero-mean, news signals $\tilde{n}_0$ and $\tilde{n}_1$,

$$\tilde{v} = \mu + \sum_{t=0}^{1} \tilde{n}_t. \tag{1}$$

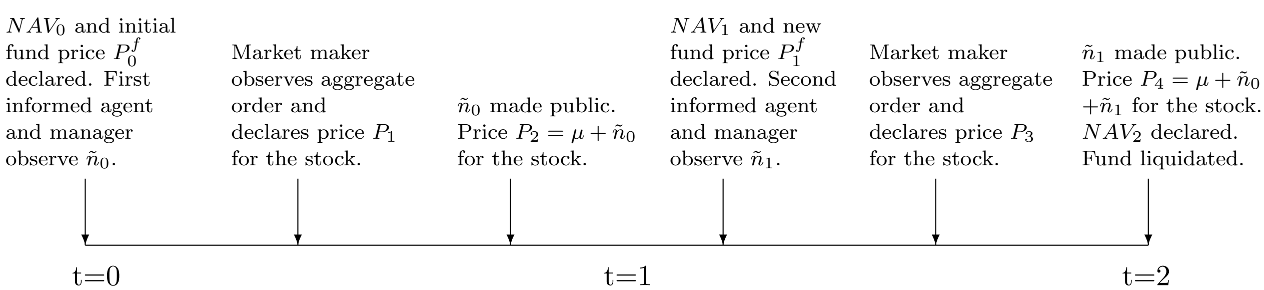

Figure 1. Sequence of events

[3] We extend our model to a two-asset economy in Appendix B and to a multi-asset economy with a myopic manager in Section 6.

In each period, there is an informed trader who observes the next period's news perfectly. The informed trader in the first period maximizes his profits over the first period by trading optimally. Another informed trader enters in the second period and maximizes his wealth over the second period. Unlike the informed traders, the manager is informed in both periods and solves his maximization problem over two periods. There are two competitive market makers: one for the risky asset and one for the fund. All agents are risk neutral.

The fund is formed with the intent of raising an initial NAV_0. The (fund) market maker declares the price P_0^f at which this NAV_0 is raised. At the beginning of the second period (t = 1), the NAV is declared again and based on this new NAV, the market maker for the fund will declare the new fund price P_1^f. The risky asset is traded during the period after the news has been observed by the informed traders. The fund is traded prior to the observation of news by the informed traders. Assume that there is no informed trading in the closed-end fund.[4]

In the first period, after the fund price has been declared, the manager and the informed trader observe the first piece of news which is made public at the end of the period after trading is completed. Once this news is made public, everybody is equally informed and the price is updated accordingly to $P_2 = \mu + \tilde{n}_0$. The new NAV is calculated based on this new price and is made public. The manager now has the option to either return a part of the new NAV to the shareholders or to invest at least a certain fraction γ of the NAV back in the risky asset.[5] At the beginning of the second period, after the new fund price has been declared and all liquidity traders in funds have readjusted their holdings, the manager and the informed trader see the second piece of news and trade accordingly. The equilibrium price attained in this period is denoted as P_3. This news and the final payoff are made public at the end of the second period. At this time the fund and the risky asset are liquidated.

We denote the manager's and the informed trader's demands for the risky stock at time t (t = 0 or 1) as X_t and Y_t, respectively. In addition, we assume that there is a liquidity demand denoted as $\tilde{Z}_t$, where $\tilde{Z}_t$ is independent of $\tilde{n}_t$ (t = 0 or 1) and is distributed with mean zero and variance

[4]This assumption shall be validated in Section 6 by assuming a large number of assets and restricting the informational advantage of traders to a maximum of one asset. In the presence of a small transaction cost, it shall be shown that the informed traders will not trade in the fund.

[5]We shall demonstrate in Theorem 1 that the manager will never return money to shareholders for agency reasons.

σ_z^2. Denote the aggregate demand for the risky stock as $\omega_t = X_t + Y_t + \tilde{Z}_t$.

The manager is bound by some fund policies to invest at least a certain percentage of the NAV in risky assets.[6] Each fund claims to specialize in certain category of assets and therefore has to invest at least a certain fraction of its total net assets in those assets. Since his holdings are revealed after each period, if his portfolio is seen as mostly against the stated policy, his reputation might be tarnished and he might be liable to a legal action against him. So, for his reputation and legal concerns, we assume that the manager is obligated to invest according to the fund policy.[7]

In our model the manager is faced with a two-period dynamic problem which he solves through backward induction. We assume that he is paid a fraction of the NAV at the end of each period.[8]

At time t = 1, the manager's problem is the following:

$$\max_{X_1} E\left[NAV_2 \mid \tilde{v}, NAV_1\right] \tag{2}$$

subject to

$$E\left[X_1 P_3 \mid \tilde{v}, NAV_1\right] \geq \gamma NAV_1, \tag{3}$$

$$NAV_2 = NAV_1 + X_1 (\tilde{v} - P_3). \tag{4}$$

The policy constraint (3) ensures that the manager puts at least a fraction γ in the risky asset on an expected basis.[9] The budget constraint (4) is the law of motion for the NAV of the fund.

The (second period) informed trader solves

$$\max_{Y_1} E\left[Y_1 (\tilde{v} - P_3) \mid \tilde{v}\right]. \tag{5}$$

[6] This assumption is based on our study of closed-end funds in *Morning Star Closed-end Funds* (1996). For an example, refer to the All-Market Advantage Fund policy quoted in Appendix A.

[7] We also assume that the fund has a sufficiently large cost to interim liquidation, i.e., once formed, the fund can be liquidated only after the second period. Dismantling or open-ending needs the support of the majority of shareholders. This implies a free-rider problem and in equilibrium, nobody will act towards dismantling of the fund.

[8] Of the 380 funds reviewed in *Morningstar Closed-End Funds* (1996), nearly all of them had compensation structure of this nature. A similar compensation structure has been observed in most empirical literature on closed-end funds. See, e.g., Coles, Suay and Woodbury (2000). Since the investors of the fund do not observe any signals, optimal contracting is extremely challenging. Our basic results hold as long as the manager is compensated a non-zero fraction of the NAV.

[9] Since the manager does not know the stock price P_3 when he submits his order X_1, the policy constraint can only be satisfied on an expected basis.

Note that, unlike the manager, the informed trader is assumed to trade for his own account and therefore faces no policy constraints.

Therefore, at t = 0, the manager's problem is the following:

$$\max_{X_0} E\left[NAV_1 + E[NAV_2 \mid \tilde{v}, NAV_1] \mid \tilde{n}_0, NAV_0\right], \tag{6}$$

subject to

$$E\left[X_0\, P_1 \mid \tilde{n}_0, NAV_0\right] \geq \gamma\, NAV_0, \tag{7}$$

$$NAV_1 = NAV_0 + X_0\, (\mu + \tilde{n}_0 - P_1). \tag{8}$$

Taking the manager's expected payoff in the second period as a given function of the state variables NAV_1 and $\tilde{v}$, i.e.,

$$E[NAV_2 \mid \tilde{v}, NAV_1] = NAV_1 + f(NAV_1, \tilde{v}), \tag{9}$$

the objective function (6) becomes

$$\max_{X_0} E\left[2\, NAV_1 + f(NAV_1, \tilde{v}) \mid \tilde{n}_0, NAV_0\right], \tag{10}$$

subject to the same constraints as before. The two periods are inter-linked due to the manager's getting an interim payment, which is a fraction of the NAV at the end of the first period. The second period works like the Kyle (1985) one-period problem with the exception of the policy constraint for the manager. The first period is more difficult to solve because $f(\cdot, \cdot)$ is of an unknown form.

The (first period) informed trader's maximization problem at time t = 0 is the following:

$$\max_{Y_0} E\left[Y_0\, (\mu + \tilde{n}_0 - P_1) \mid \tilde{n}_0\right]. \tag{11}$$

The (stock) market maker is competitive and will therefore price the stock in each period such that

$$P(\omega_t) = E[\tilde{v} \mid \omega_t]. \tag{12}$$

Because of the policy constraint on the manager, our problem does not have a closed-form solution and we will solve it numerically by using the following strategy. We will first solve the second-period problem by approximating functional forms for the various agents in the economy.

We will next approximate the manager's value function for the second period in terms of NAV_1 and $\tilde{v}$. We will then solve the first period problem. The details are provided in Appendix B.

However, even without invoking the specific numerical techniques, we are able to derive some general properties of the model. We demonstrate that these general properties help explain qualitatively most of the puzzles associated with closed-end funds.

3 General Results

From equation (12), it is clear that

$$E\left[\omega_t\left(\tilde{v} - P(\omega_t)\right)\right] = 0. \tag{13}$$

We assume that on an *ex ante* basis, $\tilde{n}_t$ is normally distributed with mean zero and variance σ_n^2. Let $\theta_0 = \mu$ and $\theta_t = \mu + \tilde{n}_0$. The manager's expected gain in period t based on publicly available information at time 0 , denoted by Π_t^M, is

$$\Pi_t^M = E\left[X_t(\tilde{n}_t)\left(\theta_t + \tilde{n}_t - P(\omega_t)\right)\right]. \tag{14}$$

Denote the profit realized by the fund in period t as

$$\tilde{\Pi}_t = X_t(\tilde{n}_t)\left(\theta_t + \tilde{n}_t - P(\omega_t)\right). \tag{15}$$

Its expectation with respect to information at time s ($0 \leq$ s $\leq$ t) is given as:

$$\Pi_t^s = E\left[X_t(\tilde{n}_t)\left(\theta_t + \tilde{n}_t - P(\omega_t)\right) \mid NAV_s\right]. \tag{16}$$

The fund market maker sets the fund price (with respect to information set at time s) as

$$P_s^f = E\left[NAV_2 \mid NAV_s\right] = NAV_s + \sum_{t=s}^{1} \Pi_t^s, \qquad s = 0, 1. \tag{17}$$

The first term is the NAV at time s and the second term denotes the expected trading profits based on publicly available information at s.

The informed agent's expected gain, denoted by Π_t^I, is given by

$$\Pi_t^I = E\left[Y(\tilde{n}_t)(\theta + \tilde{n}_t - P(\omega_t))\right]. \tag{18}$$

The expected gain of the liquidity traders, denoted by Π_t^Z, can be simplified (using Stein's Lemma and noticing that $\tilde{Z}_t$ is independent of X_t and Y_t)[10] to the following:

$$\Pi_t^Z = E\left[\tilde{Z}_t\left(\theta_t + \tilde{n}_t - P(\omega_t)\right)\right] = -\sigma_z^2 E\left[\frac{\partial P}{\partial \tilde{Z}_t}\right]. \tag{19}$$

For any reasonable pricing function, $E\left[\frac{\partial P}{\partial \tilde{Z}_t}\right] = E\left[\frac{\partial P}{\partial \tilde{\omega}_t}\right] \geq 0$. Therefore it is clear that the liquidity traders are always expected to lose to the informed traders.

Since our (stock) market maker is a rational and competitive agent, in equilibrium, for any arbitrary functions X_t, Y_t, and $\tilde{Z}_t$, he will set a pricing function $P(\omega_t)$ such that equation (13) is satisfied so that his expected profit is zero, i.e.,

$$\Pi_t^M + \Pi_t^I + \Pi_t^Z = 0. \tag{20}$$

This leads to a key result of the paper. We formalize it in Lemma (1).

Lemma 1 *If the fund manager has a monopoly on information then, in equilibrium, he will always be expected to make a profit, regardless of the magnitude of agency costs and other restrictions, and a fund managed by such a manager will always trade at a premium.*

Proof: In the absence of other informed traders, the second term in equation (20) reduces to zero. Since the last term is negative, we get

$$\Pi_t^M = E\left[P'(\cdot)\right]\sigma_z^2 \geq 0. \qquad \textbf{Q.E.D.}$$

The other aspect of this result is that as the number of informed traders increases, the informational gain of the manager will decrease since he will have to share this gain with other informed traders. If he is the only one facing a policy constraint that forces him to take a non-informationally motivated trade, then he may lose to other informed traders in the economy. But if the number of informed traders increases, then it will be easier for the market maker to infer the true information, thereby making the market deeper.[11] This would reduce the liquidity loss of the uninformed traders

[10] Stein's Lemma states that for a normally distributed variable x, $Cov(x, f(x)) = E[f'(x)]\sigma_x^2$, where f is a differentiable function of x. See Rubinstein (1976) for a proof.

[11] The depth of a market can be understood as the inverse of the sensitivity of the price to demand. See, e.g., Kyle (1985) and O'Hara (1995).

as well as the loss of the manager due to non-informational trade. In the limit, when everybody is informed, there would be no gain to informed traders and no loss to liquidity traders.

Given our discussion above, we can formalize the following result:

Proposition 1 *The fund will trade at a premium in the beginning. In the second period, it is expected to trade at a discount if* $\Pi_1^0 < 0$*, and will definitely trade at a discount if* $\Pi_1^1 < 0$*, where* Π_t^s *is defined in (16).*

Proof: For the fund to exist in the beginning, the basic condition is that the investors would not want to lose money on their initial investment, i.e.,

$$P_0^f \geq NAV_0. \tag{21}$$

Since there is no informed trading in the closed-end fund, the market maker will price the initial fund conditional on the amount of NAV_0 that the fund hopes to attain. This leads to the following condition:

$$P_0^f = E[NAV_2 \mid NAV_0]. \tag{22}$$

Equations (21) and (22) lead to:

$$E[NAV_2 \mid NAV_0] - NAV_0 \geq 0. \tag{23}$$

In the absence of condition (23), nobody will put money in the fund and it will never be introduced in the market. This implies that the fund has to trade at a premium in the beginning. **Q.E.D.**

Notice that given (23) it is still possible that $\Pi_1^0 < 0$, which implies the fund is *expected* to trade at a discount in the second period, and that $\Pi_1^1 < 0$, which implies the fund *will* trade at a discount in the second period. These cases are demonstrated through a numerical example in Appendix B.

Condition (23) implies that the investors will pay a premium, only if they believe that the manager is going to make a profit due to his superior information. The question that now arises is that if there is a premium paid at the beginning, then why doesn't everyone buy the fund at its initial NAV and immediately sell it at a premium? The answer is obvious after taking into account the initial cost associated with introducing a fund. The amount that the initial investors pay when the fund is launched as an IPO does not fully get converted to the initial NAV. In fact, a significant sum goes out as the initial cost C. So, if $E[NAV_2 \mid NAV_0] - NAV_0 = C$, then there is no opportunity to make money at the beginning. This illustrates two points. First, the initial premium exists because the manager is expected to gain due to his information. Second, the investors in the fund do not make a gain because a rent in the form of the initial premium is already extracted from them at the time of the issue of the fund.

The manager will try to extract as much rent as possible since as long as condition (23) is satisfied, the investors will want to put their money in the fund. The manager's extraction of rent comes in the form of a higher compensation, which is possible if the NAV is high. But if the NAV is high, the agency costs will increase (as demonstrated in the corollary following Theorem 1). This hurts the expected future performance of the fund. Ultimately, it comes down to the bargaining power of the manager with the market. Ideally, the manager will want to extract enough NAV from the market such that condition (23) becomes a strict equality. This implies two things. First, the fund will trade at a premium initially. Second, the informational gain will dominate the non-informational loss of the manager in at least one of the periods. The domination is more likely to occur in the first period than in the second period. This is because if the market gives him just about enough, then he will be expected to make profits in the first period. But in the second period, the manager might have more than what he can handle. Now, it is likely that condition $\Pi_1^1 < 0$ is satisfied, and therefore the fund will exhibit a pattern of premium followed by a discount.

So where, specifically, is the role of agency in our model, i.e., how can conditions $\Pi_1^0 < 0$ and $\Pi_1^1 < 0$ be satisfied when the manager has an informational advantage? This question can be answered by noticing that the manager does not have any incentive to return money to shareholders even if he has run out of good investment opportunities. Take, for example, a fund with an NAV of \$100. The fund manager is required to invest 80% in the risky stock and 20% in the riskless asset. Assume that the manager has \$60 worth of information, i.e., if his optimal trade is 60 units and he expects the price to be \$1. On the one hand, if he trades optimally, he should ideally demand 60 units of the risky asset and put \$15 (20%) in riskless asset and return \$25 to the shareholders. This means that his NAV declines from \$100 to \$75. In this case if he makes a 100% gain on his trade in the risky asset by trading optimally, his NAV in the next period goes up to \$135. On the other hand, if he decides to invest the entire NAV of \$100 according to the fund policy by investing \$80 worth in the risky asset and \$20 in the riskless asset. This will lead to an excess demand in the risky asset. The market maker cannot infer how much demand is due to good information and how much is due to the agency problem of the manager. So, he will move the price more than he would have if the manager had demanded optimally. This implies that the manager's informational gain goes down, since he is buying the stock at a higher price. As a result, the gain from the manager's investment in the risky asset falls from 100% to 70%. He now expects his NAV in the next period to become \$156.[12] Since the objective of the manager is to maximize his compensation (which is a percentage of the fund NAV), he will choose the second option since that gives him a higher compensation even though it is sub-optimal for the investors of the fund.

Let us formalize this argument:

Theorem 1 *If the fund manager has a policy restriction that requires him to invest at least a fraction γ of his NAV in the risky asset and return the uninvested portion to the shareholders, then he will prefer investing the entire NAV in the risky and the riskless asset.*

Proof: Suppose the manager's compensation is δ% of his total NAV. He can put in a demand of X_t^R units in the risky asset and X_t^{Rf} units in the riskless asset. Without loss of generality, the riskless asset is assumed to have a constant price of \$1. The only restriction on the manager is that $E[X_t^R \, P(\omega_t) \mid \tilde{n}_t, NAV_t] \geq \gamma \, NAV_t$. The NAV of the fund is expected to grow by the expected profit in the first period[13], which is given by $E\left[X_1^R \, (\tilde{v} - P(\omega_1)) \mid \tilde{v}, NAV_1\right]$. The NAV drops by the amount that the manager returns to his shareholders, which is given by $E[NAV_1 - X_1^R \, P(\omega_1) - X_1^{Rf} \mid \tilde{v}, NAV_1]$. His expected compensation for the next period would then be δ% of

$$NAV_1 + E\left[X_1^R \, (\tilde{v} - P(\omega_1)) - (NAV_1 - X_1^R \, P(\omega_1) - X_1^{Rf}) \mid \tilde{v}, NAV_1\right] = X_1^R \, \tilde{v} + X_1^{Rf}. \quad (24)$$

Note that at t = 1, the manager knows $\tilde{v}$, and that his compensation is independent of the stock price. It is clear that, given a positive $\tilde{v}$, the manager would like to have X_1^R and X_1^{Rf} to be as large as possible given his initial (budget) NAV and policy constraints. Therefore, regardless of the ratio of X_1^R to X_1^{Rf} (policy constraint), the manager will invest all his NAV and has no incentive to return money to the shareholders. **Q.E.D.**

[12]Had the manager traded 60 units, the total payoff for the shareholders would be 160: 135 plus 25 returned.

[13]In our setup, the manager invests the entire NAV in the first period. The conflict between investing or returning takes place only at the beginning of the second period. So this theorem considers the scenario at the beginning of the second period.

Theorem 1 implies that in the absence of any borrowing, NAV_t is given by

$$NAV_t \quad = \quad E\left[X_t^R P(\omega_t) + X_t^{Rf} \mid \tilde{n}_t, NAV_t\right] \tag{25}$$

by investing all NAV_t. The fund profit can therefore be expressed as $E[X_t^R(\theta_t + \tilde{n}_t - P(\omega_t))]$. X_t^R is motivated by the manager's compensation maximization problem, which differs from a profit maximization problem. It hurts the fund NAV if the extra demand is motivated by pure non-informational reasons. This can be seen by simply extending equation (19) to our needs. Suppose that $\tilde{e}_t$ is the additional non-informational demand for the manager. Assume that it is normally distributed with mean zero and variance $\sigma_{e_t}^2$, and that it cannot be credibly communicated to the market. Referring to equation (19), it can be seen (using Stein's Lemma) that this extra trade will result in a loss of $E[P'(\omega_1)]\sigma_{e_t}^2$. This hurts the fund NAV while benefits the manager. If $\sigma_{e_t}^2$ is too high then the loss due to non-informational trade might offset the gains on informational trade. Note that this is a crude argument. It is not possible to obtain a clean functional form of the non-informational trade. We will demonstrate through numerical results in Appendix B that this intuition holds. In Section 5, we will introduce a simplified assumption to get more results that are otherwise computationally demanding.

Corollary: *Ceteris paribus, the higher the NAV, the higher the likelihood of incurring a loss due to policy restrictions and therefore the higher the probability of either* $\Pi_1^0 < 0$ *or* $\Pi_1^1 < 0$. *The probability of discounts in the latter stages increases with the NAV of the fund.*

Proof: The proof follows trivially from Theorem 1. As the NAV increases, the possibility of a non-informational investment increases, leading to a potential discount. **Q.E.D.**

This corollary leads to another interesting result. If a manager performs well in one period, he will tend to make less money in the next period due to the constraint of trading, reducing the premium. Therefore the premium and the NAV performance tend to move in opposite directions. Since the premium change is approximately the difference between the fund return and the NAV return,[14] this negative correlation implies that closed-end fund prices under-react to NAV returns. This intuition is consistent with Chen, Kan and Miller (1993) and Pontiff (1997), who find a negative correlation between changes in premiums and NAV returns using monthly data. Bodurtha, Kim

[14] For details, see equation (3) of Pontiff (1997).

and Lee (1995) and Klibanoff, Lamont and Wizman (1998) find the same result using weekly data on country closed-end funds.

Malkiel (1977) and Pontiff (1995) find a negative correlation between changes in premium and concurrent stock price returns. If there is a positive shock to the economy, then the prices rise and the NAV grows. This implies an increased likelihood of the manager possessing more than the optimally required amount in the absence of agency problem. So he is more prone to wasting some of the NAV in the future, leading to a reduction in premium.

Note that Theorem 1 is very robust and is totally independent of the form of pricing function. However, the demand policy that the manager follows can depend on various factors such as the signals he observes, the NAV he has, and the policy constraints he faces. Our basic point is that the manager has an agency problem, i.e., he does not want to return money to the investors. This agency problem, coupled with the fact that he faces the policy constraints, is what drives the main results of our model.

Having exploited the general properties of the model, we next compare our model implications with the empirical evidences.

4 Empirical Implications

Based on the general results in the previous section and our numerical examples in Appendix B, we can propose the following empirical implications:

(i) The fund should trade at a premium initially and this premium should go down or actually turn into a discount later on. This follows from the fact that the market will assess the tendency of the manager to lose some of the NAV and will therefore give him just enough so that the gains on his informational trade dominate the losses on his liquidity trade and yet the NAV is large enough for the manager to participate in the fund rather than trade for his own account. By the end of the first period the fund grows but the manager's information level stays the same. This means that the manager has a potential to lose. So, his new expected informational gain might be dominated by his loss due to the policy constraints, which may lead to a discount.

(ii) Discount (premium) is expected to fluctuate. Over multiple periods, it could be mean reverting. Although our model does not directly say this, it implies a mean reverting phenomenon.

Once the manager has lost a lot of money, his agency costs go down and his informational gains start dominating. So the discount goes down and can even turn into a premium. Once the NAV goes up again, the discount increases due to an increase of agency cost.

(iii) The higher is the NAV, the higher is the discount (in dollar amount). The percentage amount, therefore, does not disappear even when the fund expands. The agency problem is more severe when the NAV is high. As a result, the manager loses more when the NAV is higher.

(iv) The NAV of the fund grows initially and then either falls or grows at a slower rate.

(v) The return on the fund price could be more volatile than the return on the underlying NAV. This is because the fund price at t = 1 is expressed as:

$$P_1^f \quad = \quad NAV_1 + E[X_1(\tilde{v} - P(\omega_1)) \mid NAV_1] = NAV_1 + \Pi_1^1(NAV_1). \tag{26}$$

Because of the manager's non-linear demand due to his policy constraints, the expected profit in the second period, $\Pi_1^1(NAV_1)$, is non-linear in NAV_1. Thus we would expect the return on the fund price to be more variable than the return on the fund NAV. We have not yet established this puzzle described by Pontiff (1997). To do so, it is important that we have a closed-form solution for the fund premium in the second period. This can be achieved by making some simplifying assumptions that we introduce in the next section.

5 A Simplified Approach

The numerical work in Appendix B demonstrates that our main results are robust with respect to the constraints on the manager. Except the manager, all other traders and the market makers have features similar to those in Kyle (1985) and therefore respond optimally. The simplified assumption in this section drives tractability, but not the nature of the results.

Let $\tilde{e}_t$ represent the manager's demand for the risky asset in excess of what it would have been if he had optimally responded to the strategies of the other traders in the economy. It is the manager's non-informational trade due to his policy constraints and the nature of his compensation and we ssume that it cannot be viewed by the market. We also assume that the market views $\tilde{e}_t$ as a normally distributed variable with mean zero and variance $\sigma_{e_t}^2$ independent of $\tilde{n}_t$. As can be observed from the numerical examples presented in Appendix B, the variance of the non-informational trade increases as the NAV grows. So we assume that $\sigma_{e_t}^2$ is an increasing function of the NAV_t. We will perform our numerical work in this section with an exogenous $\sigma^2_{e_1}$ given by the form $\sigma^2_{e_1} = A\exp\left(B\left(NAV_1 - NAV_0\right)\right)$. This assumption captures the intuition that the variance of the non-informational trade increases as the NAV increases. Any functional form that captures this intuition should give the desired results. It also ensures that the variance is always positive.

Given this simplified structure of our model, we can derive in closed form both the demand functions of other informed traders and pricing functions of the market makers. In addition, we can introduce multiple informed traders in each period (with each informed trader still maximizing his one-period profit). We denote by K the number of informed traders.

5.1 Equilibrium

At t = 1, we conjecture that the price function and the demand functions in the second period are given by

$$\begin{aligned} P(\omega_1) &= \mu + \tilde{n}_0 + \lambda_1\left(\omega_1 - E\left(\omega_1\right)\right), & (27)\\ Y_1^j &= \beta_1\,\tilde{n}_1, \qquad j = 1 \quad to \quad K, & (28)\\ X_1 &= \beta_1\,\tilde{n}_1 + \tilde{e}_1. & (29) \end{aligned}$$

Superscript j represents the j^{th} informed trader. ω_1 is the aggregate order flow observed by the market maker. Note that $\beta_1\,\tilde{n}_1$ represents the optimal demand by the informed agents (manager and informed traders) and $\tilde{e}_1$ is the excess demand (non-informational) of the manager due to his policy constraints.

The informed trader j's objective function is

$$\max_{Y_1^j} E\left[Y_1^j\left(\mu + \tilde{n}_0 + \tilde{n}_1 - (\mu + \tilde{n}_0 + \lambda_1\,(\sum_{l=1}^{K} Y_1^l + X_1 + \tilde{Z}_1)\right) \mid \tilde{n}_1\right], \qquad \forall\; i. \tag{30}$$

On solving the first order condition, we get

$$\lambda_1\beta_1 = \frac{1}{K+2}. \tag{31}$$

The market maker prices the asset according to $P(\omega_1) = E\left[\tilde{v}|\omega_1\right]$. Using the projection theorem, λ_1 is calculated as

$$\lambda_1 = \frac{(K+1)\beta_1\sigma_n^2}{(K+1)^2\beta_1^2\sigma_n^2 + \sigma^2_{e_1} + \sigma^2_{z_1}}. \tag{32}$$

Equations (31) and (32) give the following results:

$$\lambda_1 = \frac{\sigma_n}{K+2}\sqrt{\frac{K+1}{\sigma_{e_1}^2+\sigma_{z_1}^2}}; \quad \beta_1 = \frac{1}{\sigma_n}\sqrt{\frac{\sigma_{e_1}^2+\sigma_{z_1}^2}{K+1}}. \tag{33}$$

The (*ex ante*) expected gain of the manager in the second period by trading in the risky asset is

$$\Pi_1^M = E\left[X_1(\tilde{v} - P(\omega_1))\right] = E\left[(\beta_1\tilde{n}_1 + \tilde{e}_1)(\frac{\tilde{n}_1}{K+2} - \lambda_1(\tilde{e}_1 + \tilde{Z}_1)\right], \tag{34}$$

$$= \frac{\beta_1\sigma_n^2}{K+2} - \lambda_1\sigma_{e_1}^2 = \frac{\sigma_n\left(\sigma_{z_1}^2 - K\sigma_{e_1}^2\right)}{(K+2)\sqrt{(K+1)}\sqrt{\sigma_{e_1}^2+\sigma_{z_1}^2}}. \tag{35}$$

Note that this is not just an agency cost model but also an information sharing model. If the manager had a monopoly on the information (i.e., K = 0) then, as can be seen above, the fund would have always traded at a premium regardless of the extent of the agency cost. We have already shown this result in a more general setting through Lemma 1. The only problem agency cost can pose in this case is to reduce the premium. But since the manager is not the only informed agent in the market,[15] the information (and therefore the informational gain) is shared by many others. However, the non-informational trading loss is borne by the manager in our model. An increase in the number of informed traders annihilates the profits at a rate of $K^{-1.5}$ while it alleviates the liquidity losses only at a rate of $K^{-0.5}$. Note that when $K > \sigma_{z_1}^2/\sigma_{e_1}^2$, the fund is expected to trade at a discount.

At t = 0, the manager's problem is to maximize his value function $E\left[NAV_1 + NAV_2 \mid \tilde{n}_0, NAV_0\right]$. This can also be expressed as $E\left[2NAV_1 + E[\Pi_1 \mid \tilde{n}_1, NAV_1] \mid \tilde{n}_0, NAV_0\right]$. We solve this problem by conjecturing the following demand function:

$$X_0 = \beta_0\tilde{n}_0 + \tilde{e}_0. \tag{36}$$

Given the manager's demand, all other demand functions can be calculated in closed form. The fund can then be priced as:

$$P_0^f = NAV_0 + E\left[\Pi_0 + \Pi_1 \mid NAV_0\right], \tag{37}$$

where Π_t is defined by (15). We next solve a specific numerical example.

[15] A fairly reasonable assumption to make, considering that there are hundreds of funds and other informed trading bodies in the market.

5.2 A Numerical Example

We solve the above example using the following parameter values: $\sigma_n^2 = 0.8$, $\sigma_z^2 = 1$, K = 2, $\sigma_{e_0}^2 = 0.05$,[16] $\sigma_{e_1}^2 = A \exp\left(B\left(NAV_1 - NAV_0\right)\right)$, A = 0.6, B = 1.8 and $\mu = 1$. We compare the variances of the return on the fund price and the return on the fund NAV through the following expressions:

$$Var(R_{fund}) = Var\left(\frac{NAV_1 + E[\Pi_1 \mid NAV_1] - P_0^f}{P_0^f}\right), \;\; Var(R_{NAV}) = Var\left(\frac{NAV_1 - NAV_0}{NAV_0}\right). \quad (38)$$

The results for several starting values of the NAV are presented in Table 1. As expected, the numbers look consistent with the findings of Pontiff (1995). In our model, this excess volatility arises from the fact that the price of the fund is a highly non-linear function of the NAV and is therefore more volatile than NAV itself. Another interesting aspect to be noted is that the covariance of the return on NAV and the change in premium is negative. This is consistent with the observed empirical phenomenon (Pontiff, 1995; Khorana, Wahal and Zenner, 2002). We would like to further resolve our setup in a multi-asset framework. However, the computational task for such a resolution is enormous.[17] In the next section, we take yet another simplifying assumption that make our model solvable in a two-period, multi-asset framework.

6 A Myopic Manager

The problem of a multi-asset two-period framework can be solved by assuming that the manager of the fund is myopic.[18] Under this assumption, the problem is to solve two separate one-period problems. We now have the demand function and the pricing function in closed-form in both

[16]The first period σ_{e_0} is really small, assuming minimal agency problems. In the second period, σ_e will depend on how much the manager gains. For this example, we simply calculate the deviation to be the ratio of profits to the expected price. The rationale is that as profits go up, he can deviate more from the optimal strategy. However, if the expected price of the asset is very high, he cannot deviate a lot from the expected amount, in terms of the units demanded.

[17]Each asset has 3 state variables $(\tilde{n}, \tilde{Z}, \tilde{e})$ associated with it. For example, if we use a 7 quadrature node points and 10 assets, this means each iteration needs 7^{30} computations.

[18]This is crude but logical to some extent if one assumes that there is a significant probability that the manager might be removed or fired from his current position. In that case, he will put more weight on the compensation of his current period than on his overall compensation. A myopic manager is an extreme case where he puts the entire weight on the current period.

periods. We assume that there are N assets in the economy with a similar payoff and news schedules as discussed in Section 5.

6.1 Equilibrium

We conjecture that the price function and the demand functions are given by

$$\begin{aligned} P(\omega_t^i) &= \theta_t^i + \lambda_t^i \left(\omega_t^i - E(\omega_t^i)\right), \qquad t = 0 \quad or \quad 1, \quad i = 1 \quad to \quad N, && (39) \\ Y_{t,i}^j &= \beta_t^i \tilde{n}_t^i \qquad j = 1 \quad to \quad K, && (40) \\ X_{t,i} &= \beta_t^i \tilde{n}_t^i + e_t^i, && (41) \end{aligned}$$

where $\theta_0^i = \mu^i$ and $\theta_1^i = \mu^i + \tilde{n}_0^i$. Superscript j represents the j^{th} informed trader. ω_t^i is the aggregate order flow for asset i observed by the market maker for that asset. e_t^i is the manager's non-informational demand due to policy constraints on asset i in period t.

The informed trader j's objective function is

$$\max_{Y_{t,i}^j} E\left[Y_{t,i}^j \left(\theta_t^i + \tilde{n}_t^i - (\theta_t^i + \lambda_t^i (\sum_{l=1}^{K} Y_{t,i}^l + X_{t,i} + Z_{t,i})\right) \mid \tilde{n}_t^i\right], \qquad \forall\ i. \tag{42}$$

On solving the first order condition, we get

$$\lambda_t^i \beta_t^i = \frac{1}{K+2}. \tag{43}$$

Using steps similar to those in Section 5, we get the total expected gain of the manager as

$$\Pi_t^M = \sum_{i=1}^{N} \frac{\sigma_{n,i}\left(\sigma_{z_{t,i}}^2 - K\sigma_{e_{t,i}}^2\right)}{(K+2)\sqrt{(K+1)}\sqrt{\sigma_{e_{t,i}}^2 + \sigma_{z_{t,i}}^2}}. \tag{44}$$

The fund price at t = 0, when the initial net asset value NAV_0 is declared, is given as:

$$P_0^f = E[NAV_2 \mid NAV_0] = NAV_0 + E[\Pi_0 + \Pi_1 | NAV_0]. \tag{45}$$

The term Π_1 depends on NAV_1 due to the dependence of the manager's strategy to invest the excess funds, and the variance of his non-measurable component of trade, i.e., e_1^i, on NAV_1. NAV_1, in turn, depends on the realization of $\tilde{e}_0^i$, Z_0^i, and n_0^i for i = 1 to N. $E[\Pi_1|NAV_0]$ can therefore be determined numerically since we have closed form expressions for all these random variables and we know the probability density function for them.

$$E[\Pi_1|NAV_0] = \int_{-\infty}^{+\infty} \sum_{i=1}^{N} \frac{\sigma_{n,i}\left(\sigma^2_{z_{1,i}} - K\sigma^2_{e_{1,i}}\right)}{(K+2)\sqrt{(K+1)}\sqrt{\sigma^2_{e_{1,i}} + \sigma^2_{z_{1,i}}}} dF\left(\tilde{n}_0, \tilde{e}_0, \tilde{Z}_0\right), \tag{46}$$

where $\mathrm{F}\left(\tilde{n}_0, \tilde{e}_0, \tilde{Z}_0\right)$ is the joint cumulative density function and $\tilde{n}_0, \tilde{e}_0$, and $\tilde{Z}_0$ are N×1 vectors of random variables. In the above integral, $\sigma^2_{e_{1,i}}$ is an exogenously specified function of NAV_1, which in turn is given as:

$$NAV_1 = NAV_0 + \sum_{i=1}^{N} \left(X_{0,i}(\tilde{n}^i_0 - \lambda^i_0 (\sum_{l=1}^{K} Y^l_{0,i} + X_{0,i} + Z_{0,i})) \right). \tag{47}$$

When the market maker prices the fund, he does so by conjecturing that there is no informational trading. This conjecture can be validated by assuming a Θ% transaction cost. If an informed trader wants to make any profit by buying an undervalued fund, his expected profit can only be on the asset he is informed of. To make a profit, he will have to buy the entire fund at a price close to the fund NAV. With the transaction cost involved, such a trade can only be a loss making proposition.

This point can be illustrated by looking at the net return (after transaction cost) of the informed trader in the k^{th} asset of trading in the fund if the fund is undervalued, i.e., the realization of $\tilde{n}^k_t$ is high. His expected profit resulting from his information on the k^{th} asset would be:

$$E\left[\Pi_t|\tilde{n}_{t,k}\right] \quad = \quad \frac{\beta_{t,k}\,\tilde{n}^2_{t,k}}{K+2} - \lambda_{t,k}\,\sigma^2_{e_{t,k}} = \frac{\beta_{t,k}\,(\tilde{n}^2_{t,k} - \sigma^2_{n,k}/\beta^2_{t,k})}{K+2}. \tag{48}$$

His return on investment after incurring the transaction cost would be:

$$E\left[\tilde{R}_t|\tilde{n}_{t,k}\right] \quad = \quad \frac{\beta_{t,k}\,(\tilde{n}^2_{t,k} - \sigma^2_{n,k}/\beta^2_{t,k})}{(K+2)\,P^f_t} - \Theta\%. \tag{49}$$

This would always be negative for any (arbitrarily small) positive transaction cost if P^f_t is large enough.[19] All informed trades are therefore precluded from the fund.

Note that the fund manager is not allowed to trade on his own fund. Therefore the *ex ante* valuation of the manager's profits is the premium on the fund. If the liquidity traders trade in a stand-alone asset, they will expect to lose to an informed trader. But since there is no informed trading in a fund, and any liquidity loss that the fund might entail has already been discounted from the price, the liquidity traders will get the fair price for the fund. Therefore most traders

[19]Equivalently, if NAV_t is large enough since P^f_t would be close to NAV_t.

trading for liquidity needs should invest in closed-end funds rather than individual assets. This is an interesting result in the sense that closed-end funds have an important role to play in the economy.

There is ample evidence that closed-end funds are owned and traded primarily by individual investors. Weiss (1989) found that three calendar-quarters after the launch of new closed-end funds, institutions hold less than 5% of the shares, in comparison to 23% of the shares of a control sample of IPOs for operating companies. Lee, Shleifer and Thaler (1991) found the average institutional ownership in closed-end funds at the beginning of 1988 to be just 6.6%. The same number for the smallest 10% stocks and the largest 10% stocks on NYSE was 26.5% and 52% respectively. Our findings are thus consistent with the empirical literature about the ownership structure of the funds.

6.2 A Numerical Example

We solve the above example using the following parameter values: $\sigma_n^2 = 1$, $\sigma_z^2 = 1$, K = 2, $\sigma_{e_0}^2 =$ 0.05 ; $\sigma_{e_1}^2 = A \exp\left(B(NAV_1 - NAV_0)\right)$, A = 0.6, B = $\frac{1.8}{\sqrt{N}}$,[20] and $\mu_n^i = 1$.

We use simulation techniques to generate the expected premium in the second period. This is a standard method that uses law of large numbers to guarantee convergence to the expected mean. (See, e.g., Judd, 1998). In order to decide on the size of the simulation, we try different sizes. We find that averaging over 30 sets of 5000 simulations gives a reasonably accurate result.

In Table 2, we present the fund premiums and discounts with different number of assets. As expected, a pattern of premium followed by discount can be attained even by our crude assumptions.

7 Conclusion

We have presented a dynamic model that relies on the agency cost and information sharing. The model leads to a potential explanation of the closed-end fund premium and discount puzzle. Our model relies on not only the fact that the manager is bound by rules and regulations but also that

[20] As the number of assets increases, the profits will be shared by many assets and therefore the volatility of the manager's demand for each asset will reduce. We use this specification for the exogenous functional form for $\sigma_{e_2}^2$. As noted in Section 5, this is just one of the many functional forms that would lead to similar patterns.

he is only one of the many informed traders in the market. Both of these assumptions seem to be fairly reasonable. The question remains as to whether these policies are good for investors. In their absence, a second problem may takeover, the one of brash over-speculation on part of the manager. It was to tackle this second problem that various policy constraints were formed. In real life, investors are not risk neutral and would like to know exactly what risks they are taking by investing in a fund. In addition, they may not want to fall into the hands of an over-confident manager who does not have a high cost of risk. Perhaps the policies are to protect the investors (liquidity traders) who may not assess their risks properly, or perhaps it is to prevent the manager from taking any extreme risk that might not have been priced for. We conclude by posing an interesting but debatable question: are the funds better off with absolutely no pre-commitment to any sector, niche, or style of investment hoping that the manager's compensation will remove any misalignment between the manager's interests and the investor's interests or are they better off by imposing extra rules and regulations on the manager? We leave this question for future research.

A Funds policies and their impact

The initial growth of closed-end funds was slow and only 18 funds were formed prior to World War I. American Investment Trusts soared during the economic boom of the early 1920s. Most of these funds used some form of leverage in their capital structure. On average, 40% of their capital consisted of bonds and preferred equity. During this period there were not many restrictions on the managers. These funds used to trade at a premium in that period.[21] When the market crashed, many investors lost vast sums of money. After their losses in the 1920s, investors began to seek security in their investments and, therefore, were drawn towards the redemption policy of open-ended funds.

A provision in the 1935 Public Utility Holding Company Act directed the SEC to study investment company practices. Under this provision, investment companies were subject to investigation and regulation. The SEC's investigations culminated in a call for specific legislation to deal with investment companies.

The Investment Company Act of 1940 was an omnibus legislation covering the formation, management, and public offering of every investment company that has more than 50 security holders or that proposes to offer securities to the public. The following provisions of the Act are important to our model:

- **Income sources:** At least 90% of an investment company's gross income must be in the form of dividends, interest, and gains from securities. For any taxable year, a maximum of 30% of its profits can be derived from sales of securities held for less than 3 months, without deducting for losses and including any gains from the short-sale of securities. These provisions ensure that an investment company's non-investment activities do not significantly contribute to its revenues and, at the same time, discourages managers from speculating on short-term fluctuations.

- **Portfolio Composition:** At the end of each quarter during the taxable year, the company must (a) have at least 50% of its assets in cash, cash items, government securities, securities of other regulated investment companies; (b) limit its investment in a single security to 5%

[21] See DeLong and Shleifer (1992).

or less of its total assets; (c) not have an investment in any single company that represents more than 10% of the outstanding voting securities of the issuer; (d) limit its investment in the securities of any one issuer to 25% or less of the company's total assets.

- **Investment Policy Statement:** Upon the initial organization of a fund, or the effective date of the Act of 1940 for existing funds, investment companies must provide a statement of their investment policies. That statement addresses in general terms the kinds of financial assets the company will invest in, the kind of risks that will be undertaken, etc. Once in place, an investment policy cannot be changed unless voted on by the firm's shareholders. For example, Alliance All-Market Advantage policy says

> *"...Alliance All-Market Advantage Fund seeks long-term capital appreciation. The fund invests at least 65% of assets in large-cap growth equities. The advisor emphasizes a core portfolio of 25 companies selected from the advisor's research universe. Up to 30% of assets may be held in short positions at any time. The fund seeks to provide stable growth in all market conditions through a strategy that involves the use of short sales, financial futures, forward contracts, and options. The fund, by policy, has an 8% annual distribution, payable on a quarterly basis. The fund may leverage up to 25% of assets through borrowing..."*

SEC Spokesman John Nester warns that, "If a prospectus says a fund is committed to safety and then it starts buying risky derivatives, that is a violation of a legal contract between the fund and its shareholders. This is the worst thing a fund can do." (Investors Business Daily, March 12, 1998).

Clearly, the main purpose of a policy statement is to help potential investors familiarize with the kinds of risks they would encounter by investing in the fund's shares.[22] However, these fund

[22] Anecdotal evidence from financial press is consistent with this argument. For example, in discussing the investment practices of global funds, one reporter noted that

> *"... Some global funds focus on stocks of developed countries and are restricted from purchasing too many emerging-market assets. Other global funds, by contrast, have more flexibility to place a large chunk of their assets in emerging markets... "*

[Some Global Funds are playing Flip-Flop, *Wall Street Journal,* October 10, 1998] policies and Investment laws put a lot of restrictions on the fund managers in terms of how he plans to invest his money. Deli and Varma (2002) compare the opportunity costs of contractual restrictions with the trading costs in the absence of these restrictions.

B A Numerical Example of the Model in Section 2

We begin by specifying the first order conditions for the manager's and the informed trader's problems at t = 1, as given in Section 2. The manager's objective function is specified as a Lagrangian, i.e.,

$$\max_{X_1,\psi} \left(E[NAV_1 + X_1\left(\tilde{v} - P_3\right) + \psi\left(X_1 P_3 - \gamma NAV_1\right) \mid \tilde{v}, NAV_1]\right). \tag{50}$$

The first order conditions with respect to ψ and X_1 are:

$$E\left[X_1 P_3 - \gamma NAV_1 \mid \tilde{v}, NAV_1\right] = 0, \tag{51}$$

$$E\left[\tilde{v} - (X_1 \frac{\partial P_3}{\partial X_1} + P_3)(1-\psi) \mid \tilde{v}, NAV_1\right] = 0. \tag{52}$$

Note that we are solving the problem by making the policy constraint an exact equality instead of an inequality. In general, when the NAV is high enough, the information of the manager will not be strong enough to warrant an investment of more than the requisite minimum fraction γ. In this case the inequality will act like a strict equality. Similarly, the first order condition for the (second period) informed trader's problem is given by:

$$E\left[\tilde{v} - (Y_1 \frac{\partial P_3}{\partial Y_1} + P_3) \mid \tilde{v}\right] = 0. \tag{53}$$

The market maker's problem is specified as:

$$E\left[(\tilde{v} - P_3) \mid \omega_1\right] = 0. \tag{54}$$

In order to solve the above maximization problems numerically, we approximate the functional form of each agent with a sum of Hermite polynomials. Specifically, we assume that

$$X_1 = \sum_{i=0}^{3} a_i H_i(\tilde{v}), \qquad Y_1 = \sum_{i=0}^{3} b_i H_i(\tilde{v}), \qquad P_3 = \sum_{i=0}^{2} c_i H_i(\omega_1).$$

Hermite polynomials are chosen because we have normally distributed random variables. We choose the demand functions to the cubic term and the pricing function to the quadratic term for economic and computational reasons. We will elaborate on these later in this appendix.

Our purpose is to find the above eleven coefficients and the Lagrangian multiplier ψ which satisfy the above first order conditions. In accordance with the projection technique specified by Judd (1992), we fix twelve directions by making use of the following properties:

$$E\left[(X_1P_3 - \gamma NAV_1)f_1(\tilde{v})\right] = 0, \tag{55}$$

$$E\left[(\tilde{v} - (X_1\frac{\partial P_3}{\partial X_1} + P_3)(1-\psi))f_2(\tilde{v})\right] = 0, \tag{56}$$

$$E\left[(\tilde{v} - (Y_1\frac{\partial P_3}{\partial Y_1} + P_3))f_3(\tilde{v})\right] = 0, \tag{57}$$

$$E\left[(\tilde{v} - P_3)f_4(\omega_1)\right] = 0, \tag{58}$$

for any arbitrary functions f_1, f_2, f_3 and f_4. The conditional expectation is therefore equivalent to an infinite number of unconditional expectations. Making use of these properties, we fix the following twelve dimensions:

$$E\left[(X_1P_3 - \gamma NAV_1)H_i(\tilde{v})\right] = 0, \qquad i = 0,1, \tag{59}$$

$$E\left[(\tilde{v} - (X_1\frac{\partial P_3}{\partial X_1} + P_3)(1-\psi))H_i(\tilde{v})\right] = 0, \qquad i = 0,1,2,3, \tag{60}$$

$$E\left[(\tilde{v} - (Y_1\frac{\partial P_3}{\partial Y_1} + P_3))H_i(\tilde{v})\right] = 0, \qquad i = 0,1,2,3, \tag{61}$$

$$E\left[(\tilde{v} - P_3)H_i(\omega)\right] = 0, \qquad i = 0,1. \tag{62}$$

We tried different choices of dimensions and the same pattern evolved, i.e., the premium decreased as the NAV of the fund increased. We decided on the above conditions because they capture the non-linear nature of demand functions up to the third degree. In that sense we follow the Galerkin method.[23] We make sure that the policy constraint is satisfied unconditionally and conditional to any linear function of the manager's signal. This can be seen by substituting i = 0 and 1 in equation (59), respectively. Our dimensions also ensure that the market maker fixes a price so that unconditionally, the price is the same as the expectation of the final payoff and he does not make any losses unconditionally. The two constraints are satisfied by substituting i = 0

[23] Using the first n elements of the basis as the projection conditions is known as the Galerkin method. Other projection conditions could be chosen. See Judd (1992) for a detailed discussion.

and 1 in equation (62), respectively. We tried to invoke the sensitivity of the pricing function to a higher degree by using a cubic function of the aggregate demand. However, the pricing function continues to be extremely small in higher powers and takes an unnecessarily high amount of time computationally.[24]

We solve the above system of equations for a range of values of NAV_1 and $\tilde{n}_1$, and estimate the expected NAV_2 by calculating

$$E\left[X_1(\tilde{v} - P_3) \mid \tilde{n}_1, NAV_1\right] = E[\Pi_1 \mid \tilde{n}_1, NAV_1]. \tag{63}$$

We then try to approximate NAV_2 as a function of NAV_1 and $\tilde{n}_1$. We use the standard polynomial approximation technique for this. We choose the following polynomial form for the profit in the second period:

$$E[\Pi_1 \mid \tilde{n}_1, NAV_1] = \sum_{i=0}^{2} d_i H_i(NAV_1) + \sum_{i=1}^{2} e_i H_i(\tilde{n}_1). \tag{64}$$

The five coefficients are estimated by minimizing the sum of squares over 220 observations. This functional form is inserted back in the manager's original objective function at t = 0. The problem at time t = 0 in equation (50) now becomes:

$$\max_{X_0} E\left[2NAV_1 + \sum_{i=0}^{2} d_i H_i(NAV_1) + \sum_{i=1}^{2} e_i H_i(\tilde{n}_1) \mid \tilde{n}_0, NAV_0\right] \tag{65}$$

subject to

$$E\left[X_0 P_1 \mid \tilde{n}_0, NAV_0\right] = \gamma NAV_0, \tag{66}$$

$$NAV_1 = NAV_0 + X_0(P_2 - P_1). \tag{67}$$

The (first period) informed trader's objective function at t = 0 is the following:[25]

$$\max_{Y_0} E\left[Y_0(\mu + \tilde{n}_0 - P_1) \mid \tilde{n}_0\right]. \tag{68}$$

[24] An alternate method is to fix four dimensions for each of the constraints above which would give us an over-identified system of 16 equations. But since there are 12 unknowns, we would have to compute them by using the minimum sum of squares method (see, e.g., Judd, 1998) or by defining any other loss function and minimizing it with respect to the projection conditions. This is analogous to the GMM estimation. We choose to use an exactly identified system because most of our chosen dimensions, i.e., the constraints in our problem have a direct economic interpretation (the unconditional budget constraint and the unconditional unbiasedness of price, for example). The solution might not have much economic meaning if we choose the over-identified system route.

[25] Since this trader has information for only one period and therefore maximizes his profit over one period.

The market maker prices the stock in each period such that $P = E[\tilde{v} \mid \omega_t]$. The same steps can be repeated with the only difference being the objective function for the manager. Note that we have a quadratic objective function for the manager. The NAV itself is up to the ninth power of the state variable $\tilde{n}_0$. So after taking the first order conditions and using the projection conditions on them, we have a function that is up to the 18^{th} power of $\tilde{n}_0$. So while taking expectations, we use the Gauss-Hermitian quadratures with 10 nodes while solving our first period problem.[26] Therefore, we calculate all expectations using only 10 nodes for the Gauss-Hermitian quadrature. The second period problem has a linear objective function and is not as complicated.

We are now ready to discuss the approximate solutions for some specific parameter values.

B.1 Solution for a specific numerical problem

Unless otherwise specified, the parameter values we chose were the following: $\gamma = 1$, $\sigma_n^2 = 0.8$, $\sigma_z^2 = 1.0$. The results are reported in Table 3 through Table 12.

As predicted by the corollary in the text, the manager makes an informational gain at low levels of NAV. As the NAV goes up, the probability of making an adverse trade increases and therefore the manager is more likely to make a non-informational loss. Table 3 shows that beyond an NAV of 0.47, the non-informational loss dominates the informational gain, resulting in a discount in the second period. The informed trader's gain is monotonically increasing with NAV for NAV greater than 0.5. An interesting feature is that the liquidity trader's loss is monotonically decreasing as the fund NAV increases. This is because as the NAV goes up, the manager has to invest more and therefore more is revealed through the prices. The market becomes deeper in this case taking some load off the liquidity traders.

In the one-period model of Holden and Subrahmanyam (1992) with two informed traders, the optimal expected investment (in dollar amount) is given as $2\beta^2\lambda\sigma_n^2$. Note that β is the sensitivity of the informed trader's demand to a news signal and λ is the inverse of market depth. For our parameter values, this turns out to be 0.376.[27] The manager makes a fairly low premium at this

[26] A function is best approximated by choosing up to $N+1^{th}$ quadrature node points, when the function is defined up to $2N^{th}$ power in a normally distributed variable. So a choice of more than 9 quadrature points is accurate for our purpose.

[27] Calculations of this form are presented in Section 6, where we solve this problem using some simplifying assumptions.

value. The Kyle trader, acting without a constraint, would have made an expected profit of $\frac{\beta\sigma_n^2}{3}$ which, given our parameter values, is 0.19. Therefore, our manager is substantially below this maximum attainable profit due to his policy constraints. The fund manager wants to invest more when he sees a good signal. But, if there is a good signal, he anticipates a higher price and this makes him cut down on his demand, keeping in mind that he cannot invest more than his NAV. So he cannot make as much profit as he would like to. When the signal is bad, the manager would like to demand less. But he has to invest a minimum amount in the risky asset due to his policy constraints and so he is forced to order more than he should. In either case, he is not acting as he should in the absence of any policy constraints. As the NAV goes up, the constraints become more and more binding (consistent with the corollary) and the fund begins to trade at a discount.

This intuition can be confirmed through the manager's demand policies presented in Table 4. As the NAV increases, his demand policy becomes more and more non-linear, i.e., the second-degree and the third-degree coefficients begin to increase in magnitude. As one would expect, the linear and the cubic terms have a positive coefficient indicating that he continues to increase the demand as the signals grow positive. A negative second-degree term indicates that he needs to curb the demand as the signal becomes higher because he cannot afford it given his policy constraint. A negative constant term in his policy indicates that given a certain signal, he will need to curb his demand since he is restricted by his budget in the form of NAV.[28]

The demand strategy for the informed trader is presented in Table 5. It can be seen that his trading strategy is more linear than that of the manager. This is because he is operating under no constraints. He makes his strategy non-linear only because he needs to respond rationally to the manager's demands. Unlike the manager, he has a positive constant coefficient. He takes advantage of the constraint on the manager and the fact that he moves the price adversely.

The pricing policy of the market maker is given in Table 6. An interesting result is that this strategy is fairly linear, even more so at higher NAV's. This can be explained by observing that as NAV increases, the demand strategies become more and more aggressive with the linear terms becoming very large. So most of the information in the aggregate demands is revealed through the linear component. Therefore, he does not have to infer much from the non-linear components. We

[28]Note that the terms given in Table 4 are coefficients of the Hermitian bases. So the constant coefficient will be given as $a_0 - a_2$ because $H_0(x) = 1$, $H_1(x) = -x$, $H_2(x) = x^2 - 1$ and $H_3(x) = -x^3 + 3x$.

tried going up to the cubic term in the pricing function but that was fairly small as well.

Before we move on to solve the first-period problem, it would help to check whether our equilibrium is consistent with some of the intuition we derive from the analytical solutions of Kyle (1985) in the absence of a policy constraint. It is expected that the informed trader and the manager will benefit more if the variance of the news event σ_n or the variance of liquidity trade σ_z increases. Table 7 and Table 8 show the profits of the three categories of traders for different values of σ_n and σ_z, respectively. As expected, the profits of the informed agent and the manager increase if the news or the liquidity trade is more volatile. This increased profit comes at the expense of liquidity traders. We also need to check whether the equilibrium is consistent with the result introduced in Lemma 1. For this, we solve our model without any informed trader. The results are presented in Table 9. We find that as expected, the fund continues to make a profit even at a very high NAV of 1.4. The profit goes down as NAV increases. This once again is consistent with our arguments. Further, we solve our model without assigning any policy constraint to the manager. This setup reduces to that of the one-period version of Holden and Subrahmanyam (1992) with two informed traders and is easily solvable. Our numerical results in this case match the analytical results.

We are now in a position to solve the first-period problem. We must first determine the value function for the manager at the end of the first period. To do so, we first generate the profits for the fund in the second period for 220 different values of NAV_1. We next approximate this profit as a polynomial function of NAV_1 and $\tilde{n}_1$. We approximate our value function as the following:

$$\Pi_1^M = 0.1723 - 0.1826H_1(NAV_1) + 0.0560H_2(NAV_1) - 0.1987H_1(\tilde{n}_1) - 0.0419H_2(\tilde{n}_1). \qquad (69)$$

We substitute this function in the manager's objective function at t = 0 as in equation (65) and repeat the procedure.

In Table 10, we present the expected net profits of the fund over the two periods, and the expected profits in the second period given the information at t = 0. This table shows two things clearly. First, a fund begins with a premium. This premium is expected to decrease in the second period. However, the initial investors would still be willing to buy the fund at a premium because even though the manager does lose in the second period, he more than makes up for it in the first period. Second, as expected from the corollary, the discount would show a mean reverting phenomenon. If we give the manager a very high NAV, he would not be able to handle it and would be expected to lose some of it. This would increase the discount. On losing some of the NAV, he is in a better position to handle the rest. This reduces the discount.[29]

B.2 A single-period two-asset economy

In order to check for the robustness of our equilibrium, we repeat our procedure for a two-asset economy in one period. We feel that this is important because a one-asset model does not capture the effect of signals on other assets on the demand of a particular asset. This might affect the nature of our equilibrium. In order to support the results of the one-asset case, we need to make sure that the basic nature of our results stays unaffected in a multi-asset environment.

In this setup, we denote the news on asset i by $\tilde{n}_i$, which is normally distributed with mean zero and variance σ_n^2, where i = 1, 2. The payoffs of the two assets are independent of each other. The manager is endowed with an initial NAV_0 and seeks to maximize the end of the period NAV since his compensation is a fraction of this NAV. Therefore the manager's problem is the following:

$$\max_{X_1, X_2} E\left[NAV \mid \tilde{v}_1, \tilde{v}_2, NAV_0\right] \tag{70}$$

subject to

$$E\left[X_1 P_1 + X_2 P_2 \mid \tilde{v}_1, \tilde{v}_2, NAV_0\right] \geq \gamma NAV_0, \tag{71}$$

$$NAV = NAV_0 + X_1(\tilde{v}_1 - P_1) + X_2(\tilde{v}_2 - P_2). \tag{72}$$

Just like before, the above two constraints are the policy and budget constraints for the manager.

The informed trader in asset i is assumed to have his information restricted to asset i only and therefore his objective function is the following:

$$\max_{Y_i} E\left[Y_i\left(\tilde{v}_i - P_i\right) \mid \tilde{v}_i\right]. \tag{73}$$

The market maker for asset i is competitive, and prices asset i such that $P_i = E[\tilde{v}_i \mid \omega_i]$, where $\omega_i = X_i + Y_i + Z_i$ is the total demand on asset i. Note that in this case, X_i will not be a function

[29] Ideally, we would like to check for the robustness of our procedure by going to higher degrees of Hermite polynomials. We tried our demand policies up to the third degree because beyond that the convergence becomes extremely slow. We feel that by going up to the cubic term, we have at least captured the basic economic features, i.e., the first two moments of the demand and pricing strategies.

of the news on asset i alone. It will also depend upon the news on the other asset. This is because if the manager sees a moderately positive signal on asset 1 and a very high signal on asset 2, he will demand more of asset 2 than in the case when he sees a very high signal on both assets. We therefore conjecture the demand policy of the manager as

$$X_i = f_0 + f_{11}H_1(\tilde{n}_i) + f_{12}H_1(\tilde{n}_j) + f_{21}H_2(\tilde{n}_i) + f_{22}H_2(\tilde{n}_j) + f_3 H_1(\tilde{n}_1)H_1(\tilde{n}_2), \quad j \neq i = 1, 2. \tag{74}$$

The above equation represents a complete Hermitian polynomial in the second degree and works as well as a tensor product base.[30] The same form holds for the manager's demand function in either asset. The informed agents are identical in both assets and therefore have the same demand:

$$Y_i = g_0 + g_1 H_1(\tilde{n}_i) + g_2 H_2(\tilde{n}_i) \qquad i = 1, 2. \tag{75}$$

The pricing function is conjectured as

$$P_i = h_0 + h_1 H_1(\omega_i) + h_2 H_2(\omega_i) \qquad i = 1, 2. \tag{76}$$

We now have thirteen unknown coefficients (including the Lagrangian multiplier for the manager). We take the first order conditions[31] and fix the following thirteen directions:[32]

$$E\left[\left(\tilde{v}_1 - (X_1 \frac{\partial P_1}{\partial X_1} + P_1)(1-\psi)\right) H_j(\tilde{v}_k)\right] = 0, \qquad j = 0,1,2 \quad k = 1,2; \tag{77}$$

$$E\left[(\gamma\, NAV_0\, H_i(\tilde{v}_1) - X_1\, P_1\, (H_i(\tilde{v}_1) + H_i(\tilde{v}_2)))\right] = 0, \qquad i = 0,1,2; \tag{78}$$

$$E\left[\left(\tilde{v}_1 - Y_1 \frac{\partial P_1}{\partial Y_1} - P_1)\right) H_j(\tilde{v}_1)\right] = 0, \qquad j = 0,1,2; \tag{79}$$

$$E\left[(\tilde{v}_1 - P_1)H_i(\omega_1)\right] = 0, \qquad i = 0,1. \tag{80}$$

Tables 11 and 12 show the manager's profits and demand strategy, respectively. Consistent with the intuition, we do find that the profits of the manager go down as the NAV increases. The fund turns into a discount at an NAV slightly less than twice the NAV at which the fund turns into a discount in a single asset environment. This is because there is one extra state variable

[30]See Judd (1998) for further discussion.

[31]Note that for reasons stated in B.1, we are once again solving the problem by making the policy constraint an exact equality instead of an inequality.

[32]Note that all the above conditions are fixed with respect to asset 1. By symmetry, the conditions with respect to the second asset will be identical. In condition (78) we have used the symmetric property that $E\left[X_2 P_2 H_i(\tilde{v}_1)\right] = E\left[X_1 P_1 H_i(\tilde{v}_2)\right]$.

uncorrelated with the signal on a particular asset, i.e., the signal on the other asset. Since the manager cannot communicate the effect of this signal on his demand, this part of his demand forms a non-informational trade which contributes to a loss on his trade.

The demand strategy looks fairly intuitive. One interesting feature is the negative sign on coefficient f_3. This means that $\frac{\partial^2 X}{\partial \tilde{v}_1 \partial \tilde{v}_2}$ is negative. In other words, the demand of a risky asset increases at a faster rate with its signal when the signal on the other asset is lower than when the signal on the other asset is higher. This is intuitive because if asset 1 has a high signal and asset 2 has a low signal, then the manager can utilize most of his NAV by demanding asset 1. However, if both assets have a high signal, the manager does not have to buy a lot of any one asset. Another feature to be noted is that as the NAV goes up, the demand becomes more and more non-linear. This is similar to what we found in a single asset environment. The demand strategy of the informed trader and the pricing strategy of the market maker are fairly similar to those in the one-asset case and therefore are not shown here. In the analysis of the two-asset model, we went up to the second degree only. Since our main objective was to demonstrate that our equilibrium is intuitive and is identical in nature to the single asset case, we did not go further.[33]

[33] A cubic demand policy will need a complete polynomial of third degree which consists of 8 elements. The computational requirements will increase considerably for that case.

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NAV_0	$Var(R_{fund})$	$Var(R_{NAV})$	$Cov(R_{NAV}, \Delta Pr)$
0.20	3.75	1.67	-0.33
0.25	2.66	1.06	-0.26
0.30	1.98	0.74	-0.22
0.35	1.53	0.54	-0.19
0.40	1.22	0.42	-0.16
0.45	1.00	0.33	-0.15
0.50	0.83	0.27	-0.13

Table 1: A Comparison of variances of return on fund price and the return on NAV for a one-asset simplified model. ΔPr denotes the change in premium.

N	Initial Premium	Premium (2^{nd} Period)
1	0.066	-0.05
2	0.10	-0.13
3	0.11	-0.23
4	0.09	-0.37
5	0.05	-0.52

Table 2: A Comparison of fund premiums and discounts with different number of assets. (Number of simulations = 30 x 5000).

NAV_1	Π_1^M	Π_1^I	Π_1^Z
0.2	0.065	0.175	-0.240
0.3	0.039	0.165	-0.204
0.4	0.014	0.160	-0.174
0.5	-0.008	0.160	-0.152
0.6	-0.029	0.162	-0.133
0.7	-0.049	0.166	-0.117
0.8	-0.067	0.172	-0.105
0.9	-0.085	0.180	-0.095
1.0	-0.102	0.188	-0.086
1.1	-0.119	0.198	-0.079
1.2	-0.135	0.208	-0.073
1.3	-0.150	0.218	-0.068
1.4	-0.166	0.229	-0.063

Table 3: Comparison of the profits of the manager, the informed trader and the liquidity trader for different values of NAV_1. $\tilde{n}_0$ is kept at its average value of 0.

NAV_1	a_0	a_1	a_2	a_3
0.2	-0.297	0.769	-0.079	0.106
0.3	-0.320	0.918	-0.097	0.131
0.4	-0.351	1.081	-0.117	0.156
0.5	-0.388	1.255	-0.137	0.187
0.6	-0.430	1.437	-0.158	0.216
0.7	-0.474	1.625	-0.180	0.246
0.8	-0.522	1.817	-0.202	0.277
0.9	-0.571	2.013	-0.225	0.308
1.0	-0.621	2.211	-0.248	0.339
1.1	-0.672	2.410	-0.271	0.370
1.2	-0.724	2.611	-0.294	0.402
1.3	-0.777	2.814	-0.317	0.434
1.4	-0.830	3.017	-0.340	0.465

Table 4: Demand strategies of the manager for different values of NAV_1. The strategy is given as $\sum_{i=0}^{3} a_i H_i(\tilde{n}_1)$. $\tilde{n}_0$ is kept at its average value of 0.

NAV_1	b_0	b_1	b_2	b_3
0.2	0.035	0.943	-0.062	0.075
0.3	0.121	1.124	-0.079	0.099
0.4	0.161	1.321	-0.097	0.122
0.5	0.200	1.533	-0.115	0.146
0.6	0.238	1.754	-0.134	0.171
0.7	0.277	1.982	-0.153	0.196
0.8	0.316	2.216	-0.173	0.221
0.9	0.355	2.453	-0.192	0.247
1.0	0.394	2.694	-0.212	0.273
1.1	0.433	2.937	-0.232	0.298
1.2	0.472	3.181	-0.252	0.324
1.3	0.511	3.428	-0.272	0.350
1.4	0.550	3.675	-0.292	0.376

Table 5: Demand strategies of the informed trader for different values of NAV_1. The strategy is given as $\sum_{i=0}^{3} b_i H_i(\tilde{n}_1)$. $\tilde{n}_0$ is kept at its average value of 0.

NAV_1	c_0	c_1	c_2
0.2	1.227	0.252	0.0006
0.3	1.230	0.214	0.004
0.4	1.232	0.183	0.003
0.5	1.234	0.159	0.002
0.6	1.235	0.139	0.002
0.7	1.236	0.123	0.001
0.8	1.236	0.111	0.001
0.9	1.237	0.100	0.001
1.0	1.237	0.091	0.001
1.1	1.237	0.084	0.001
1.2	1.237	0.077	0.000
1.3	1.238	0.072	0.000
1.4	1.238	0.067	0.000

Table 6: Pricing policy of the market maker for different values of NAV_1. The policy is given as $\sum_{i=0}^{2} c_i H_i(\omega_1)$. $\tilde{n}_0$ is kept at its average value of 0.

σ_n^2	Π_1^M	Π_1^I	Π_1^Z
0.80	0.0362	0.1647	-0.2009
0.85	0.0968	0.1864	-0.2832
0.90	0.1413	0.2116	-0.3529
0.95	0.1758	0.2217	-0.3975
1.00	0.1967	0.2296	-0.4263
1.05	0.2134	0.2447	-0.4581
1.10	0.2256	0.2658	-0.4906

Table 7: Comparison of the profits of the manager, the informed trader and the liquidity traders for different values of σ_n^2. The parameter values are: $\tilde{n}_0$= 0, NAV_1=0.30, and σ_z^2= 1.00.

σ_z^2	Π_1^M	Π_1^I	Π_1^Z
0.50	-0.0156	0.0810	-0.0654
0.60	-0.0063	0.0958	-0.0895
0.70	0.0037	0.1118	-0.1155
0.80	0.0142	0.1288	-0.1430
0.90	0.0251	0.1464	-0.1715
1.00	0.0362	0.1647	-0.2009

Table 8: Comparison of the profits of the manager, the informed trader and the liquidity traders for different values of σ_z^2. The parameter values are: $\tilde{n}_0$= 0, NAV_1=0.30, and σ_n^2= 0.80.

NAV_1	Π_1^M	Π_1^Z
0.2	0.179	-0.179
0.3	0.169	-0.169
0.4	0.159	-0.159
0.5	0.150	-0.150
0.6	0.141	-0.141
0.7	0.133	-0.133
0.8	0.126	-0.126
0.9	0.119	-0.119
1.0	0.113	-0.113
1.1	0.107	-0.107
1.2	0.101	-0.101
1.3	0.096	-0.096
1.4	0.092	-0.092

Table 9: Comparison of the profits of the manager and the liquidity trader in the absence of any other informed trader. $\tilde{n}_0$ is kept at its average value of 0.

Initial NAV NAV_0	Initial Premium $\Pi_0^M + \Pi_1^M$	Expected Second period premium Π_1^M
0.20	0.102	-0.009
0.25	0.093	-0.020
0.30	0.087	-0.030
0.35	0.084	-0.039
0.40	0.082	-0.046
0.45	0.082	-0.051
0.50	0.085	-0.055

Table 10: The initial and expected premium in the second period given the initial NAV.

NAV_0	Π^M	Π^I	Π^Z
0.5	0.047	0.140	-0.163
0.6	0.024	0.137	-0.148
0.7	0.023	0.135	-0.136
0.8	-0.018	0.134	-0.125
0.9	-0.037	0.135	-0.116
1.0	-0.056	0.135	-0.107
1.1	-0.074	0.137	-0.100
1.2	-0.091	0.139	-0.093
1.3	-0.108	0.142	-0.088
1.4	-0.125	0.145	-0.082

Table 11: Comparison of the profits of the manager, each informed trader and the liquidity trader for different values of NAV_1. Parameter values are $\sigma_n^2 = 0.8$, $\sigma_z^2 = 1.0$.

NAV_1	f_0	f_{11}	f_{12}	f_{21}	f_{22}	f_3
0.5	-1.456	1.528	-0.383	0.274	-0.022	-0.389
0.6	-1.581	1.672	-0.416	0.309	-0.026	-0.440
0.7	-1.712	1.821	-0.450	0.345	-0.029	-0.492
0.8	-1.849	1.977	-0.486	0.381	-0.033	-0.544
0.9	-1.991	2.137	-0.523	0.418	-0.036	-0.598
1.0	-2.137	2.301	-0.561	0.456	-0.040	-0.652
1.1	-2.287	2.469	-0.600	0.494	-0.044	-0.707
1.2	-2.440	2.640	-0.640	0.533	-0.047	-0.763
1.3	-2.596	2.814	-0.681	0.572	-0.051	-0.819
1.4	-2.753	2.990	-0.723	0.611	-0.055	-0.875

Table 12: Demand strategies of the manager for different values of NAV_1. The strategy is given as $f_0 + \sum_{i=1}^2 \sum_{j=1}^2 f_{ij} H_j(\tilde{n}_i) + f_3 H_1(\tilde{n}_1) H_1(\tilde{n}_2)$. Parameter values are $\sigma_n^2 = 0.8$, $\sigma_z^2 = 1.0$.