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Portfolio Pumping, Trading Activity and Fund Performance*

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Abstract. We develop a model of trading by an informed fund manager compensated on the basis of her fund's Net Asset Value (*NAV*). We show that she has an incentive to pump her portfolio by buying securities she already holds. Pumping leads to excessive trading and hurts long-term fund performance. It also biases upward measured *NAV*s and contributes to closed-end fund discounts. Despite such costs, it may still be optimal to base her compensation on *NAV*.

JEL Classification: D02, G12, G20

1. Introduction

Investments in financial assets are increasingly undertaken through mutual funds and retirement plans. Financial assets held through mutual funds, life insurance companies and retirement funds presently account for ~ 50% of the total investment in corporate equities in the USA.[1] The greater presence

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of institutions in general, and delegated portfolio management in particular, is commonly perceived to have consequences for trading volume and liquidity in financial markets. Dow and Gorton (1997), for instance, provide evidence that suggests a causal connection between increased institutional holdings and increased trading volume in financial markets. In addition, there is widespread reliance in the broadcast media on institutional trades to "explain" large variations in daily volume and prices in equity and other financial markets.

While the popular media pays significant attention to trading decisions of financial institutions, theoretical models of price determination in financial markets tend not to distinguish between trading by individuals on their own account and by fund managers acting in a fiduciary capacity. In this article, we focus on the role of short-term performance measurement in distorting a fund manager's incentives to engage in the trading of financial assets. We show that a fund manager rewarded periodically on the measured value of her portfolio will trade excessively and tend to deviate from the objective of long-term value maximization.

Our basic model features a risk neutral, informed fund manager rewarded on both short and long-term performance. She manages a fund comprising a risk-less asset and a risky asset and trades the risky asset in a Kyle (1985)-type batched order market. In this environment, we show that she trades excessively in the direction of her existing holdings of the risky asset in order to bolster the short-run measured value of her fund. Such activity is often referred to as "portfolio pumping,", "painting the tape," or "marking up." Portfolio pumping increases with the size of her holdings of the risky security and the weight placed on her short-term performance. Importantly, her pumping incentives do not depend on the liquidity characteristics of the risky security since both the costs and benefits associated with incremental trade depend linearly on the liquidity parameter.

In equilibrium, a competitive market-maker takes into account the manager's pumping incentives and sets his pricing schedule to offset any anticipated impact on market clearing price. Faced with such an adjustment on the market-maker's part, the manager rationally anticipates a decline in her fund's short-run NAV in the absence of pumping. Thus, pumping emerges in our model as an equilibrium phenomenon and generates excessive levels of trading, even when the manager's position in the risky asset is

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[1] The Federal Reserve's Flow of Funds data reveal that the total market value of corporate equities held in the USA at the end of 2010 amounted to $23.2 trillion. Of this, $11.4 trillion was held by mutual funds, traded funds, brokers and dealers, insurance companies, and private, state and federal government retirement funds.

perfectly known to the market-maker. More realistically, when portfolio holdings are the manager's private information, pumping affects the market clearing price and biases upward short-run *NAV* even when the risky security is priced properly on average. This is because the manager's incentive to pump induces a positive correlation between the fund's holding of the risky asset and its market clearing price. At the same time, uncertainty about holdings promotes liquidity in the market for the risky security and increases the scale of information-based trades. We show that private information on inventory levels, together with managerial concern about short-term performance, can generate trade in equilibrium even without liquidity traders.

The manager engages in portfolio pumping even when it adversely impacts her fund's long-term performance. Pumping lowers long-term performance due to trades undertaken at distorted prices. However, the manager's concern with short-term measured performance always provides her with adequate incentives to pump. In fact, to preserve her ability to trade at distorted prices, she strictly prefers to avoid public disclosure of her holdings even when such disclosure may be in the interest of long-term investors. Her pumping incentives survive even when trades have transactions costs associated with them. A fund with a larger position in the risky asset has a worse long-term performance in the presence of such transactions costs, irrespective of the level of information asymmetry about fund holdings.[2]

Since pumping incentives generate an upward bias in interim *NAV*, deviations of closed-end fund prices from *NAV* arise naturally in our setting. As a result, our model provides an alternate channel through with closed-end funds could rationally trade at a discount and we provide conditions under which premia and discounts arise.[3] Since uncertainty about holdings likely increases as funds are invested, our model also provides a rational explanation for the emergence of a discount even for funds starting out at a premium after their initial public offering. Extending our basic model to an environment where value-relevant information arrives over time, we also show that discounts can persist over time even as *NAV* performance reveals information about holdings.

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[2] Berk and Green (2004) present an analysis of mutual fund trading activity where managerial talent is assumed to have decreasing returns to scale. Our analysis shows that pumping incentives, in the presence of transactions costs, can result in decreasing returns to scale without imposing restrictions on managerial ability.

[3] See Dimson and Minio-Kozerski (1999) for a survey of the literature on the closed-end fund puzzle.

Since the dependence of managerial compensation on short-term measured performance is crucial for our results, we outline several situations where such a compensation plan may be optimal. In particular, we argue that risk-sharing, with or without other agency conflicts, would induce such dependence. Risk-averse investors, faced with the chance of early redemption, would like managers to care about interim fund values. Even risk-neutral long-term investors may prefer to link compensation of risk-averse fund managers to short-term performance despite costs of pumping. This is because such linkage provides her incentives to trade more aggressively on value-relevant information and also counters her incentives to rebalance away from exposures to long-term risks associated with her positions.

A growing empirical literature studies the impact of possible portfolio pumping activity on stock prices and mutual fund performance. Prominent among these studies are papers by Sias and Starks (1997); Carhart *et al* (2002); Bernhardt and Davies (2005). These papers document quarter- and year-end price impact on stocks held by mutual funds and provide evidence consistent with the hypothesis that fund managers inflate quarter-end portfolio values with last-minute purchase of stocks already held. Our results are broadly consistent with the evidence provided by these papers. In particular, Carhart *et al.* (2002) hypothesize that such behavior is induced by managerial compensation considerations. Our model, indeed, establishes formally that such a pattern would be expected when managerial compensation considerations are important.

Bernhardt and Davies (2009) analyze a case where mutual fund managers focus on short-term performance to generate inflows from investors. Assuming trades always have price impact, they also show that managers invest more in securities their fund already owns. In our model, in contrast, the manager optimally trades off short-term benefits of pumping with diminished long-term performance. In addition, we incorporate pumping incentives explicitly into the price formation process and, thereby, establish conditions for pumping to have price impact. The focus on equilibrium allows us to show that NAV bias arises even when individual security price is unbiased and when anticipated pumping is fully accounted for in the price-setting process. Allowing the market-maker to react optimally also enables us to distinguish between the price and volume implications of portfolio pumping and to show that pumping incentives exist even without guaranteed price impact. As a result, we establish that increased levels of security holding through funds lead to increased levels of trading in security markets, in line with the results in Dow and Gorton (1997). While these authors attribute increased trade levels to uninformed managers mimicking the optimal actions of informed managers, we show that *all* fund managers have incentives to trade excessively when they care about measured short-term performance. Our model, in addition, generates implications for the pricing of closed-end funds.

The article proceeds as follows. Section 2 presents the basic model and its implications. Section 3 focuses on disclosure incentives and Section 4 on implications for the pricing of closed-end funds. Section 5 addresses optimality considerations for the contractual form and discusses extensions. Section 6 concludes. Proofs not useful for the exposition are provided in Appendices (A and B).

2. The Model

In this section, we first present our basic model in which a single fund manager with a single risky security in her portfolio engages in a single round of trading. We highlight the principal trade-offs faced by fund managers in their trading decisions and outline empirical implications. We then extend our formulation to the case of multiple fund managers.

2.1 STRUCTURE

A risk neutral fund manager allocates funds between a risk-free asset and a risky asset. The latter is traded once in a batched order market as in Kyle (1985). There are three dates, $t=0$,1 and 2. At $t=0$, there is symmetric information about the terminal value of the risky security and its per-unit price is P_0. The fund's NAV is I_0, comprising z units of the risky security and $I_0 - zP_0$ invested in the risk-free asset. The precise composition of the fund's portfolio is privately known by the manager.[4] Outsiders view her position in the risky security as a random variable, $\tilde{z} \sim N(\bar{z}, \sigma_z^2)$.

Between Dates 0 and 1, the manager receives perfect information about the risky security's final payoff.[5] All other players view this as a random variable $\tilde{v} \sim N(P_0, \sigma_v^2)$. The manager then places a market order, $x(v, z)$, for execution at Date 1 along with a collective order of u from uninformed liquidity traders, where $\tilde{u} \sim N(0, \sigma_u^2)$. As in Kyle (1985), the batched orders are cleared at price $P_1 = E(\tilde{v}|y)$ by a risk-neutral, competitive market-maker who observes the net order flow. The fund then publicly announces its *NAV* computed using the market-clearing price. The liquidation value of the risky security is realized at Date 2. The risk-free rate is normalized to zero.

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[4] Although regulations vary across jurisdictions and fund types, those required to disclose portfolio composition do so with delay. As a result, it is natural for the manager to possess more up to date information on her holdings at the time of trading. We discuss disclosure requirements and incentives in greater detail in Section 3.

[5] This assumption is only for expositional ease; noisy information does not change our qualitative results. Justification for fund managers having access to valuation relevant information can be found in Edelen (1999).

The fund manager cares about both short- and long-term values of *NAV*: she places a weight of γ on the *NAV* at Date 1 and a weight of $(1-\gamma)$ on the fund's liquidation value, where $0<\gamma<1$. This objective function is motivated by the prevalent compensation patterns in the fund industry where a substantial portion of per-period management fees is in the form of a set percentage of assets under management.[6] In addition, net flows into and out of open-end mutual funds are strongly related to lagged measures of performance, as shown by Ippolito (1992); Chevalier and Ellison (1997); Sirri and Tufano (1998), among others.[7] Therefore, mutual fund managers have additional incentives to care about short-run performance through its impact on assets under management. We discuss the optimality considerations associated with such an objective function in Section 5.

2.2 EQUILIBRIUM

Following Kyle (1985), we look for the unique equilibrium in linear strategies and conjecture the equilibrium price schedule set by the market-maker to be:

$$P_1 = P_0 + \lambda(y - \bar{y}), \qquad \lambda > 0 \tag{1}$$

with $\bar{y}$ the expectation of net order flow and λ, the liquidity parameter, its per-unit price impact.

The manager chooses her trading order, $x(v, z)$, to maximize her objective function:

$$W = I_0 + \gamma[z(E(P_1) - P_0)] + (1-\gamma)[z(v - P_0) + x(v - E(P_1))]. \tag{2}$$

The first bracketed term is the contribution of the change in the fund's value over the first period, and the second the contribution from the final payoff. Date 1 transactions, being marked to market, have no short-run impact on measured performance. It is only at Date 2 that the cost of accumulating a suboptimal position at Date 1 is reflected in measured values.

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[6] Several papers in the literature, e.g., Miller and Rock (1985) in modeling dividend policy, use a similar objective function. Linearity, although not essential for our results, allows for closed-form solutions.

[7] Del Guercio and Tkac (2002) also provide evidence of the importance of the performance–flow relationship in both mutual funds and pension plans.

Proposition 1 describes the resulting equilibrium:

Proposition 1
The unique equilibrium in linear strategies has the following properties:

(1) *The fund manager's optimal order strategy is given by*:

$$x^*(v, z) = \frac{(v - P_0)}{2\lambda} + \beta\left(\bar{z} + \frac{(z - \bar{z})}{2}\right), \tag{3}$$

where

$$\beta = \frac{\gamma}{1 - \gamma}$$

(2) *The price schedule set by the market-maker is*:

$$P_1(y) = P_0 + \lambda(y - \beta\bar{z}), \tag{4}$$

where

$$\lambda = \frac{\sigma_v}{2(\beta^2 \frac{\sigma_z^2}{4} + \sigma_u^2)^{\frac{1}{2}}} \tag{5}$$

(3) *The expected level of trade in the risky security is given by* $\bar{y} = \beta\bar{z}$.

Equation (3) shows that both the inventory level of the risky security, z, and the manager's concern with short-term performance, β, affect her trading strategy. For $\beta = 0$, her trading strategy reduces to that found in Kyle (1985), the value maximizing trading strategy. For $\beta > 0$, her added concern about interim *NAV* leads to excessive trade in the direction of her existing holdings, even at a possible cost to long-run performance. We call such a deviation portfolio pumping. The market-maker takes into account the manager's portfolio pumping incentives and, hence, prices are affected only when the amount of pumping deviates from its expected level. The manager's concern with short-run performance and the uncertainty associated with her portfolio holdings contribute to a more liquid market in the risky security.

Our model cannot directly account for monetary flows into and out of the fund and their possible impact on the manager's trading strategy. This is an artifact of the Kyle (1985) model where the investor can always borrow to invest. It is, however, possible to reinterpret our results in the context of a world where fund flows matter. In particular, we can interpret the uncertainty in portfolio holdings, σ_z^2, as being partly driven by imperfectly observed monetary flows into and out of the fund. Such unanticipated flows, by triggering buying and selling activity, will also promote liquidity, as in our model.[8] This suggests that much of the intuition behind our results will carry over to a more complicated model that explicitly accounts for the role of fund flows.

In the following subsection, we elaborate on the empirical implications of our model.

2.3 PORTFOLIO PUMPING: MAGNITUDE AND PRICE IMPACT

The manager deviates from her value maximizing trading strategy solely due to her concern with measured short-run performance. We highlight below the factors that influence the magnitude of her pumping trades.

Remark 1
The manager's incentive to pump increases with her holding of the risky security, z, and her level of concern, β, with short-run performance. It does not depend on the level of her informational advantage, the level of uncertainty associated with her portfolio holdings or on the liquidity parameter λ.

Remark 1 suggests that increased holdings in fund portfolios will be accompanied by increased trading volume. Unlike in Dow and Gorton (1997), this effect is not the result of uninformed managers engaging in excessive trading in order to conceal their lack of superior information or expertise. This predicted relation between pumping incentives and fund inventory levels also finds empirical support in Gallagher *et al.* (2009) who report that fund managers are more likely to trade in stocks in which they have relatively larger holdings at quarter-end, when their performance would normally be evaluated.

Our model shows that pumping volume does not depend on the degree of informational advantage of the manager. Nor does it depend on the liquidity characteristics, λ, of the risky security being traded. This follows from the fact that both the costs (long-term performance) and benefits (short-term price impact) associated with incremental trade depend linearly on the liquidity parameter λ. As a result, the manager's deviation from her *value maximizing trading strategy* is independent of the liquidity parameter she

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[8] Edelen (1999) shows that mutual fund managers will typically buy to accommodate an inflow of funds. Large redemption requests also typically lead to selling. Bernhardt and Davies (2009) assume such trades have short-term price impact and argue that managers pump their portfolios to attract funds from investors focused on short-term performance. Their exogenous specification of the liquidity levels of individual securities precludes them from accounting for the impact of anticipated fund flows on market liquidity.

faces in the market.[9] This is in sharp contrast to the case in Bernhardt and Davies (2009) where the manager does not take into account her fund's long-term performance and, therefore, pumps more in less liquid stocks. Consistent with our equilibrium prediction, Hu *et al.* (2009) report that quarter-end excess trading by institutional traders is not confined to small, illiquid stocks where pumping may be expected to have the greatest price impact but is, instead, even more prevalent in larger, liquid stocks.

Since the manager's incentive to pump is rationally anticipated by the market-maker, pumping has realized price impact in equilibrium only when the manager's actual holdings are different from what is anticipated by the market-maker.[10] At the same time, it is the market-maker's anticipation of pumping that gives rise to pumping trades in the first place. This is because, faced with the market-maker's conjectured level of portfolio pumping, a fund manager who abstains from pumping her portfolio anticipates suffering a decline in her fund's interim NAV. Therefore, the manager is forced to engage in portfolio pumping not because she hopes to fool the market-maker, but because she does not want to suffer the price consequences associated with inadequate pumping. The following Remark characterizes the price impact of portfolio pumping:

Remark 2
The price impact of portfolio pumping, $\beta(\lambda(z-\bar{z}))/(2)$, is proportional to the deviation in the holding of the risky security from its expected level, the liquidity characteristics of the risky security, λ, and the manager's level of concern with short-run performance, β.

There is a substantial empirical literature exploring the price impact associated with portfolio pumping. Carhart *et al.* (2002) report that equity fund returns, net of the S&P 500, are abnormally high at quarter-ends and abnormally low the next day. These effects are more pronounced for year-end quarters and do not exist for month-ends that are not quarter-ends. Given that compensation considerations would tend to make managers particularly concerned with fund valuations at year and quarter-ends, it stands to reason that portfolio pumping activities would be concentrated around these periods. They conclude, therefore, that portfolio pumping is widespread and is likely to be caused by managerial compensation considerations, consistent with our model. Bernhardt and Davies (2005) provide further evidence that portfolio pumping also affects the return characteristics of the S&P 500 index at quarter and year-ends. They argue, therefore, that the magnitude of the price impacts reported in Carhart *et al.* (2002) may be significantly biased downwards. In a complementary vein, Sias and Starks (1997) find that, at year-ends, stocks with greater institutional ownership show higher returns, followed by worse returns at the beginning of the year. Although they attribute their findings to tax-loss selling, their results are also consistent with our prediction that greater institutional ownership gives rise to higher levels of portfolio pumping.

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[9] The intuition behind the result that pumping trade size is independent of market liquidity is likely to carry over to settings other than the current linear structure. Since the price impact of pumping trade affects both marginal costs and marginal benefits in a similar fashion, optimal trading quantity will depend on factors such as inventory and preference for short versus longer-term performance, rather than liquidity *per se*.

[10] That is, when pumping activity is fully anticipated, the resultant equilibrium price is the same as it would have been in a situation where the fund manager had no short-term incentives and, hence, no incentive to pump. Of course, in any equilibrium with asymmetric information, every unit of trade has price impact.

Our result that the level of pumping activity is independent of the liquidity parameter, λ, predicts that portfolio pumping has greater price impact in illiquid markets. Consistent with this prediction, Carhart *et al.* (2002) report a four-fold difference, from 50 to 200 basis points, in the quarter-end returns of funds specializing in large capitalization stocks and those specializing in more illiquid small stocks. Similarly, Gallagher *et al.* (2009) find the stock price effects of pumping to be larger for less liquid stocks.[11]

Finally, Carhart *et al.* (2002) also establish that these abnormal return patterns are more pronounced for funds that have performed well in the immediate past. They argue that given (i) managerial compensation based on assets under management and (ii) the convex response pattern of fund inflows to lagged performance as established by Ippolito (1992); Chevalier and Ellison (1997); Sirri and Tufano (1998), we would expect better performing funds to be more concerned with quarter and year-end short-term performance. In terms of our model, such funds can be viewed as having a higher β and, therefore, a greater incentive to move prices in the short term.

2.4 PORTFOLIO PUMPING AND *NAV* BIAS

As in Kyle (1985), competitive market making leads to unbiased pricing of the risky security in our model. But portfolio pumping still enables the manager to bias upward the NAV of her fund! To see how, note first that, in the absence of portfolio pumping, the expected value of the fund's NAV at

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[11] Gallagher *et al.* (2009) also find that the price impact of pumping was moderated after rules were changed on the Australian Securities Exchange to enhance liquidity at the close. Duong and Meschke (2008) show that increased market making activity dampens the price impact of pumping and that such impact has diminished post 2001.

date 1 would be I_0, since any trading profits are only realized at Date 2. With portfolio pumping, the fund's expected Date 1 NAV (denoted by NAV_1), is given by:

$$E[NAV_1] = I_0 + E[\tilde{z} \cdot (\tilde{P}_1 - P_0)]. \tag{6}$$

From Equations (3) and (4), we know that:

$$\tilde{P}_1 - P_0 = \frac{\tilde{v} - P_0}{2} + \beta\frac{\lambda(\tilde{z} - \bar{z})}{2} + \lambda\tilde{u}.$$

Since $\tilde{z}$ is uncorrelated with $\tilde{v}$ and $\tilde{u}$, it follows that:

$$E[\tilde{z} \cdot (\tilde{P}_1 - P_0)] = \beta\lambda\frac{\sigma_z^2}{2}$$

and, therefore, for $\sigma_z^2 > 0$,

$$E[NAV_1] = I_0 + \beta\lambda\frac{\sigma_z^2}{2} > I_0. \tag{7}$$

Substituting for λ (Equation (5)) in the equation above gives us the following result:

Proposition 2
Portfolio pumping, on average, biases upward a fund's short-run measured performance even though the market price of the risky security is unbiased. The level of bias in the short-run NAV, $(\beta\sigma_v\sigma_z^2)/(4(\beta^2\frac{\sigma_z^2}{4} + \sigma_u^2)^{\frac{1}{2}})$, *increases in the informational advantage of the fund manager, as measured by both* σ_v *and* σ_z.

This bias is rooted in the positive correlation between the price impact of pumping and the fund's actual holding of the risky security: a higher (lower) than expected holding level leads to higher (lower) than expected order flow and, in turn, to a higher (lower) market clearing price. However, since the fund's holding of the risky security is higher (lower) than expected, the change in the fund's NAV is more (less) than what it would have been if the price change had applied to the expected level of its inventory. This positive correlation between holding level and market price makes NAV convex in z and biases expected NAV upward.

This result casts doubt on the widespread practice of relying on quarter- and year-end NAV figures to accurately gauge fund performance of active fund managers. As Carhart *et al.* (2002) and Bernhardt and Davies (2005) have shown, funds are able to boost their measured performance at quarter- and year-ends despite the fact that their incentives to engage in portfolio pumping may be known to market participants. An additional implication of our analysis is that passively managed funds should exhibit no such bias even in the presence of portfolio pumping by active managers.

Such a bias in *NAV* also implies that investors in an actively managed open-end, no-load mutual fund have incentives to cash out at inflated *NAV* levels at quarter-ends and to reinvest when the levels are no longer inflated. Such actions would, of course, transfer value from longer term investors and adversely affect measured performance over the longer term. Most open-end mutual funds engaged in active trading put in place redemption fees, contingent deferred loads at the back-end and restrictions on frequent trading. Such fees and restrictions serve to discourage investors from engaging in mechanical redemption and reinvestment activity to try and take advantage of the fund manager's incentives to pump her portfolio.[12] This leaves open the possibility, however, of such a bias in *NAV* showing up as a price discount in a closed-end fund. We address this issue in greater detail in Section 4.

2.5 PORTFOLIO PUMPING: MARKET LIQUIDITY AND EXPECTED PROFITS

From the market-maker's perspective, pumping trades provide no information about the future value of a security and are, effectively, a form of noise trading. Consistent with this intuition, the liquidity parameter in Proposition 1, $\lambda = (\sigma_v)/(2(\beta^2 \frac{\sigma_z^2}{4} + \sigma_u^2)^{\frac{1}{2}})$, incorporates the impact of uncertainty about inventory holdings $(\beta^2(\sigma_z^2)/(4))$ along with the uncertainty about liquidity trades in the denominator. The greater liquidity thus generated promotes larger information-based trades, $(v - P_0)/2\lambda$. The following remark summarizes:

Remark 3
Uncertainty about a fund's holding of a risky security enhances liquidity in the market for the security and amplifies the magnitude of information-based trades.

It is worth noting here that the expression for λ implies that, unlike in Kyle (1985), trading activity can arise in our setting even in the absence of individual liquidity traders. Specifically, even with $\sigma_u^2 = 0$, the liquidity parameter, λ, remains finite as long as $\sigma_z^2 > 0$. Therefore, the fund manager has an incentive to pump her portfolio, along with her incentive to profit from

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[12] See Chordia (1996) for similar arguments and for empirical evidence showing that mutual fund managers levy fees to discourage redemptions. For simplicity, we do not explicitly account for the cost associated with redemption on investors who do not redeem early.

her valuation information. Of course, without liquidity traders to exploit, such trading will not generate expected profits for the fund. However, in general, when σ_z^2 and σ_u^2 are both strictly positive, portfolio pumping by the manager will tend to harm the fund's profit performance as we show below.[13] The result below characterizes the expected profits of a long-term fund investor who, like the market-maker, is unaware of the fund's precise portfolio composition:

Proposition 3
At date 0, the expected profits of the fund are given by:

$$E(\pi) = \lambda\sigma_u^2 = \frac{\sigma_v^2}{4\lambda} - \frac{\lambda\beta^2\sigma_z^2}{4}, \quad \text{where} \quad \lambda = \frac{\sigma_v}{2(\beta^2\frac{\sigma_z^2}{4} + \sigma_u^2)^{\frac{1}{2}}}. \tag{8}$$

The first part of Equation (8) indicates that, as in Kyle (1985), the entire profits of the fund accrue from the losses incurred by the (individual) liquidity traders.[14] The second part shows that a higher level of uncertainty about the fund's portfolio position hurts expected profits, even though it enhances the ability of the fund manager to exploit her asymmetric information about terminal value. If uncertainty about portfolio holdings were higher for larger funds (σ_z^2 increasing with $\bar{z}$), this would imply that, in the presence of short-term performance incentives, fund performance declines with size, in line with results in Chen *et al.* (2004) and Chan *et al.* (2009).

The manager's expectation of profits can be similarly derived as:

$$E(\pi|\tilde{z} = z) = \frac{\sigma_v^2}{4\lambda} - \frac{\lambda\beta^2(z^2 - \bar{z}^2)}{4}. \tag{9}$$

Equation (9) indicates that expected profits decrease with z^2, that is, with the absolute size of the holdings, $|z|$: the larger the position in the risky security, the more aggressive the portfolio pumping and the greater the expected price impact. This joint distortion of trades and prices decreases expected long-term profits. As a result, investors in a fund may benefit from policies limiting a manager's discretion in deviating from prescribed ranges for holdings in risky securities.[15]

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[13] For simplicity, we assume that managerial compensation is determined competitively and normalize it to zero.

[14] Without liquidity traders, unconditional profits are zero. However, it is simple to show that a fund with a larger than expected position in the risky security will perform worse than a fund with a smaller position.

[15] However, strict restrictions on managerial discretion can also contribute to diminished performance by restricting profitable trades. Alternatively, the equation may be interpreted

2.6 PORTFOLIO PUMPING WITH MULTIPLE FUNDS

Our analysis easily extends to the case of multiple funds. Keeping other aspects of the model unchanged, consider the case of N otherwise identical funds with the i-th fund's holding of the risky security given by $z_i = \bar{z} + \tilde{\delta} + \tilde{\epsilon}_i$. Here, $\bar{z}$ is the expected holding, the term $\tilde{\delta} \sim N(0, \sigma_\delta^2)$ represents a random component common across funds, while $\tilde{\epsilon}_i \sim N(0, \sigma_\epsilon^2)$ is a fund-specific random component (uncorrelated with $\tilde{\delta}$). The market-maker knows $\bar{z}$, but not the realizations of the two random components. Also, while the manager of a fund i knows her portfolio holdings and components $\tilde{\delta}$ and ϵ_i, she does not know the fund-specific realizations of ϵ_j of other funds $j \neq i$. Each manager, as before, knows the liquidation value of the risky security. With these assumptions we have:

Proposition 4
For N ex ante identical fund managers with inventory levels in the risky security $z_i = \bar{z} + \tilde{\delta} + \tilde{\epsilon}_i$, $i = 1, \ldots, N$, $\tilde{\delta} \sim N(0, \sigma_\delta^2)$ *and* $\tilde{\epsilon}_i \sim N(0, \sigma_\epsilon^2)$, *managerial concern with short and long-term performance produces a symmetric equilibrium in linear strategies*:

$$x_i^* = \frac{(v - P_0)}{(N+1)\lambda} + \beta \bar{z} + \frac{\beta}{N+1}\delta + \frac{\beta}{2}\epsilon_i, \qquad j = 1, \ldots, N$$

$$P_1 = P_0 + \lambda\left[\frac{N}{N+1}\frac{(v - P_0)}{\lambda} + \frac{1}{2}\beta\sum_{i=1}^{N}\epsilon_i + \beta\frac{N}{N+1}\delta + u\right] \to v, \text{as } N \to \infty$$

$$\lambda = \frac{\sigma_v}{(N+1)(\beta^2\frac{\sigma_z^2}{4} + \frac{N}{(N+1)^2}\beta^2\sigma_\delta^2 + \frac{\sigma_u^2}{N})^{\frac{1}{2}}} \to 0, \text{as } N \to \infty.$$

As in Holden and Subrahmanyam (1992) and Foster and Viswanathan (1993), the presence of competing traders leads to more aggressive trading and results in a dissipation of their collective informational advantage. Consequently, the liquidity parameter, λ, goes to 0 as $N \to \infty$.

Managerial concern with short-term performance, however, still results in excessive trading: expected volume, given by $\sum_{i=1}^{N} E(x_i) = N\beta\bar{z}$, increases with aggregate holdings of the risky security, as before. The level of expected aggregate trade does not, in addition, depend on the correlation

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as a rationale for "profit-taking," that is, trading out of appreciated positions for reasons other than portfolio rebalancing. Accumulation of a large position in a stock binds a manager to destroy value through an enhanced incentive to pump. Thus, trading out to "normal" positions when liquidity levels are high may restore incentives for ongoing performance.

structure of the holdings across funds. Thus, *ceteris paribus*, the volume of trades in risky securities should be expected to increase with the extent to which they are held by professionally managed funds, in line with the finding of Dow and Gorton (1997). Note that expected level of portfolio pumping trades is also independent of the degree of the managers' informational advantage.

Correlated holdings, however, will impact the volatility of pumping trades. Consider, for example, an increase in variance of the common component σ_δ^2, while keeping $\sigma_\delta^2 + \sigma_\epsilon^2$ fixed. From the expression for x_i^* above, it is evident that funds will mute their trading response to common shocks in holdings. This restraint comes about due to anticipated correlated pumping trades by other funds. As fund holdings become strongly correlated across funds, say as $\sigma_\delta^2/\sigma_\delta^2 + \sigma_\epsilon^2 \to 1$, the variance of aggregate pumping trades falls below $\beta^2\sigma_\delta^2$. So, even though expected pumping levels increase in total holdings, their volatility may remain bounded. This, in turn, implies that short-term biases in NAV will be muted with correlated fund holdings.

3. Inventory as Information

We have shown that pumping incentives arise from the manager's concern with short-term performance. In particular, she pumps her portfolio even when her portfolio holding is publicly known (see Remark 1). Pumping affects prices and long-term profits only when the market-maker does not know her holdings in the risky security. Consequently, the impact of her pumping on prices and long-term profits depends critically on the level of information asymmetry about her holdings.

The level of information publicly available about a fund's holdings is likely affected by regulatory policies in place. In the USA, the Securities and Exchange Commission (SEC) administers and enforces disclosure requirements with respect to funds' portfolio information. All institutions with investment discretion of over \$100 million in specified securities are required to file Form 13F disclosing their quarter-end holding in such securities within 45 calendar days of the close of the quarter. This information is immediately available to the public.[16] Such mandated disclosure allows market participants to update their information about fund holdings, but only with a time lag. For actively managed funds in particular,

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[16] However, the SEC also grants confidential treatment for certain holdings by providing for delayed disclosure for up to a year and the filing of 13F amendments. Agarwal *et al.* (2011) discuss disclosure requirements in detail and show that confidential filings contain value-relevant information.

at quarter-end, significant uncertainty about portfolio positions can remain in spite of such disclosure requirements. Consequently, our assumption about a manager having an informational advantage with respect to holdings is in line with prevailing disclosure requirements.

Of course, a fund can choose to disclose more about its holdings than what is required by law. To the extent that optimal exploitation of long-lived value-relevant private information requires a confidential accumulation of a position over time, both fund investors and the manager may prefer delaying disclosure to preserve competitive advantage. In our simple, three date model with a single fund, however, disclosing portfolio position prior to trade conveys no value-relevant information to outsiders. Further, a commitment of credible disclosure prior to trading eliminates pumping's price impact and increases profits as per Proposition 3. Even in this simple setting, however, the result below shows that a fund manager dislikes committing to a policy of disclosure.[17]

Proposition 5

A commitment to disclose the holding of the risky asset prior to trading decreases σ_z^2 *and results in*:

(1) *An increase in expected profits of long-term investors,*

(2) *A decrease in the value of the fund manager's objective function.*

The Proposition establishes that while long-term investors would prefer a full inventory disclosure policy, the manager does not. This discrepancy in preferences is directly due to the bias in NAV that arises when $\sigma_z^2 > 0$. Due to her (partial) interest in long-term performance, the manager, like the long-term investor, suffers from trading at price levels distorted by her pumping. However, she also benefits from short-term NAV performance. What is key is that this benefit is convex in her inventory holdings due to the positive correlation between unanticipated holdings and realized interim price. Thus, *ex ante*, she has an incentive to exploit the bias that arises from her informational advantage with respect to her inventory level, even at the cost of impaired longer term performance. Put another way, long-term investors gain only at the expense of liquidity traders, while the manager gains, in addition, at the expense of long-term investors. Thus, in contrast to the sunshine trading setting of Admati and Pfleiderer (1991), a manager rewarded partially on interim performance will not want to engage in full disclosure when she anticipates being able to affect interim prices.

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[17] The result also extends to the multiple fund setting. Also note that credible disclosure of up-to-date portfolio information, even if feasible, is likely to incur significant costs.

Proposition 5 shows the existence of a conflict between disclosure preferences of long-term investors and the manager in our specific setting. As mentioned earlier, such a stark conflict may not exist in the presence of long-lived value-relevant private information. Also, as we discuss in Section 5, there are settings in which long-term investors strictly prefer rewarding managers for interim performance despite costs associated with pumping. As an example, risk-neutral investors may optimally reward risk-averse managers for interim performance to get them to trade aggressively on shorter term value-related information. In such a setting, long-term investors will trade off the gains from inducing optimal information-based trading against losses arising from portfolio pumping and disclosure preferences of long-term investors need not differ as sharply from those of managers. Note also that imposing full disclosure requirements on a manager only removes the price impact of her pumping trades but does not remove her incentives to pump *per se*.

The manager's preference for pumping may, however, be exploited by a strategic trader who can learn about her inventory position even when such knowledge conveys no value-relevant private information. Such a trader, being able to anticipate the magnitude of the pumping trade, can profit by taking a partially offsetting position that allows him to sell (buy) the stock at a price artificially inflated (depressed) by the manager's pumping. Competition from such a trader hurts not only the manager's short-term performance, but also lowers long-term profits. Hence, in the presence of fund watchers who monitor fund holdings and trade based on such information, long-term investors may very well favor the manager's preference for guarding inventory information. The Proposition below establishes this result.

Proposition 6

Information on the portfolio position of the fund is valuable to a strategic trader. The ex ante value of such information to the trader is $\frac{1}{9}\lambda_s\beta^2\sigma_z^2$, *where* λ_s (λ) *is the liquidity parameter in the presence* (*absence*) *of the trader. The presence of the trader results in*:

(1) *A lowering of the inventory noise component in net trades from* $\frac{1}{4}\beta^2\sigma_z^2$ *to* $\frac{1}{9}\beta^2\sigma_z^2$ *and a higher liquidity parameter* $\lambda_s > \lambda$,

(2) (*a*) *Lower profits for the fund*; (*b*) *a lower value for the fund manager's objective function*; *and* (*c*) *an increase in losses suffered by liquidity traders*,

(3) *The strategic trader appropriating profits at the expense of both liquidity traders and fund investors.*

4. The Closed-end Fund Puzzle

A closed-end fund manager's compensation, like that of other fund managers', is typically based on the market values of assets under her management. However, unlike an open-end fund manager, she does not have to deal with issues of redemptions or inflows into the fund.[18] A closed-end fund typically trades at a discount to its *NAV*, although some funds occasionally trade at a premium. Discounts of 10–20% are quite common and have been regarded as anomalous in markets that have otherwise been regarded as reasonably efficient. The persistence of the discrepancy between market values and *NAV* of closed-end funds has been called the "closed-end fund puzzle."

Several explanations, relying on both rational and behavioral approaches, have been offered for the closed-end fund puzzle. Rational explanations, generally, are based on the notion that *NAV* may overestimate the market value of the fund portfolio on account of factors such as agency costs, tax liabilities, and the illiquidity, of asset holdings.[19] The agency cost theories argue that *NAV* figures do not take into account management expenses and expectations of future managerial performance, while market values do.[20] Partially motivated by the failure of these approaches to explain satisfactorily either the magnitude or the time-series properties of the discount, Lee, Shleifer, and Thaler (1991), advance the case for a behavioral approach.[21]

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[18] Of course, closed-end funds do offer rights issues and some may be opened up and allow for redemptions. In our simple, three date model, we abstract from these possibilities.

[19] The tax explanation is that the NAV overstates market value since tax liabilities on unrealized capital gains are not reflected in the NAV. Similarly, according to the liquidity approach, reported NAVs may overestimate the actual market values of illiquid holdings. Although each of these explanations has significant conceptual appeal, extensive empirical analysis has failed to demonstrate convincingly that they explain a significant amount of the magnitude of these discounts. Malkiel (1977) studies the influence of several of the factors reported above, while Barclay, Holderness, and Pontiff (1993) focus on agency costs. Brickley, Manaster and Schallheim (1991) and Pontiff (1995) study the impact of tax issues, while Pontiff (1996) studies the influence of trading costs.

[20] See, for example, the forceful arguments presented in Ross (2005).

[21] Building on the ideas in Zweig (1973) and Delong *et al.* (1990), they argue that fluctuations in the sentiment of small investors may be responsible for deviations of the market value from fundamental value. Such deviations are not subject to exploitation by arbitraguers because, in the presence of unpredictable sentiments, attempts to arbitrage deviations become inherently risky. Moreover, Lee, Shleifer, and Thaler (1991) argue that the investor sentiment models are consistent with the patterns in the time-series variation of these discounts, while earlier approaches fail to satisfy in this regard. See, however, Banerjee (1996); Oh and Ross (1994); Spiegel (1999) for alternate approaches to explaining closed-end fund discounts and their time-series patterns.

When managers care about short-term performance, our model shows that fund discounts and premia may arise even in a world without taxes, transactions costs, or behavioral biases. We do not claim that our explanation alone is sufficient to explain the observed magnitude of discounts and premia. However, our demonstration that discounts and premia can exist for closed-end funds even in the absence of "the usual suspects" may serve to undermine somewhat the commonly accepted notion that market values of closed-end funds should move in lock-step with measured *NAV*s.

4.1 SINGLE TRADING PERIOD MODEL

To extend our analysis to the case of closed-end funds, we make the simplest possible set of assumptions about the mechanics of how and when a closed-end fund is priced in the market. Obviously, at Date 2, when payoffs are realized, there is no distinction between *NAV* and market value. In our model, the Date 0 *NAV* of the fund is I_0. We assume that Date 1 *NAV* is calculated using market clearing price for the risky security.

The fund's Time 0 market value already incorporates profits anticipated from the manager's trading activity. Equation (8) gives us the market value of the fund at Date 0:

$$V_0 = I_0 + E(\pi) = I_0 + \lambda\sigma_u^2. \tag{10}$$

Since the fund's *NAV* at this point is I_0, the fund trades at a premium to its *NAV* at Date 0.

The fund's market value does not change from Time 0 to Time 1 as profits are realized only at Date 2. So, $V_1 = V_0$. However, as per Equation (7), portfolio pumping biases upward expected *NAV* at Date 1: $E[NAV_1] = I_0 + \beta\lambda(\sigma_z^2)/(2)$. This means that, unconditionally, NAV_1 is expected to exceed the fund's market value, V_1, by $\beta\lambda\frac{\sigma_z^2}{2} - \lambda\sigma_u^2$. Thus, we have the following result:

Proposition 7
A closed-end fund's market price will, in general, be different from its NAV at both initial and interim dates. For $\sigma_v^2 > 0$, *the fund is expected to start with its market price at a premium to its NAV at Date* 0. *At interim Date* 1, *the fund is expected to trade at a discount relative to its NAV if* $\beta\sigma_z^2 > 2\sigma_u^2$ *and at a premium if the inequality is reversed.*

Without any imperfections in the market where the fund is priced, the fund price, like the price of the traded risky security, is always an unbiased expectation of its liquidation value. It is, thus, the level of bias in *NAV* associated with short-run performance incentives that drives the extent of premia or discounts relative to *NAV*. The greater the incentive problem introduced by short-run performance measurement, the higher the probability of a discount. In addition, the likelihood of a discount reduces with the level of uncertainty associated with noise trading: a high enough level of such uncertainty can have the fund price at a premium to its *NAV*. The level of uncertainty associated with noise-trading has sometimes been interpreted as a measure of sentiment. Proposition 7 shows that discounts and premia in closed-end funds may well have a rational explanation that, in terms of measurement, may be hard to distinguish from behavioral explanations.

Currently, there exists no explanation for the fact that often a closed-end fund trading at a discount starts out at a premium to *NAV* after its initial public offering.[22] This is particularly troublesome, as no rational investor should buy into a new fund while anticipating a subsequent fall in price. Our analysis points to a rational explanation for such patterns. Right after an IPO, uncertainty about a fund's holdings of risky assets is low. With a skilled fund manager, we should expect the fund to trade at a premium to *NAV* at launch. As the fund gets fully invested, the uncertainty with respect to its holdings likely grows. Pumping by its manager, then, biases *NAV* upward and leads to a fund discount. In our world, therefore, there is nothing surprising about a closed-end fund trading at a discount to *NAV*, nor in its transition from a premium to a discount.

4.2 EXTENSION TO MULTIPLE TRADING PERIODS

The closed-end fund model presented above can be readily extended to allow for multiple rounds of trading. In our model, a fund manager's concern with short-term performance causes her to pump. As we have seen, such portfolio pumping will have a price impact only if the manager has private information about security value and her fund's inventory. In a multi-period setting, however, such information asymmetry could dissipate due to the market learning about inventory levels from *NAV* performance over time. Despite such learning by the market, we show that information asymmetry about the fund's holdings and, hence, its discount or premium relative to *NAV* need not disappear. We illustrate this by augmenting our basic model by a second date on which trading takes place and managerial performance gets evaluated (and rewarded). We describe below the structure of this augmented model and its implications for the evolution and persistence of expected fund discounts and premia. The details of the analysis are in Appendix B.

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[22] See, for example, Peavy (1990) for a description of this phenomenon.

The extension maintains most of the assumptions of the single trading date model. As in that model, there is a single fund and a single traded risky security. The first relevant date is $t=0$ and there are two rounds of trading of the risky security at Dates 1 and 2 , followed by the realization of terminal value at date $t=T$. To economize on symbols and with little loss of generality, we will assume that the fund manager places an equal weight on the fund's performance as of Dates 1, 2, and T. Prior to trading at Date $t=1$, the fund's inventory level is $z_1 \sim N(0, \sigma^2_{z_1})$. We denote the fund's inventory prior to the second round of trading by z_2. Here, $z_2 = z_1 + x_1$, where x_1 is the quantity that the fund manager trades on Date 1. After each round of trading is completed, the fund's NAV is assumed to be announced as well. Corresponding to the two Dates 1 and 2, the NAVs are denoted by NAV_1 and NAV_2, respectively.

A key difference from the single-period model is the arrival of value-relevant information over time. At date $t=0$, the terminal value of the risky security has an unconditional distribution $v_T \sim N(0, \sigma^2_{v_T})$. Between trading dates 1 and 2, there is the realization of a noisy public signal, v_1, about the terminal value, where $v_T = v_1 + \delta$. v_1 and δ have independent unconditional distributions $v_1 \sim N(0, \sigma^2_{v_1})$ and $\delta \sim N(0, \sigma^2_\delta)$. Therefore, after the public signal v_1 becomes available, the conditional distribution of v_T is $N(v_1, \sigma^2_\delta)$.

The fund manager's private information develops as follows. She receives information about v_1 at date 0. However, the information she receives is noisy. Specifically, she learns $v^\#_1$, with $v^\#_1 = v_1 + \epsilon$, where $\epsilon \sim N(0, \sigma^2_\epsilon)$ and is independent of v_1. Prior to trading on date $t=2$ the fund manager become informationally advantaged by privately learning about δ and, hence, v_T. The prices at which the market-maker clears the market on Dates 1 and 2 are given, respectively, by P_1 and P_2. Note that $P_0 = 0$, since the unconditional $E(v_T) = 0$. The trades by the fund manager on these dates are denoted by x_1 and x_2. The trading by noise traders is u_1, u_2 where, as before, these are *i.i.d* draws from a distribution $N(0, \sigma^2_u)$.

The structure outlined above implies a full public disclosure of initial inventory level, z_1, as soon as the fund announces NAV_1. This is because trading takes place in a single risky security whose market-clearing price, P_1, enables perfect inference of z_1 since $NAV_1 = I_0 + z_1 P_1$. This does not, however, mean that there is symmetric information about the fund's holding, z_2, before the second round of trade. Despite v_1 and z_1 being known before trade at Date 2, market participants cannot precisely discern x_1 and, by implication, z_2. The reason is that x_1 is a function of a noisy signal $v_1^{\#}$, rather than of v_1 itself. Further, noise traders also contribute to aggregate trading volume at $t = 1$. As a result, the market-maker remains uncertain about the fund's holding, z_2, prior to the second round of trading.

This extension preserves the principal features of our basic single trading period model. In particular, weights on interim performance provide incentives for portfolio pumping at both trading dates. The fact that the manager's level of trade cannot be perfectly discerned maintains uncertainty about the inventory level of the risky security before trading Date 2. Hence, pumping can affect security prices in both trading periods and reduce expected profits as in our basic model. Appendix B shows that, with reasonable restrictions on parameters, a fund starting out at a premium may transition to a discount. In addition, a fund expected to trade at a discount to its *NAV* at Date 1 is more likely to trade at a discount to its *NAV* at Date 2. Thus, discounts of fund value to *NAV* may persist over time. The analysis in Appendix B can, in principle, be extended to an arbitrary number of trading rounds as long as the manager's private information about end-of-period values is noisy and, thus, preserves uncertainty associated with beginning-of-period inventory levels for the next round of trading. It is worth noting that in a more realistic setting with multiple securities, *NAV* performance itself would at best provide a partial revelation of information about beginning-of-period inventory levels of each security. As a result, uncertainty about inventory levels of individual securities would be even more persistent over time and only strengthen our results.

5. Discussion of the Objective Function and Extensions

A manager's concern with her fund's short-run performance is a crucial ingredient of our model. We have motivated such a concern by appealing to commonly observed compensation contracts. However, this leaves unanswered the question of whether such managerial contracts are optimal in the first place, especially given our result that such concern may hurt long-term performance. Agency problems can cause optimal managerial contracts to have a short-term component, particularly when managerial tenure is stochastic.[23] Financing investment activities through short-term borrowings would also induce managerial concern with short-run performance due to the possibility of margin calls (or runs) triggered by short-term price drops.

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[23] See von Thadden (1995) for a discussion of the effects of short- and long-term compensation schemes.

Trading off long- and short-term performance would, however, be natural in the presence of differential risk aversion even absent other agency concerns. Consider, for example, the case of a manager of an open-end mutual fund acting in the interest of *ex ante* identical risk-averse investors with claims on the fund. With some probability, each investor suffers an interim liquidity shock that leads him to fully redeem his claim. In such a setting, despite modest redemption fees and costs associated with pumping, it may still be optimal to base managerial compensation on both the liquidation value of the fund and its interim NAV.[24]

More generally, even in the absence of interim redemption, it may be in the interest of long-term risk-neutral investors to base a risk-averse manager's compensation partly on measures of short-term performance. Such a linkage gives her greater incentive to trade more aggressively on value-relevant information. In addition, inducing pumping by making her care about short-term performance allows risk-neutral investors to counter her incentives to rebalance her existing stock positions in order to reduce her personal risk exposure at the cost of expected long-term performance. As a consequence, rewarding short-term performance can be optimal even for investors interested solely in long-term performance.[25]

We have made a number of simplifying assumptions to enhance analytical tractability. Our principal results are, however, robust to changing several of these assumptions. For instance, we follow Kyle (1985) in assuming frictionless markets. However, transactions costs can actually strengthen some of our results. Note that small transactions costs will not change the basic imperatives to trade. They do, however, affect fund profitability. Thus, larger funds, engaging in higher levels of pumping, would exhibit worse long-term performance. This is consistent with the findings in Chen *et al.* (2004) and Chan *et al.* (2009) that mutual fund performance declines with size and that liquidity considerations are important in accounting for the decline.[26]

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[24] This follows the logic in Diamond and Dybvig (1983). Adapting their model to the case with early redemption based on interim NAV and long-term costs of enhancing interim NAV, it is easy to find sufficient conditions in terms of risk-aversion, redemption and enhancement costs for investors to benefit from giving managers some short-term incentives.

[25] Such an extension to the model can be obtained from the authors.

[26] A model with quadratic transaction costs that establishes these results is available from the authors.

6. Conclusion

We analyze the impact of compensation based on short-term performance on the trading decisions of a fund manager. Parameterizing her short-term focus in a simple way, we establish that she has an incentive to engage in portfolio pumping, even when such activity is fully anticipated by the market-maker. When her portfolio holding is privileged information, pumping causes long-term performance to suffer and introduces an upward bias in measured *NAV*s. Yet, it is not optimal for the manager to commit to disclosing her portfolio composition before trading.

We have demonstrated that aggregate trading volume and market liquidity are both enhanced by managerial pre-occupation with measured short-term performance. As a result, a greater extent of delegated fund management should be expected to be accompanied by greater trading in financial markets. In fact, pumping incentives engendered by short-term performance-based compensation can generate trading even in the absence of value-relevant information.

Our model generates premia and discounts for closed-end funds even in the absence of factors that have already been stressed in the existing literature. We view the effect of pumping and inventory uncertainty as offering an alternative explanation, though not one that is mutually exclusive of other extant explanations. Finally, we offer explanations for why, despite the induced incentive to engage in costly, excessive trading, managerial compensation may be optimally linked to short-term portfolio performance.

Appendix A: Proofs of Propositions

Proof of Proposition 1. In equilibrium, the manager takes the values of λ and $\bar{y}$ as given and chooses her Date 1 trading order, $x(v, z)$, to maximize her objective function (Equation (2)):

$$W = I_0 + \gamma[z(E(P_1) - P_0)] + (1-\gamma)[z(v - P_0) + x(v - E(P_1))].$$

Substituting the expected market price, $E(P_1) = P_0 + \lambda(x - \bar{y})$, we get:

$$W = I_0 + \gamma[\lambda z(x - \bar{y})] + (1-\gamma)[z(v - P_0) + x(v - P_0) + \lambda\bar{y}x - \lambda x^2]. \quad \text{(A.1)}$$

The strict concavity of W in x ensures sufficiency of the first-order condition below for a maximum:

$$\gamma z\lambda + (1-\gamma)(v - P_0 + \lambda\bar{y} - 2\lambda x) = 0. \quad \text{(A.2)}$$

Rearranging, we have the manager's optimal trading strategy, $x^*(v, z)$:

$$x^*(v,z) = \frac{(v - P_0)}{2\lambda} + \beta\frac{z}{2} + \frac{\bar{y}}{2}, \quad \text{where} \quad \beta = \frac{\gamma}{1-\gamma}. \tag{A.3}$$

The market-maker incorporates the order strategy into his expectations for order flow. Since the expected level of trade by the liquidity traders is $E(\tilde{u}) = 0$, we have:

$$\bar{y} = E\left\{\frac{1}{2\lambda}[(\tilde{v} - P_0) + \beta\lambda\tilde{z} + \lambda\bar{y}] + \tilde{u}\right\} = \beta\frac{\bar{z}}{2} + \frac{\bar{y}}{2},$$

yielding his (correct) anticipation of expected net order flow as $\bar{y} = \beta\bar{z}$. The manager's optimal trading strategy can then be re-written as [Equation (3), Proposition 1] :

$$x^* = \frac{1}{2\lambda}[(v - P_0) + \beta\lambda z + \beta\lambda\bar{z}] = \frac{(v - P_0)}{2\lambda} + \beta\frac{(z - \bar{z})}{2} + \beta\bar{z}, \tag{A.4}$$

and the market-maker's price schedule [Equation (4), Proposition 1] as:

$$P_1(y) = P_0 + \lambda(y - \beta\bar{z}). \tag{A.5}$$

Following Kyle (1985), the properties of the Normal distribution and competition in market-making together give the value of λ as [Equation 5, Proposition 1]:

$$\lambda = \frac{Cov(\tilde{y}, \tilde{v})}{Var(\tilde{y})} = \frac{\frac{1}{2\lambda}\sigma_v^2}{\frac{1}{4\lambda^2}\sigma_v^2 + \beta^2\frac{\sigma_z^2}{4} + \sigma_u^2} \quad \Longrightarrow \quad \lambda = \frac{\sigma_v}{2(\beta^2\frac{\sigma_z^2}{4} + \sigma_u^2)^{\frac{1}{2}}}.$$

Proof of Proposition 3. Expected profits can come from profits on trading x on Date 1 and gains on initial holding z:

$$E(\pi) = E[\tilde{z}(\tilde{v} - P_0) + \tilde{x}^*(\tilde{v} - P_1)], = E[\tilde{x}^*(\tilde{v} - P_1)], \qquad \text{since } E(\tilde{v}) = P_0.$$

Substituting for x^* and P_1 from Equations (3) and (4), we have:

$$E(\pi) = E\left[\left\{\frac{\tilde{v} - P_0}{2\lambda} + \beta\frac{(\tilde{z} + \bar{z})}{2}\right\}\left\{\tilde{v} - P_0 - \lambda\left(\frac{\tilde{v} - P_0}{2\lambda} + \beta\frac{(\tilde{z} - \bar{z})}{2} + \tilde{u}\right)\right\}\right]. \tag{A.6}$$

Hence,

$$E(\pi) = E\left[\frac{(\tilde{v} - P_0)^2}{4\lambda} - \frac{\beta(\tilde{v} - P_0)(\tilde{z} - \bar{z})}{4} - \frac{\tilde{u}(\tilde{v} - P_0)}{2} + \frac{\beta(\tilde{v} - P_0)(\tilde{z} + \bar{z})}{4} \right.$$
$$\left. - \frac{\lambda\beta^2(\tilde{z}^2 - \bar{z}^2)}{4} - \frac{\beta\tilde{u}\lambda(\tilde{z} + \bar{z})}{2}\right] = \frac{\sigma_v^2}{4\lambda} - \frac{\lambda\beta^2\sigma_z^2}{4}.$$

Substituting $\lambda = \frac{\sigma_v}{2(\beta^2 \frac{\sigma_z^2}{4} + \sigma_u^2)^{\frac{1}{2}}}$ in the equation above gives us $E(\pi) = \frac{\sigma_v \sigma_u^2}{2(\beta^2 \frac{\sigma_z^2}{4} + \sigma_u^2)^{\frac{1}{2}}} = \lambda \sigma_u^2$.

Proof of Proposition 4. As in Proposition 1, the linear pricing schedule conjectured is $E(P_1) = P_0 + \lambda(y - \bar{y})$, where, y, the aggregate net orders from N fund managers and noise traders is now $y = \sum_{j=1}^{N} x_i + u$.

The i-th fund manager chooses her optimal order, $x^*(v, z_i)$, taking as given the aggregate orders from other fund managers, x_{-i}, to maximize her objective function:

$$W = I_0 + \gamma[\lambda z_i(x_j + E(x_{-i}) - \bar{y})] + (1-\gamma)[z_i(v - P_0) + x_i(v - P_0) + \lambda \bar{y} x_i - \lambda x_i(x_i + E(x_{-i}))]. \tag{A.7}$$

The first-order condition for a maximum gives us:

$$x_i^* = \frac{(v - P_0)}{2\lambda} + \beta \frac{z_i}{2} + \frac{\bar{y}}{2} - \frac{E(x_{-i})}{2}. \tag{A.8}$$

Following the proof strategy for Proposition 1 and utilizing the symmetry feature we get:

$$E(x_i) = \beta \bar{z} \implies \bar{y} = N\beta\bar{z}.$$

The optimal order with symmetric strategies may now be written as:

$$x_i^* = \frac{(v - P_0)}{(N+1)\lambda} + \beta\bar{z} + \frac{\beta}{N+1}\delta + \frac{\beta}{2}\epsilon_i. \tag{A.9}$$

Substituting (A.9) into the market-maker's pricing schedule gives:

$$P_1 = P_0 + \lambda\left[\frac{N}{N+1}\frac{(v - P_0)}{\lambda} + \frac{1}{2}\beta\sum_{i=1}^{N}\epsilon_i + \beta\frac{N}{N+1}\delta + u\right]$$

and, following Kyle (1985) it can be shown that:

$$\lambda = \frac{\sigma_v}{(N+1)\left(\beta^2 \frac{\sigma_z^2}{4} + \frac{N}{(N+1)^2}\beta^2\sigma_\delta^2 + \frac{\sigma_u^2}{N}\right)^{\frac{1}{2}}}.$$

It is easily verified that $P_1 \to v$ and $\lambda \to 0$, as $N \to \infty$.

Proof of Proposition 5. Equation (8) shows that *ex ante* expected long-term profits of investors monotonically decreases with σ_z^2. Thus, disclosure commitments benefit long-term investors.

The manager's *ex ante* expected Time 1 benefit comes from *NAV* bias, $(\lambda\beta\sigma_z^2)/(2)$, derived in Equation (7). Her Time 2 benefit comes from expected long-term profits, $\lambda\sigma_u^2$, derived in Equation (8). She maximizes a weighted average of these two:

$$\gamma\frac{\beta}{2}\lambda\sigma_z^2+(1-\gamma)(\lambda\sigma_u^2)=(1-\gamma)\frac{\sigma_v}{2(\beta^2\frac{\sigma_z^2}{4}+\sigma_u^2)^{\frac{1}{2}}}\left[\beta^2\frac{\sigma_z^2}{2}+\sigma_u^2\right] \tag{A.10}$$

that increases with σ_z^2. Therefore, she prefers a commitment to non disclosure.

Proof of Proposition 6. For notational simplicity, we restrict our proof to the case of $P_0=\bar{z}=0$, since the extension to the general case is straightforward. The net order flow, $y=x+x_s+u$, comprises orders from the fund, x, the strategic trader, x_s, and noise traders, u. The market-maker's pricing function is conjectured to be $\lambda_s y$ in the presence of the strategic trader.

The fund manager's objective function is:

$$W=I_0+\gamma[z\lambda_s(x+x_s)]+(1-\gamma)[v(x+z)-x\lambda_s(x+x_s)], \tag{A.11}$$

and her optimal order strategy is:

$$x^*(v,z,x_s)=\frac{v}{2\lambda_s}+\beta\frac{z}{2}-\frac{x_s}{2}. \tag{A.12}$$

The strategic trader, taking $E(v)=0$, anticipates the manager's pumping trade to be $E(x^*|z)$:

$$E(x^*|z)=\beta\frac{z}{2}-\frac{x_s}{2}. \tag{A.13}$$

He chooses an order level, x_s, to maximize his expected payoff $E(\Pi_s)$:

$$E(\Pi_s)=x_sE[v-\lambda_s(x^*+x_s+u)]=x_s[-\lambda_s(E(x^*)+x_s)], \tag{A.14}$$

the second part following from $E(v)=E(u)=0$. The first order condition of his maximization is:

$$-\lambda_s(E(x^*)+2x_s^*)=0. \tag{A.15}$$

Equations (A.12) and (A.15) together yield optimal trading strategies of:

$$x_s^*(z)=-\frac{\beta z}{3} \tag{A.16}$$

and,

$$x^*(v,z)=\frac{v}{2\lambda_s}+\frac{2}{3}\beta z. \tag{A.17}$$

Equation (A.17) shows that the fund manager increases her pumping levels to partially offset the possible impact of the strategic trader's trading in the opposite direction.

Using equations (A.16) and (A.17) in (A.14) yields the strategic trader's expected profits:

$$E(\Pi_s) = E(x_s[-\lambda_s(E(x^*) + x_s)]) = E\left(-\frac{1}{3}\beta z\left[-\lambda_s\left(\frac{1}{3}\beta z\right)\right]\right) = \frac{1}{9}\lambda_s\beta^2\sigma_z^2. \tag{A.18}$$

The net order flow observed by the market-maker now is:

$$y = x + x_s + u = \frac{v}{2\lambda_s} + \frac{2}{3}\beta z - \frac{1}{3}\beta z + u = \frac{v}{2\lambda_s} + \frac{1}{3}\beta z + u.$$

The lower sensitivity of order flow to inventory position (1/3 versus 1/2 in Proposition 1) leads to lower liquidity in the market for the risky security. The resulting higher liquidity parameter, λ_s, is given by:

$$\lambda_s = \frac{cov(y, v)}{var(y)} = \frac{\frac{\sigma_v}{2\lambda_s}}{\frac{\sigma_v^2}{4\lambda_s^2} + \frac{1}{9}\beta^2\sigma_z^2 + \sigma_u^2} = \frac{\sigma_v}{2(\sigma_u^2 + \frac{1}{9}\beta^2\sigma_z^2)^{\frac{1}{2}}}. \tag{A.19}$$

This completes the proof for 6.1.

The increase in the liquidity parameter immediately implies greater losses for liquidity traders in the presence of a strategic trader, since $\lambda_s\sigma_u^2 > \lambda_0\sigma_u^2$. This proves part (c) of 6.2.

Using Equation (A.18) gives us the long-term investors' expected profits as $E(\pi_s) = \lambda_s\sigma_u^2 - \frac{1}{9}\lambda_s\beta^2\sigma_z^2$. To show long-term fund investors's profits suffer with a strategic trader, we need to show that

$$E(\pi) = \lambda\sigma_u^2 > E(\pi_s) = \lambda_s\sigma_u^2 - \frac{\lambda_s\beta^2\sigma_z^2}{9}.$$

This is equivalent to showing:

$$\frac{\sqrt{1 + k/9}}{\sqrt{1 + k/4}} > 1 - k/9, \tag{A.20}$$

where $k > 0$ stands for $\beta^2\sigma_z^2/\sigma_u^2$. $k > 9$ automatically satisfies the condition since the right-hand side is negative. Algebraic manipulation of (A.20) yields the equivalent condition:

$$k/9 > k/36 - 7/162\,k^2 + k^3/324$$

which, by inspection, is satisfied for $9 \geq k > 0$. This proves part (a) of 6.2.

The strategic trader's presence lowers the sensitivity of total order flow to inventory level. This makes the total order flow more informative about future value and, hence, increases the sensitivity of the market-maker's price response to order flow, making pumping more expensive. It is easy to show that the net effect is a reduction in expected NAV bias. The lower level of liquidity also makes information-based trade more expensive, reducing long-term expected profits. The manager effectively maximizes a weighted average of expected NAV bias and expected profits. Hence, the value of her objective function reduces in the presence of the strategic trader. This proves part (b) of 6.2.

This completes the proof for 6.2.

We have shown above that the presence of the strategic trader increases the losses of noise traders as well as decreasing the profits of long-term fund investors. Given the zero sum nature of the equilibrium, the strategic trader profits at the expense of both noise traders and long-term fund investors.

Appendix B: Closed-end Funds with Multiple Trading Periods

The analysis below follows the structure laid out in Section 4.2. For brevity, we do not repeat the notational details. The main elements of the extension to a setting with two rounds of trading can be summarized as follows:

- After the first round of trading on Date 1 and the announcement of NAV_1, the market precisely infers the fund's prior inventory holdings z_1. However, information asymmetry about the fund's holdings, z_2, at the time of the second round of trading does not disappear. This is since $z_2 = z_1 + x_1$: while z_1 and v_1 become known to the market-maker, the manager's actual trade x_1 is not fully revealed as it is based on a $v_1^{\#}$, a noisy signal about v_1.
- The fund manager has private information about the terminal security value on both Dates 1 and 2. She also has private information about the inventory holdings on both Dates. As a result, pumping on both dates 1 and 2 would be expected to affect prices. Hence, closed-end fund discounts/premia could occur on both dates.
- For notational ease, we assume that weight of each period of performance is equal. This allows us to dispense with an explicit presentation of per-period weights.

As before, we restrict the manger to linear trading strategies. At Date 1, she chooses an order level, x_1, to optimize the objective function:

$$W = z_1(E_1(P_1)) + x_1(E_1(v_T) - E_1(P_1)) + E_1(z_2(P_2 - v_1)) + E_1(x_2(v_T - P_2)), \tag{B.1}$$

where $E_1(\cdot)$ denotes her expectation before trading at Date 1. By our assumptions, $P_0 = 0$ and the market-maker's expectation of Time 1 inventory is 0. At Date 1, the manager's security value expectation is $E_1(v_T) = v_1^{\#}$. The first term and third terms in the objective function denote the benefits from pumping in the two periods. The second and fourth terms are the profits from trading that are recognized on Dates 2 and T, respectively. Prior to trading on Date 2, the market-maker's expectation of v_T, $E_2(v_T)$, is v_1, the realization of the public signal.

In equilibrium, since the market-maker learns z_1 and v_1 prior to trading on Date 2, he will update his expectation of x_1 and, thereby, of z_2, based on the information available at the time. His information set prior to Date 2 trading includes z_1, v_1 and y_1. Since the market-maker does not have access to the signal $v_1^{\#}$ or to u_1, the orders from the noise traders, he can only make a noisy inference about x_1 and, hence, about z_2.

We claim that only the first two terms in (B.1) are relevant for the choice of x_1 at Date 1. This is straightforward to show and we defer this to later in the proof. The intuition is that in our structure, as discussed, the manager expects the market-maker to update his expectations about x_1 based on the realizations of v_1, z_1, and y_1. While the manager expects to develop information asymmetry with regard to both the inventory level and security value by Date 2, these developments cannot be predicted on Date 1.

We denote the manager's trading strategy at Date 1 by $x_1(v^{\#}, z_1)$ and at Date 2, by $x_2(\delta, z_2)$. The respective liquidity parameters are denoted by λ_1 and λ_2, respectively. The first-order condition with respect to x_1 is, then:

$$z_1\lambda_1 + v_1^{\#} - 2\lambda_1 x_1^* = 0,$$

or

$$x_1^* = \frac{v_1^{\#}}{2\lambda_1} + \frac{z_1}{2}. \tag{B.2}$$

We can now characterize the market-maker's assessment of $z_2 = z_1 + x_1$, prior to trading on Date 2. As we have discussed, the market-maker's information set at the time will include z_1, v_1, and y_1. Substituting for x_1^*

from Equation (B.2), we can express:

$$y_1 = x_1^* + u_1 = \frac{v_1^\#}{2\lambda_1} + \frac{z_1}{2} + u_1 = \frac{v_1 + \epsilon}{2\lambda_1} + \frac{z_1}{2} + u_1.$$

The projection Proposition gives us the expression for his updated expectation of x_1 as:

$$E(x_1|v_1, z_1, y_1) = \frac{v_1}{2\lambda_1} + \frac{z_1}{2} + \eta_1\left[y_1 - \left(\frac{v_1}{2\lambda_1} + \frac{z_1}{2}\right)\right].$$

where $\eta_1 = \frac{1}{1+4(\lambda_1)^2((\sigma_u^2)/(\sigma_\epsilon^2))}$. From his perspective, then, the updated holding of the risky security is given by $z_2 \sim N(\bar{z_2}, \sigma_{z_2}^2)$, where $\bar{z_2} = z_1 + E(x_1|v_1, z_1, y_1)$ and $\sigma_{z_2}^2 = \eta_1^2\left(\frac{\sigma_\epsilon^2}{4\lambda_1^2} + \sigma_u^2\right) = \eta_1\sigma_\epsilon^2$. Hence, at Date 2, there remains information asymmetry with regard to the inventory z_2 that is held by the fund manager. Also, the fund manager receives updated information with regard to the value of the security $v_T = v_1 + \delta$. As a result, portfolio pumping will give rise to a premium or discount on both Dates 1 and 2 in precisely the same way as in the one-trading date version of the model. The order submitted by the fund manager on Date 2, x_2, can be obtained in the usual fashion and is given by:

$$x_2^* = \frac{\delta}{2\lambda_2} + \bar{z_2} + \frac{z_2 - \bar{z_2}}{2}. \tag{B.3}$$

It is straightforward to show that the values of the liquidity parameters are given by:

$$\lambda_1 = \left(\frac{\sigma_{v_1}^2 - \sigma_\epsilon^2}{\sigma_{z_1}^2 + 4\sigma_u^2}\right)^{1/2} \quad \text{and} \quad \lambda_2 = \left(\frac{\sigma_\delta^2}{\sigma_{z_2}^2 + 4\sigma_u^2}\right)^{1/2}.$$

The market value of the closed-end fund at date $t = 0$ reflects initial funds I_0 and total expected profits $E_0(\pi)$ from trade with noise traders over the two trading dates:

$$V_0 = I_0 + E_0(\pi) = I_0 + (\lambda_1 + \lambda_2)(\sigma_u^2).$$

Following Equation (7), NAV_1 after Date 1 trade is expected to be:

$$E_0(NAV_1) = I_0 + \lambda_1\sigma_{z_1}^2,$$

where the expression follows from our simplifying assumption of equal weights on measured performance at each date.

After trading at Date 2, the fund's NAV will reflect estimated profits from the first round of trading. Thus, the unconditional expected value of NAV_2 is given by:

$$E_0(NAV_2) = I_0 + (\lambda_1)(\sigma_u^2) + \lambda_2\sigma_{z_2}^2.$$

The fund will be expected to trade at a discount to NAV on Dates 1 and 2 when:

Condition for Expected discount at Date 1:

$$E_0(NAV_1) = I_0 + \lambda_1\sigma_{z_1}^2 > I_0 + (\lambda_1 + \lambda_2)\sigma_u^2,$$

or

$$\lambda_1\sigma_{z_1}^2 > (\lambda_1 + \lambda_2)(\sigma_u^2). \tag{B.4}$$

Condition for Expected discount at Date 2:

$$E_0(NAV_2) = I_0 + \lambda_1\sigma_u^2 + \lambda_2\sigma_{z_2}^2 > I_0 + (\lambda_1 + \lambda_2)\sigma_u^2,$$

or

$$\sigma_{z_2}^2 > \sigma_u^2. \tag{B.5}$$

If λ_1 is similar in magnitude to λ_2 and the per-period informational advantage of the manager does not change significantly over time, a Time 2 discount is more likely than a Time 1 discount. This is consistent with a fund starting out at a premium and switching to a discount over time. Also, a Date 1 discount makes a Date 2 discount more likely, showing that discounts can be persistent.

Verifying sufficiency of considering the first two terms (on the right-hand side) in Equation (B.1) for the manager's Date 1 trading decision:

This can be shown to be true by substituting for z_2 and x_2 in the latter two terms of the manager's objective function (Equation (B.1)), using only the information available to the manager on Date 1:

$$W = z_1(E_1(P_1)) + x_1(v_1^{\#} - E_1(P_1)) + E_1(z_2(P_2 - v_1)) + E_1(x_2(v_T - P_2)).$$

At Date 2, given the information available at that stage, the market-maker will expect a pumping trade level of $\bar{y_2}$. As in Equation (1), he will net out this level of expected trade in setting his Date 2 price schedule as:

$$P_2 = v_1 + \lambda_2(y_2 - \bar{y_2}).$$

Substituting for P_2, we can express the objective function as:

$$W = z_1(\lambda_1 x_1)) + x_1(v_1^{\#} - \lambda_1 x_1) + E_1(z_2(\lambda_2(x_2 - \bar{y_2})) + E_1(x_2(\delta - \lambda_2(x_2 - \bar{y_2})).$$

Now, we can determine the optimal x_2^* as:

$$x_2^* = \frac{\delta}{2\lambda_2} + \frac{\bar{y_2}}{2} + \frac{z_2}{2}.$$

Substituting for x_2^* and $z_2 = x_1 + z_1$ and taking expectations as of Date 1 we now have:

$$W = z_1(\lambda_1 x_1)) + x_1(v_1^\# - \lambda_1 x_1) + \frac{\lambda_2}{4}(x_1 + z_1 - \bar{y_2})^2.$$

Taking the first derivative with respect to x_1, we can obtain the optimal x_1^* in terms of z_1, $v_1^\#$, and $\bar{y_2}$. This will allow us to also determine $\bar{y_2}$. From the first-order condition we get:

$$x_1^*(4\lambda_1 - \lambda_2) = 2\lambda_1 z_1 + 2v_1^\# + \lambda_2 z_1 - \lambda_2 \bar{y_2}.$$

Now, $\bar{y_2} = E_1(x_2) = E_1(z_2) = z_1 + E_1(x_1)$. Substituting for this, gives us, from the perspective of the manager at Date 1:

$$\bar{y_2} = 1.5 z_1 + \frac{v_1^\#}{2\lambda_1},$$

and, hence, the manager's expected value for the past two terms in Equation (B.1) is given by $E_1(\frac{\lambda_2}{4}(x_1 + z_1 - \bar{y_2})^2) = \frac{\lambda_2}{4}\frac{\sigma_\epsilon^2}{4\lambda_1^2}$ – which is a constant (i.e., not a function of x_1). This is sufficient to show that the past two terms can be disregarded in determining the optimal x_1 chosen by the manager.

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