Fund managers' contracts and financial markets' short-termism*

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Abstract

This paper considers the problem faced by long-term investors who have to delegate the management of their money to professional fund managers. Investors can earn profits if fund managers collect long-term information. We investigate to what extent the delegation of fund management prevents long-term information acquisition, inducing short-termism in financial markets. We also study the design of long-term fund managers' compensation contracts. Under moral hazard, fund managers' compensation optimally depends on both short-term and long-term fund performance. Short-term performance is determined by price efficiency, and thus by subsequent fund managers' information acquisition decisions. These managers are less likely to be active on the market if information has already been acquired initially, giving rise to a feedback effect. The consequences are twofold: First, short-termism emerges. Second, short-term compensation for fund managers depends in a non-monotonic way on long-term information precision. We derive predictions regarding fund managers' contracts and financial markets efficiency.

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1 Introduction

Are short-term bonuses harmful for market informational efficiency? Does short-term compensation prevent fund managers from taking into account the long-term value of assets? A proper answer to these questions requires to investigate the link between the time structure of fund managers mandates and market efficiency. Short-termism in financial markets is hard to reconcile with finance theory because of market efficiency: If prices incorporate all available future information, the fact that agents' compensation is based on short-term prices cannot induce a short-term bias. Presumably, the only reason why short-termism could arise is because prices are not efficient. In this paper we argue that the delegation of asset management can prevent long-term information acquisition, giving rise to short-termism. We also determine the optimal fund managers' compensation contracts and explore how they affect the level of market efficiency.

A widespread view in the financial industry is that relying on short-term performance makes it harder to implement a long-term strategy. For instance, a Socially Responsible Investment fund manager reports "The big difficulty is that a lot of the reputational issues and environmental issues play out over a very long period of time [...] and if the market isn't looking at it you can sit there for a very long time on your high horse saying 'this company is a disaster, it shouldn't be trusted 'and you can lose your investors an awful lot of money... ".[1] Relatedly, the Australian sovereign wealth Future Fund acknowledges in his benchmark return statement that short-term performance might not be compatible with a long-term strategy: "[...] as the Board develops a long-term strategic asset allocation, a return lower than the benchmark return is expected."[2] As a result, voices have raised in the asset management industry to redesign long-term fund managers' compensation towards lengthening the asset managers' horizon.[3] This paper sheds light on the link between short-termism and short-term based compensation in the asset management industry and assesses whether a longer performance horizon can be helpful.

A growing body of empirical evidence suggests that some pieces of information are slow to be incorporated into stock prices. For example, Edmans (2011) reports that firms included in the list of "100 Best Companies to Work For in America" earn positive abnormal returns for a period

[1] Guyatt (2006).

[2] Future Fund Investment Mandate Direction 2014.

[3] See for instance CFA Institute (2006) and Kay (2012).

of time as long as four years after inclusion. Other studies suggest that positive abnormal long-term returns are triggered by high R&D expenditures (Lev and Sougiannis (1996)), advertising expenditures (Chan, Lakonishok, and Sougiannis (2001)), patent citations (Deng, Lev, and Narin (1999)), software development costs (Aboody and Lev (1998)), or corporate governance quality indexes (Gompers, Ishii, and Metrick (2003)). To the extent that such items are more likely to improve long-term rather than short-term financial performance, this can be seen as a sign of short-termism on financial markets. More importantly, the slow incorporation of information into stock prices can induce short-termism in the firm. Both Edmans, Fang, and Lewellen (2013) and Ladika and Sautner (2014) document that an exogenous vesting of stock options induces CEOs to cut R&D and capital expenditures in order to increase their stock price. This confirms the view that stock prices do not incorporate long-term information about firms' strategic choices, and that such short-termism affects the real investment decisions of stock-price oriented CEOs.

We consider the problem faced by long-term investors who have to delegate the management of their money to professional fund managers. Investors can earn profits if fund managers collect long-term information. However, information acquisition is subject to moral hazard, in the sense that fund managers have to exert an unobservable effort to increase the level of precision of their information. In this context, we determine the optimal compensation structure designed by investors for their fund managers. We also investigate to what extent the delegation of fund management prevents long-term information acquisition. A first contribution of the paper is to highlight a new feedback effect through which a higher market efficiency increases agency costs and short-termism. A second contribution is to show how the optimal mix of short-term and long-term bonuses varies with information precision.

More precisely, the model highlights the ambiguous impact of information precision on short-termism. On the one hand, an increase in information precision increases trading profits which encourages long-term information acquisition. On the other hand, information precision can increase agency costs through the following feedback effect. Under moral hazard, long-term investors optimally spread fund managers' compensation across the short run and the long run if short-term prices are efficient. However, whether short-term prices are efficient is endogenous. It depends on whether subsequent fund managers acquire information. They are less likely to do so if information has already been acquired initially (as in Grossman and Stiglitz (1980)). Therefore, incentive costs increase if subsequent fund managers are deterred from entering the market. An interesting result is that increasing the precision of the initial information may trigger this feedback effect. There is thus a non-monotonic relationship between information precision and short-termism. For instance, we identify cases where as information precision increases, investors renounce to hire fund managers to trade on long-term information.

The model also delivers results regarding the structure of fund managers' compensation contracts. We show that it is optimal to give a bonus to fund managers each time the fund performance is positive, and to keep this bonus constant, whatever the magnitude of the performance and the date at which it arises. The basic reason why bonuses are kept constant is that part of the positive performance is due to the presence (or not) of hedgers when the fund manager trades. When realized performance is due to liquidity demand and not to fund managers' talent or effort, it should not give rise to a bonus. Also, short-term bonuses are used to allow fund managers to smooth consumption across time, and to reduce incentive costs. The optimal compensation contract can then be interpreted as an immediate cash bonus when short-term performance is positive, plus a deferred bonus if long-term performance remains positive. When short-term performance is negative or null, fund managers only obtain a deferred bonus, conditional on long-term performance. These results speak to the debate on the structure of managers' bonus in the financial service industry and are in line with the European Union Capital Requirements Directive (CRD IV) voted in 2013. The latter explicitly sets limits to bankers' cash bonuses and specifies that a substantial part of the bonus should be contingent on subsequent performance. Our mix of cash and deferred performance contingent bonuses offers theoretical ground for these practices.

The model allows us to derive predictions regarding market efficiency and fund managers' bonus contracts. A first set of predictions is related to the impact of information precision on these variables. First, there is a non-monotonic relationship between information precision and short-termism. We expect that when ranking industries by the precision of available information (measured for instance by the variance of analysts' forecasts), prices do not incorporate more long-term information in better known industries. Next, information precision affects the level of bonuses in the fund management industry in a non-monotonic way. This implies that, if one looks at a sample of sectorial funds, fund managers' bonuses are not always lower in industries where one expects precise information to be more easily available. However, the proportion of long-term bonuses in the total fund managers' compensation should be higher in those industries. A second prediction relates to the impact of the severity of moral hazard problems. An implication of the model is that in markets where delegated portfolio management is more important, prices should incorporate less long-term information, compared to markets with more proprietary trading. This prediction relies on the premise that moral hazard problems are more easily circumvented in proprietary trading. Last, because short-termism is related to price efficiency through the feedback effect, an implication of the model is that short-termism is more present when markets are less liquid. Indeed, in illiquid markets, future informed traders' demand is more easily spotted and incorporated into prices, which discourages their entry. Anticipating this, initial investors do not enter either. The model thus predicts that long-term information should be more reflected into prices in developed markets compared to less liquid emerging markets. Likewise, we would expect to see more long-term compensation for managers of long-term-oriented funds who invest in emerging markets. For instance, pension fund managers or socially responsible fund managers should receive more long-term compensation when they invest in emerging markets.

Our analysis is related to the literature that determines how frictions on the market can prevent investors from trading on long-term information. If investors are impatient, Dow and Gorton (1994) show that they may renounce to acquire long-term information, because they are not sure that a future trader will be present when they have to liquidate their position. In Froot, Scharfstein, and Stein (1992), short-term traders herd on the same (potentially useless) information because they care only about short-term prices. Shleifer and Vishny (1990) also base short-termism on the reason that arbitrage in the long run is (exogenously) more costly than in the short-run. Holden and Subrahmanyam (1996) argue that risk averse investors do not like to hold positions for a long time when prices are volatile. And Vives (1995) considers that the rate of information arrival matters when traders have short horizons. In all of these papers, investors have exogenous limited horizon, or are risk averse and cannot contract with risk neutral agents. Having in mind the situation faced by long-term investors such as pension funds, we take a different road, and assume that investors are long-term and risk neutral. This allows us to study explicitly the delegation problem with fund managers. Gümbel (2005) also studies a problem of delegation, where investors need to assess the ability of fund managers. Short-termism arises in his model because trading on short-term information, albeit less efficient, gives a more precise signal on fund managers' ability. We depart from this analysis by assuming moral hazard instead of unknown fund managers' talent. Last, our focus on the moral hazard problem between investors and fund managers is related to Gorton, He, and Huang (2010). They explore to what extent investors can use information aggregated in current market prices to incentivize fund managers, and highlight that competing fund managers may have an incentive to manipulate prices, rendering markets less efficient. Instead, we focus on how investors can use future prices to incentives their managers: we thus ignore manipulation, but highlight a feedback effect that also decreases price efficiency.

The paper is organized as follows. The next section presents the model and determines the benchmark case when there is no moral hazard. Section 3 derives the main results of the paper: it solves the problem under moral hazard, and highlights the cost of delegation, and the optimal time structure of fund managers' mandates. Section 4 presents the predictions derived from the model. Last, Section 5 discusses the robustness of the analysis by exploring to what extent results are affected when some assumptions are relaxed. Proofs are in the Appendix.

2 The model

We consider an exchange economy with two assets: a risk-free asset with a rate of return normalized to zero, and a risky asset. There are three dates: 1, 2, and 3. The risky asset pays off a cash flow v at date 3. For simplicity, the cash flow can be 1 or 0 with the same probability $\frac{1}{2}$. The economy is populated by four types of agents: investors, fund managers, hedgers and market makers. Fund managers, hedgers and market makers trade assets on the financial market at date t with $t \in \{1, 2\}$. Investors trade assets through the fund management industry.

2.1 The fund management industry

The fund management industry is composed of investors and fund managers. Investors are risk-neutral. We assume that, because of time or skill constraints, investors cannot access the financial market directly: they have to hire a fund manager, also referred to as a manager. Precisely, one investor is born at each date t and delegates her fund management to a manager.[4] We consider that

[4]The assumption that only one investor is born at each date is made for simplicity. As will be discussed later, our main results hold with several investors.

a different manager i with $i \in \{1, 2\}$ is hired at each date. Investor 1 is born at date 1 and hires manager 1, and investor 2 is born at date 2 and hires manager 2. This delegation relationship is organized thanks to contractual arrangements. A management contract specifies the transfers from an investor to her manager. A transfer at date t to manager i is denoted R_t^i. This transfer can be contingent on all observable variables.

Managers are risk averse and have no initial wealth. The utility function of manager 1 entering the market at date 1 is

$$V(C_1^1, C_2^1, C_3^1) = U(C_1^1) + U(C_2^1) + U(C_3^1),$$

with

$$U(0) = 0, U'(.) > 0, U''(.) < 0.$$

C_1^1, C_2^1, and C_3^1 are the consumptions of manager 1 at the different dates. Identically, the utility function of manager 2 is

$$V(C_2^2, C_3^2) = U(C_2^2) + U(C_3^2).$$

A manager i receives a binary private signal $s_i \in \{H, L\}$ about the final cash flow generated by the risky asset. The precision of the signal depends on the level of effort exerted by the manager. There are two possibilities: a manager can decide to exert effort, which we denote e, or not, which we denote ne. If the manager exerts no effort (ne), the signal is uninformative, that is

$$\Pr_{ne}(s_i = H | v = 1) = \Pr_{ne}(s_i = L | v = 0) = \frac{1}{2}.$$

If manager i exerts effort (e), he incurs a private cost c which enters separately in his utility function. The precision of the signal is then denoted φ_i. We have that

$$\Pr_{e}(s_i = H | v = 1) = \Pr_{e}(s_i = L | v = 0) = \varphi_i.$$

To reflect the fact that effort improves signal informativeness about v, we consider that $\varphi_i > \dfrac{1}{2}$. For simplicity, we further assume that $\varphi_2 = 1$, that is, manager 2 gets a perfect signal when he exerts effort.[5] We denote $\varphi_1 = \varphi$. We assume that signals are independent across managers (conditional on v).

2.2 The financial market

Our financial market is modelled after Dow and Gorton (1994). Managers interact with two types of agents: hedgers and market makers. At each trading date t, a continuum of hedgers (of mass 1) enters the market with probability $\frac{1}{2}$. At date 3, those hedgers receive an income of 0 or 1 that is perfectly negatively correlated with the risky asset cash flow. For simplicity, we assume that hedgers are infinitely risk averse. They are thus willing to hedge their position by buying $q_t^h = 1$ unit of the risky asset.[6]

Market makers are risk neutral. They compete à la Bertrand to trade the risky asset, and are present in the market from date 1 to date 3.

At each date t, trading proceeds as follows. If hired at date t, a manager submits a market order denoted by q_t^m.[7] If born at date t, hedgers demand $q_t^h = 1$. Market makers observe the aggregate buy and sell orders separately, and execute the net order flow out of their inventory. Denote by q_t the aggregate buy orders. Bertrand competition between market makers along with the risk neutrality assumption implies that prices for the risky asset equal the conditional expectation of the final cash flow, that is

$$\begin{aligned} P_1 &= E\left(v|q_1\right), \\ \text{and } P_2 &= E\left(v|q_1, q_2\right). \end{aligned}$$

The timing of our model is summarized in Figure 1. Let us now study how managers' demands are formed. Since hedgers never sell, market makers directly identify a sell order as coming from

[5]This captures the idea that more precise information can be obtained when one gets closer to the cash flow delivery date. Our results go through for any precision φ_2 strictly greater than $\frac{1}{2}$.

[6]In general, if they are not infinitely risk averse, hedgers want to trade less than 1 unit of the asset. However, as shown by Dow and Gorton (1994), as long as they are sufficiently risk averse, hedgers want to trade a positive amount q_h. All our results hold if $q_h < 1$. In particular, the same conclusions hold if hedgers' income is positively correlated with the cash flow, in which case they sell the asset to cover the risk.

[7]We discuss in Section 5 the case in which manager 1 can trade again at date 2, and argue that this possibility does not modify his equilibrium strategies.

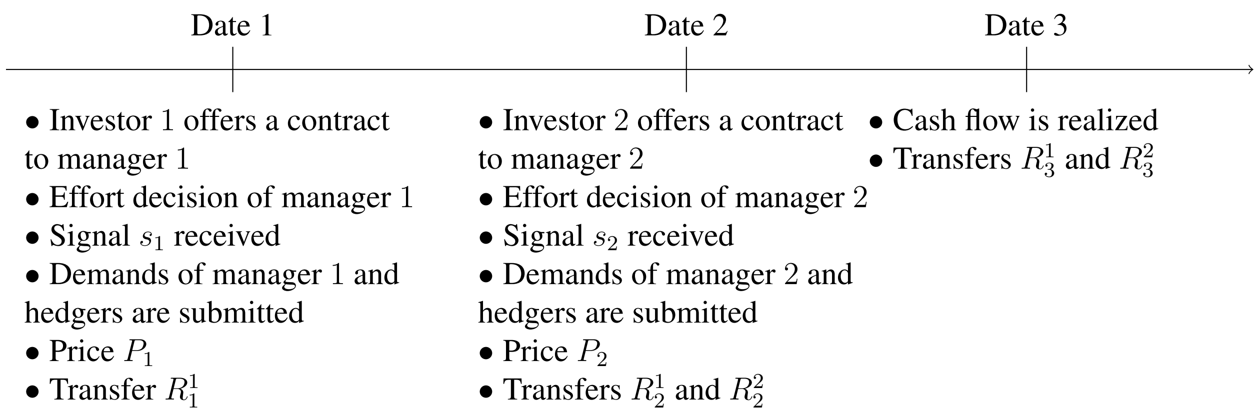


Figure 1: Timing of the model

a manager. Any information that the manager has would then directly be incorporated into prices. As a result, informed managers do not find it strictly profitable to sell the asset. For the same reason, managers who want to buy submit a market order $q_t^m = q_t^h = 1$, that is, they restrict the size of their order to reduce their market impact. Consequently, equilibrium candidates are such that managers, when they are informed, demand either one or zero unit of the asset.

When a manager is hired at date t, the potential buying order flow is thus $q_t = 0$, $q_t = 1$, or $q_t = 2$. When $q_t = 0$, market makers infer that the manager does not want to buy the risky asset. Likewise, when $q_t = 2$, market makers understand that the manager submits an order to buy. On the contrary, when $q_t = 1$, market makers do not know if the order comes from the hedgers or from the manager. As an illustration, Figure 2 displays the price path when both managers exert effort, buy after receiving a high signal, and do not buy after receiving a low signal, and when prices are set accordingly.

Consider now that a manager is not hired at date t. In this case, the potential order flow is $q_t = 0$ or $q_t = 1$ depending on hedgers' demand. Also, market makers anticipate that only hedgers are potentially trading and the order flow is uninformative.

2.3 Symmetric information between investors and fund managers

This section studies the information acquisition and investment decisions when investors can contract on the level of effort and on the signal received. This benchmark is useful to interpret the

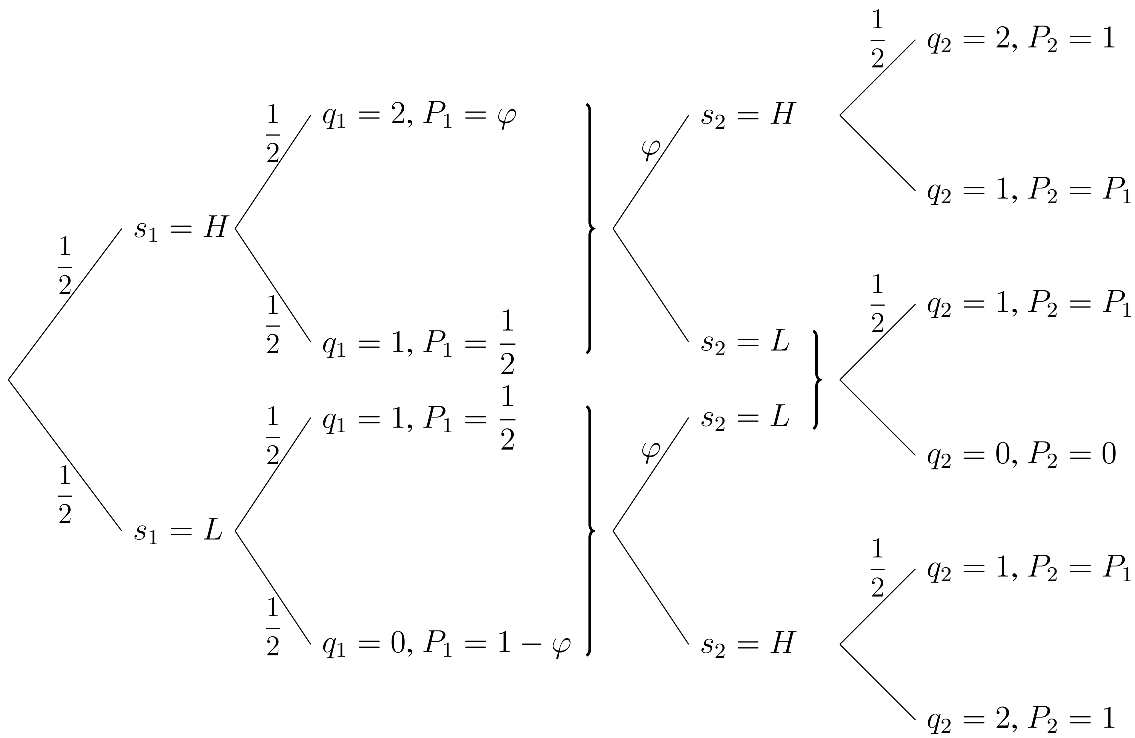


Figure 2: Prices and order flows when managers exert effort and buy only when $s = H$

results of the case in which managers' effort as well as the signal received are unobservable. In this benchmark, we consider the following equilibrium conjecture: Investors hire managers; Managers exert effort, trade $q_t^m = 1$ after receiving good news and trade $q_t^m = 0$ otherwise. In addition, the first manager trades once to open his position, and holds his portfolio up to date 3.[8]

This benchmark calls for two comments. First, from the perspective of investors, adequate use of information prescribes that managers invest after receiving a high signal and do nothing otherwise. Indeed, if managers were investing irrespective of the realization of the signal, investors would be better off saving the cost of information acquisition. Second, we discuss in section 5 the case in which the first manager trades at date 2, and argue that this cannot be an equilibrium strategy.

To ensure managers' participation, investors propose a compensation contract that gives man-

[8]We associate to this equilibrium conjecture the following out-of-equilibrium beliefs. Upon observing $q_t > 1$, market makers believe that effort has been exerted and $s_i = H$ has been observed. Upon observing $q_t < 1$, market makers believe that effort has been exerted and $s_i = L$ has been observed.

agers a utility c when effort e is chosen and when managers invest appropriately.[9] Assume for now that managers consume all their revenue, that is, they cannot privately save from one period to the next.[10]

It is straightforward to show that the investor proposes manager 1 constant transfers $R_1^{1,FB} = R_2^{1,FB} = R_3^{1,FB} = U^{-1}\left(\frac{c}{3}\right)$ such that his expected utility net of the effort cost is equal to his reservation utility, i.e. 0, when manager 1 exerts effort and invests appropriately according to the signal received. In this case, it is individually rational for the manager to accept the contract. Similarly, manager 2 obtains transfers $R_2^{2,FB} = R_3^{2,FB} = U^{-1}\left(\frac{c}{2}\right)$, and his net expected utility is also equal to 0.

Investors offer such a contract if their expected profit is larger than the cost of information acquisition. Let us consider first the investor at date 1. Her expected profit, denoted Π_1, is equal to the expected cash flow paid by the asset minus the expected price paid to acquire the asset, minus the cost of her manager's compensation, and is written

$$\Pi_1 = \Pr\left(s_1 = H\right)\left(E\left(v|s_1 = H\right) - E\left(P_1|s_1 = H\right)\right) - \sum_t R_t^{1,FB}.$$

Let us consider next the investor at date 2. Her expected profit depends on the market price P_1 when she enters the market and is written

$$\Pi_2(P_1) = \Pr\left(s_2 = H|P_1\right)\left(E\left(v|P_1, s_2 = H\right) - E\left(P_2|P_1, s_2 = H\right)\right) - \sum_t R_t^{2,FB}.$$

Proposition 1 (symmetric information benchmark) *Investor 1 hires a fund manager if and only if $\varphi \geq \varphi^{FB}$. Investor 2 hires a fund manager if and only if $P_1 \in \left[\underline{\beta}^{FB}, \overline{\beta}^{FB}\right]$.*
φ^{FB}, $\underline{\beta}^{FB}$ and $\overline{\beta}^{FB}$ are constants defined in the Appendix.

Proposition 1 is a direct consequence of the distribution of the order flows and equilibrium prices when market makers anticipate that if hired, managers 1 and 2 exert effort and buy after receiving a high signal. As illustrated in Figure 2, order flows and prices at date 1 evolve as follows: $q_1 = 2$ with probability $\frac{1}{4}$ (this event corresponds to the case in which the signal is H and

[9] We assume that managers' reservation utility is zero.

[10] This assumption does not affect our results when the second period signal is perfectly informative. We discuss this effect, as well as the manager's incentive to privately save, in Section 3.3.

in which hedgers enter), $q_1 = 1$ with probability $\frac{1}{2}$, and $q_1 = 0$ with probability $\frac{1}{4}$. Equilibrium prices are then $P_1 = E(v|q_1 = 2) = \varphi$, $P_1 = E(v|q_1 = 1) = \frac{1}{2}$, $P_1 = E(v|q_1 = 0) = 1 - \varphi$. Similarly, and given that manager 2's signal is perfect, prices set by market makers according to the observed order flow at date 2 are

$$P_2(P_1, q_2 = 2) = 1,\ P_2(P_1, q_2 = 1) = P_1 \text{ and } P_2(P_1, q_2 = 0) = 0.$$

Proposition 1 illustrates the impact of the precision of the long-term information obtained by manager 1 on the presence of fund managers on this market. At equilibrium, investor 1's profit increases with manager 1's information precision φ. This precision has to be high enough for investor 1 to recoup the cost of information acquisition. Also, investor 2's profit depends on investor 1's decision: when prices incorporate manager 1's information, the profit that investor 2 can obtain is reduced. This effect is stronger the more precise manager 1's information is (see, for example, Grossman and Stiglitz (1980)). These are standard effects of trading under asymmetric information. Another interesting insight is that investor 1's equilibrium profit and delegation decision do not depend on investor 2's decision. This is because investor 1 holds her portfolio until date 3 when dividends are realized, and because manager 1's compensation does not depend on interim prices. We will see later that this is not the case under moral hazard.

To ensure that investor 2 hires a fund manager for some realizations of P_1, we assume that $\sum_t R_t^{2,FB} \leq \frac{1}{8}$.

3 Long-term fund management contract under moral hazard

We now investigate the case in which, at date 1, the investor cannot observe whether her manager has exerted effort nor what signal was obtained. There is thus moral hazard at the information acquisition stage and asymmetric information at the trading decision stage.[11] We do consider however that the fund management contract can be contingent on the manager's trading positions. The contract is designed to provide the manager with the incentives to appropriately exert effort

[11] The assumption of asymmetric information is imposed to capture some realistic features of the asset management industry. However, from a theoretical point of view, we show later that it does not induce an additional incentive cost compared to the moral hazard problem.

and trade, taking into account that he acts in his own best interest. Fund management contracts thus include two types of incentive constraints: one type is dedicated to the effort problem while the other is dedicated to the signal and trading problem.

In order to provide adequate incentives, investor 1 bases transfers on all observable variables, that is the trading position opened by her manager (q_1^m) and the different prices that are realized at each date. Hence, investor 1 proposes the contract $\left(R_1^1\left(q_1^m\right), R_2^1\left(q_1^m, P_1, P_2\right), R_3^1\left(q_1^m, P_1, P_2, v\right)\right)$. P_1 is included in the contract proposed to manager 1 because investor 1 uses the informational content of P_2 relative to P_1 to provide incentives. It is also a convenient way to allow for performance-based transfers.

We are looking for delegation contracts that provide managers an incentive to exert effort and to invest only when they receive a high signal $s_i = H$.[12] Contracts have thus to fulfill several conditions: the incentive-compatibility constraints ensuring that manager i trades appropriately given that he exerts effort (denoted constraints (IC_H^i) and (IC_L^i)), and the incentive-compatibility constraint ensuring that manager i exerts effort (constraint (IC_e^i)). Also, to write these constraints, we need to know what managers do when they do not exert effort. There are two possibilities. Under constraint (H_1^i), manager i prefers to invest rather than not to invest. Under constraint (H_0^i), manager i prefers not to invest. To derive the optimal contract, we impose that (H_1^i) must hold. We then show that the results are the same if we impose constraint (H_0^i) instead of (H_1^i).

3.1 Characterization of the optimal fund management contract

Following the above discussions, the incentive constraints related to trading are the following:

$$E_e\left(\sum_{t=1}^{t=3} U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=H\right) \geq E_e\left(\sum_{t=1}^{t=3} U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=H\right), \qquad \left(IC_H^1\right)$$

$$E_e\left(\sum_{t=1}^{t=3} U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=L\right) \geq E_e\left(\sum_{t=1}^{t=3} U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=L\right). \qquad \left(IC_L^1\right)$$

Since the manager's compensation depends on the random variables P_1, P_2, and v, $E_e\left(.\right)$ refers

[12] As discussed in the previous section, there is no equilibrium (even without moral hazard) such that investor 1 finds it profitable to trade at date 2. Besides, it is straightforward to see that there is no equilibrium such that managers buy after a low signal and do not trade after a high signal, or such that trading is independent of signals.

to the expectation operator that uses the distribution of these variables under effort conditional on the signal received and on the trading decision. These distributions are presented in Figure 2 for the case in which manager 1 plays the equilibrium strategy. When the manager deviates, prices are set according to market makers' equilibrium beliefs but the distribution of random variables is affected by the deviation. For instance, if manager 1 does not trade after $s_1 = H$, the probability to observe $P_1 = \varphi$ is zero while it is strictly positive when manager 1 does not deviate. (IC_H^1) indicates that, upon exerting effort and receiving a high signal, manager 1 prefers to buy rather than to do nothing. (IC_L^1) indicates that, upon exerting effort and receiving a low signal, manager 1 prefers to do nothing rather than to buy.

The incentive constraint that ensures that manager 1 exerts effort is

$$\Pr_e (s_1 = H) E_e \left(\sum_{t=1}^{t=3} U \left(R_t^1 \left(q_1^m = 1 \right) \right) | s_1 = H \right) + \Pr_e (s_1 = L) E_e \left(\sum_{t=1}^{t=3} U \left(R_t^1 \left(q_1^m = 0 \right) \right) | s_1 = L \right)$$
$$-c \geq E_{ne} \left(\sum_{t=1}^{t=3} U \left(R_t^1 \left(q_1^m = 1 \right) \right) \right) \quad \left(IC_e^1 \right).$$

This constraint indicates that manager 1's expected utility has to be greater when he exerts effort and trades appropriately (left handside of the inequality) than when he exerts no effort and always invests (right handside of the inequality). In order to write down this constraint, we work under the assumption that the manager always prefers to invest when he does not exert effort. This assumption is captured by

$$E_{ne} \left(\sum_{t=1}^{t=3} U \left(R_t^1 \left(q_1^m = 1 \right) \right) \right) \geq E_{ne} \left(\sum_{t=1}^{t=3} U \left(R_t^1 \left(q_1^m = 0 \right) \right) \right). \quad \left(H_1^1 \right)$$

Investor 1 knows that, in order to induce her manager to exert effort and trade appropriately, these four constraints need to be satisfied (along with the positive compensation constraint). Given these constraints, she chooses the transfers that maximize her expected profit expressed by

$$\Pi_1 = \Pr_e (s_1 = H) \left(E_e (v | s_1 = H) - E_e (P_1 | s_1 = H) \right) - E_e \left(\sum_{t=1}^{t=3} R_t^1 \left(q_1^m \right) \right).$$

As in the benchmark, investor 1's expected profit depends on the expected dividend, the expected purchase price of the asset, and the expected managerial compensation. The expected compensation of the fund manager that solves the above program has the following properties.

Proposition 2 *The optimal contract at date* 1 *that induces effort and buying upon receiving a high signal verifies:*

$$\begin{aligned}
&E_e\left(U\left(R_2^{1*}\left(q_1^m = 1, P_1, P_2 = 1\right)\right) + U\left(R_3^{1*}\left(q_1^m = 1, P_1, P_2, v = 1\right)\right)\right) \\
&= E_e\left(U\left(R_2^{1*}\left(q_1^m = 0, P_1, P_2 = 0\right)\right) + U\left(R_3^{1*}\left(q_1^m = 0, P_1, P_2, v = 0\right)\right)\right) \\
&= \frac{\varphi c}{2\varphi - 1},
\end{aligned}$$

and all other transfers are null.

The optimal contract has to provide two types of incentives. First, it must induce the manager to exert effort and to gather useful information. Second, it must induce the manager to trade appropriately according to this information. Both incentive problems can be addressed together. To be induced to exert effort, the fund manager has to be rewarded in those states that are informative about his effort. For example, when the manager exerts effort, the high dividend $v = 1$ is more likely when observing a high signal. As reflected in Proposition 2, rewarding the fund manager when he buys ($q_1^m = 1$) and the final dividend is $v = 1$ provides adequate incentives to exert effort and trade appropriately. Similarly, when the interim price P_2 contains information on the dividend, it is potentially optimal to use it as a compensation basis: the manager can thus be rewarded at date 2 when he buys and the interim price is $P_2 = 1$. The same arguments apply for the case in which the manager receives a low signal and is induced not to trade ($q_1^m = 0$). He is then rewarded at date 3 when the final dividend is low ($v = 0$) and/or at date 2 when the interim price is low ($P_2 = 0$). In the remainder of the paper, we refer to those states as the incentive-compatible states.

Proposition 2 also indicates that transfers in all other states of nature are zero. This can happen for two reasons. First, some states of nature provide no information about manager's effort. This is for example the case when the interim price provides no additional information compared to the initial price ($P_2 = P_1$): short-term compensation should then be null. Second, in some so-called adverse states of nature, the non-negative compensation constraint is binding. This is the case when the state of nature reveals negative information regarding manager's effort (e.g., when $q_1^m = 1$ and $v = 0$). If negative payments could be imposed, the manager would optimally be punished with a negative transfer. The assumption that the fund manager is cash-poor simply puts a lower bound on the investor's ability to punish the fund manager. If the fund manager had some initial wealth, it would then be optimal to ask him to pledge some collateral that could be seized by the investor in adverse states. This would provide higher-powered incentives to the fund manager.

Manager 1's expected utility net of the effort cost is greater under moral hazard than when investors can contract on the level of effort. This is stated in the following corollary.

Corollary 1 *Manager* 1*'s agency rent is equal to* $\frac{c}{2\varphi-1}$.

The rent depends positively on the cost of effort c and negatively on the informativeness of the signal φ. The term $2\varphi - 1$ reflects the increase in the probability of being rewarded when the manager exerts effort, compared to the case in which he does not exert effort.

We now investigate further the role of the interim price P_2 in the provision of incentives to manager 1. Proposition 2 indicates that P_2 is potentially useful when it reveals additional information on the final dividend value.[13] A natural question is when the investor finds it useful to base the contract on the interim price or on the final dividend. When P_2 is informative, it perfectly reveals the final dividend: Both are thus equivalent from an incentive point of view (see Holmstrom, 1979). However, the investor may find it beneficial to pay at both dates in order to smooth manager's consumption as is studied below. Because of manager's risk aversion, this minimizes the cost of the fund manager's compensation borne by the investor.

3.2 Cost of delegation

The previous section determines what rent has to be left to the manager in order to induce him to exert effort. We now study what is the cost for the investor to offer such a rent, that is, the value of the optimal expected compensation. The optimal contract depends on the level of efficiency of the interim price. Investor 1 has thus to anticipate investor 2's equilibrium behavior. Price P_2 is informative only if manager 2 is trading on valuable information, that is, if he is actually offered

[13] Recall that, in our model, P_2 contains additional information when it is equal to 1 or 0, and is uninformative when it is equal to P_1.

an incentive contract by investor 2. Investor 2 enters the market if the price P_1 is not too close to the final dividend value. Denote $\underline{\beta}$ and $\overline{\beta}$ the lower and upper bounds of the price range, symmetric around $\frac{1}{2}$, such that investor 2 hires a manager if $P_1 \in \left[\underline{\beta}, \overline{\beta}\right]$. For example, the previous section shows that, if there is no moral hazard at date 2, $\overline{\beta} = \overline{\beta}^{FB}$ and $\underline{\beta} = \underline{\beta}^{FB}$.[14] We therefore consider two cases. When $\varphi \leq \overline{\beta}$, investor 2 hires a fund manager for all realizations of the price P_1. When $\varphi > \overline{\beta}$, investor 2 hires a fund manager only if the initial price contains no information, that is, if $P_1 = \frac{1}{2}$. The next proposition investigates how the cost of delegation varies with the level of φ.

Proposition 3 *Denote $E(R^{1*})$ the optimal expected compensation of manager 1. When $\varphi \leq \overline{\beta}$ (manager 2 is always hired), $E(R^{1*}) = \frac{3}{2}\varphi U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right)$.*

When $\varphi > \overline{\beta}$ (manager 2 is hired only when $P_1 = \frac{1}{2}$), $E(R^{1*}) = \frac{5}{4}\varphi U^{-1}\left(\frac{8c}{5(2\varphi-1)}\right)$.

The optimal expected compensation has the following properties:
i) $\frac{3}{2}\varphi U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right) < \frac{5}{4}\varphi U^{-1}\left(\frac{8c}{5(2\varphi-1)}\right)$ $\forall \varphi \in \left(\frac{1}{2}, 1\right)$,
ii) $E(R^{1*})$ decreases with φ.

Proposition 3 shows that the expected compensation of manager 1, expressed as a function of φ, is discontinuous at $\overline{\beta}$. This reflects the fact that when $\varphi \leq \overline{\beta}$, the price P_2 is more likely to incorporate additional information on the final dividend value because manager 2 is always hired. Indeed, manager 2 trades on his information for any level of the price P_1. In turn, states of the world that are informative about manager 1's effort occur more frequently. The investor uses these incentive-compatible states to design the compensation function. This enables her to better trade off the manager's desire for consumption smoothing and the need to provide incentives. As shown in property *i)*, the expected compensation jumps from $\frac{3}{2}\varphi U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right)$ to $\frac{5}{4}\varphi U^{-1}\left(\frac{8c}{5(2\varphi-1)}\right)$ when φ exceeds $\overline{\beta}$. This illustrates the negative feedback effect across generations of fund managers: when information precision increases, investors may renounce to hire managers to trade on long-term information, because it is less likely that future investors will collect short-term information that is useful to provide long-term incentives. Property *ii)* further shows that, except at $\varphi = \overline{\beta}$, the expected compensation decreases with φ. This is because, when information is more precise, incentive-compatible states are more suggestive of a high effort.

[14] Using the methodology developed in the Appendix, one can easily derive these bounds when there is moral hazard between investor 2 and her fund manager.

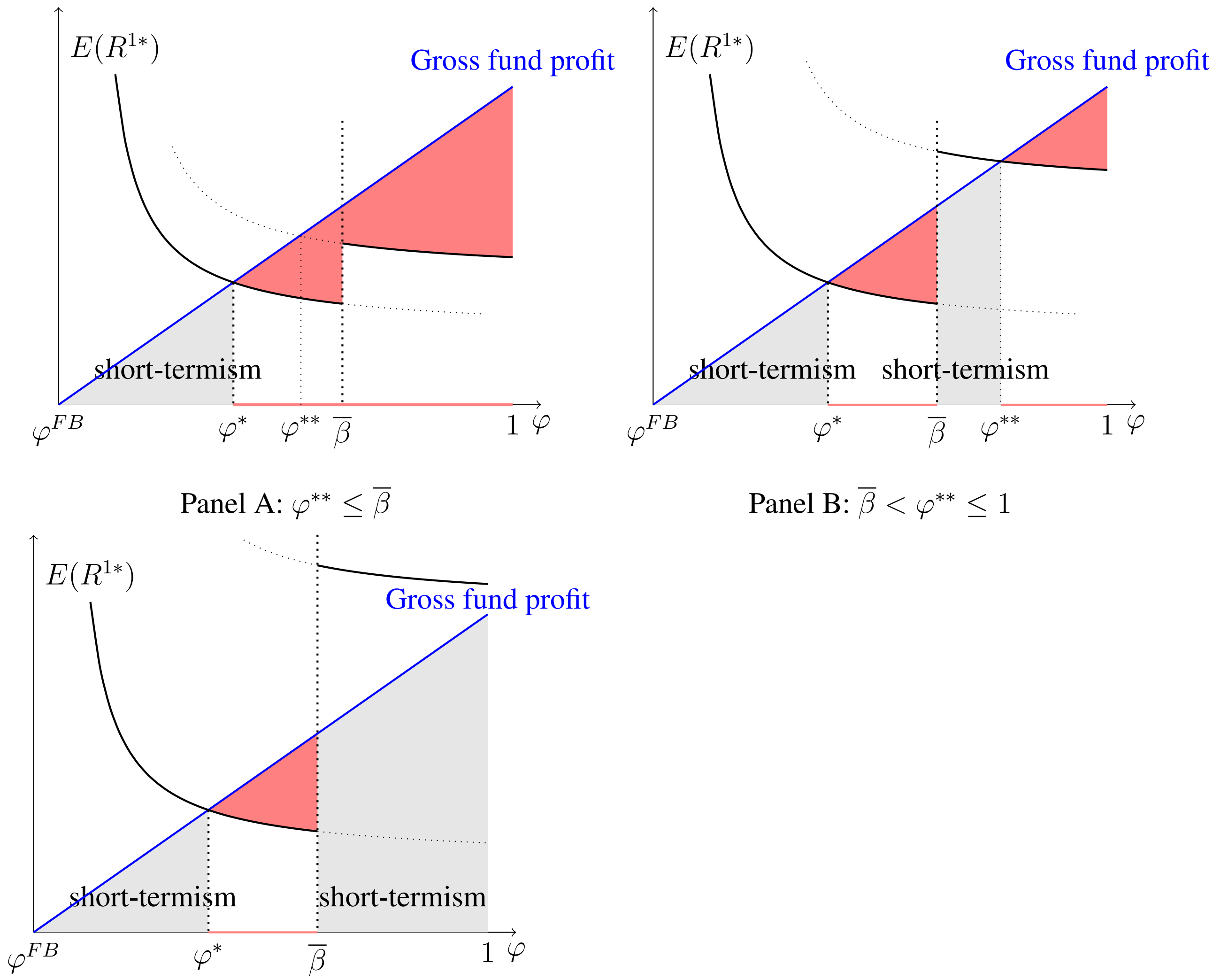
The investor compares the cost of the compensation contract to the expected gross trading profit in order to determine whether she wants to hire a manager. The hiring decisions are presented in the following corollary which illustrates the impact of moral hazard on long-term information acquisition.

Corollary 2 *There exist thresholds φ^* and φ^{**} with $\varphi^{FB} < \varphi^* < \varphi^{**}$ such that when $\varphi \leq \overline{\beta}$, investor 1 hires a fund manager (and long-term information is acquired) if and only if $\varphi \geq \varphi^*$. When $\varphi > \overline{\beta}$, investor 1 hires a fund manager (and long-term information is acquired) if and only if $\varphi \geq \varphi^{**}$.*

Corollary 2 shows that moral hazard creates short-termism, in the sense that long-term information is not acquired while it would be under perfect information. Figure 3 illustrates the main findings of Corollary 2. Short-termism arises because of two effects. The direct effect of moral hazard is that it increases the cost of information acquisition (the manager earns an agency rent). In turn, investor 1 requires a higher trading profit to cover the additional cost of hiring a fund manager. To increase profit, she thus requires a higher information precision ($\varphi^* > \varphi^{FB}$). There is also an indirect effect of moral hazard. The cost of incentive provision borne by investor 1 depends on the informed trading activity of manager 2. In particular, the presence of short-term informed trading at date 2 creates a positive externality for investor 1 in the sense that it reduces the expected compensation cost and therefore the threshold above which information is acquired ($\varphi^* < \varphi^{**}$). This effect is not present in the perfect information benchmark: Investor 1's decision is independent of manager 2's behavior because manager 1 can be paid in any state of nature (regardless of the informational efficiency of price P_2).

A natural question is whether increasing information precision always reduces short-termism. This is not necessarily the case in our model, because of the externality of manager 2's trading. As shown in Proposition 3, information precision has an ambiguous impact on the expected compensation. On the one hand, the expected compensation function decreases with φ, except at $\varphi = \overline{\beta}$. On the other hand, the expected compensation jumps upward at $\varphi = \overline{\beta}$. It is thus conceivable that increasing φ prevents investor 1 from hiring a manager. This is actually the case when $\overline{\beta} < \varphi^{**}$ (see Panels B and C, for the case $\varphi^* \leq \overline{\beta}$)[15], but not when $\varphi^{**} \leq \overline{\beta}$ (see Panel A). When $\overline{\beta} < \varphi^{**} \leq 1$

[15]The case $\varphi^* > \overline{\beta}$ is straightforwardly derived from Panel B. Then short-termism arises when $\varphi < \varphi^{**}$.



Panel A: $\varphi^{**} \leq \overline{\beta}$

Panel B: $\overline{\beta} < \varphi^{**} \leq 1$

Panel C: $\varphi^{**} > 1$

Figure 3: Short-termism and the cost of delegated portfolio management: The grey area is the region in which long-term information is not acquired because of moral hazard. The expected gross trading profit is the increasing blue line. Manager 1's expected wage is represented the black discontinuous curve $E(R^{1*})$. The red area represents investor 1's net profit from hiring manager 1 and inducing long-term information collection.

(Panel B), investor 1 hires a manager when $\varphi \in [\varphi^*, \overline{\beta}]$ but not when $\varphi \in (\overline{\beta}, \varphi^{**}]$. In Panel C, $\varphi^{**} > 1$, and short-termism is extreme: when $\varphi > \overline{\beta}$, the fund manager is never hired and no long-term information is acquired.

These results complement the analysis of Dow and Gorton (1994) that suggests that the arbitrage chain which induces long-term information to be incorporated in prices, might break. Our model highlights that the arbitrage chain might break because of a feedback effect across successive managers' contracts. Investor 1 needs investor 2 to provide incentives to her manager to collect short-term information, but if investor 1 is present, investor 2 does not (always) hire a fund manager. In turn, this can discourage investor 1 to offer an incentive contract, and no long-term information is incorporated into prices.

3.3 The structure of fund managers' compensation

We now explore how fund managers' compensation varies with the fund performance, and is structured over time. We define short-term fund performance as the return $(2\mathbb{1}_{q_1^m=1} - 1)(P_2 - P_1)$ and long-term performance as $(2\mathbb{1}_{q_1^m=1} - 1)(v - P_1)$. The dummy $\mathbb{1}_{q_1^m=1}$ equals one if manager 1 buys one unit of asset, and zero otherwise. Performance is relative to the riskfree return (normalized to zero), which is the appropriate benchmark for risk neutral investors. Recall from Proposition 2 that manager 1 is optimally rewarded if he trades and the interim price (or the final cash flow) is 1. If he does not trade, he is rewarded when the interim price (or the final cash flow) is 0. The next proposition illustrates how the fund manager's compensation varies with fund performance.

Proposition 4 *The manager is awarded a positive constant bonus after any positive short-term or long-term performance.*

Proposition 4 states that the fund manager's bonus remains constant whatever the level of the portfolio performance, and whatever the time at which positive performance materializes. Firstly, as long as performance is positive, the *level* of portfolio performance does no affect the bonus because it is beyond manager 1's control. Indeed, portfolio performance is not very high if manager 1's information is incorporated into the initial trading price P_1, that is if hedgers trade in the same direction as the manager. Portfolio performance is higher when manager 1's trade is not revealed into price P_1. Since price P_1 efficiency depends on hedgers' demands, and not on the manager's effort, manager 1 should not be punished or rewarded according to the magnitude of positive performance. Our model thus presents a setting in which caps on managers' compensation naturally arise.

Secondly, the date at which performance occurs does not affect the bonus because all incentive-compatible states (at date 2 or 3) are equally informative about managerial effort. Therefore the same bonus is offered whether positive performance accrues in the short term or in the long term. One can interpret the optimal contract as follows. When short-term performance is positive, manager 1 receives an immediate bonus, plus a deferred bonus if long-term performance remains positive. When short-term performance is negative or null, manager 1 only receives the deferred bonus, conditional on long-term performance. Thus, consumption smoothing and incentive issues combine to give rise to short-term and deferred performance-sensitive bonuses.

An interesting property of the optimal compensation is that it is robust to the possibility for manager 1 to privately save part of his income for future consumption. Our results on the compensation contract structure would be the same if manager 1 could privately save. This is due to the informational efficiency of the asset price at date 2. When manager 1 receives a bonus at date 2, he knows that he will receive the same bonus with probability 1 at date 3: marginal utilities are equal across dates, and there is no incentive to save to smooth consumption. In a more general model in which incentive-compatible states (at date 2 or 3) are not equally informative about managerial effort, the bonus size would vary with states' informativeness (but not with the level of efficiency of price P_1). In that case, the possibility of private savings would introduce an additional constraint to the optimal contract reflecting the fact that marginal utilities should be equal across states: Bonuses would then concentrate on the most informative states. Therefore, the ability of short-term managers at date 2 to gather very precise information about the final dividend helps to reduce the cost of inducing long-term information collection.

The results of Proposition 4 speak to the debate on the structure of managers' bonuses in the financial service industry. The 2013 European Union Capital Requirements Directive (CRD IV) explicitly sets limits to bankers' and asset managers' performance-based bonuses. In our model, we show that bonuses are capped to reflect the idea that some of the realized performance is due to market movements rather than managerial talent or effort. CRD IV also specifies that a substantial part of the bonus should be contingent on long-term performance. Our mix of current and deferred, performance-contingent bonuses offers theoretical ground for these regulatory practices.

The next proposition further investigates the optimal time structure of the compensation contract.

Proposition 5 *The proportion of long-term expected compensation is higher when $\varphi > \overline{\beta}$ than when $\varphi \leq \overline{\beta}$.*

Proposition 5 states that the time structure of manager 1's mandate depends on date 2 price efficiency, or more generally on the expected informed trading activity at date 2. Since the bonus granted to manager 1 is constant across across positive-performance states, the proportion of long-term compensation depends on the proportion of incentive-compatible states available at dates 2 and 3. When $\varphi \geq \overline{\beta}$, information is acquired less often by manager 2, and fewer incentive-compatible states are available. Investor 1's optimal response is to increase the proportion of long-term bonuses.

In our model, the only reason why the time structure of mandates matters relies on the consumption smoothing-incentive trade-off. Relaxing some assumptions of the model provides additional insights on the optimal compensation timing. Suppose first that manager 1 exhibits impatience in the sense that for a given level of consumption, he prefers to consume at date 2 than at date 3. This necessarily shifts his compensation towards more short-term bonuses. Suppose alternatively that the precision of manager 2's information is not perfect. The final cash flow v is then a sufficient statistic of manager 1's effort. This shifts his compensation towards more long-term bonuses. The optimal time structure thus trades off the benefit of short-term compensation to cope with manager 1's impatience, and the benefit of long-term compensation to improve incentives.

Note however that risk aversion is a necessary condition for a mix of long-term and short-term compensation to arise. Were manager 1 risk neutral, one incentive-compatible state would suffice. The optimal compensation scheme could entail payment at date 2 or at date 3 only and the feedback effect across managers' contracts would not be present.

4 Empirical implications

The results presented above allow us to derive a number of empirical implications regarding market efficiency and fund managers' compensation, according to the level of information precision, the extent of moral hazard, and the level of market liquidity.

Firstly, there is a non-monotonic relationship between long-term information acquisition and information precision φ because the incentive cost of long-term information collection jumps when φ exceeds the threshold $\overline{\beta}$. We thus expect long-term information to be more prevalent in markets or industries in which information precision is more 'extreme", either low and high. A first prediction of the model is that prices are more likely to incorporate long-term information in very well-known, or very innovative sectors, compared to standard industries.

Relatedly, information precision affects the level of bonuses in the fund management industry in a non-monotonic way. In particular, our model explains why bonuses do not necessarily decrease with information precision. This implies that fund managers' bonuses are not always lower in industries in which one expects precise information to be more easily available. However, the model predicts that the proportion of long-term performance-based compensation should be higher.

Secondly, an insight of the paper is that moral hazard creates short-termism. This feature implies that short-termism should be more pervading in markets in which delegated portfolio management has a larger market share. In particular, prices should incorporate more long-term information when there is more proprietary trading, to the extent that moral hazard problems are more easily circumvented in proprietary trading.

The fact that there is more short-termism does not a priory imply that prices are less efficient at all dates: when long-term information acquisition is precluded, prices are less efficient at date 1, but this can increase informed trading at date 2. If information precision increases with time, this implies that overall market efficiency might increase with short-termism. However, it is easy to see that this is not true in our model. Indeed short-termism enhances future informed trading when φ is rather large. This is the case in which information precision does not increase much with time.We thus expect price efficiency to be negatively correlated with the prevalence of delegated portfolio management.

Thirdly, the results of our model enable us to study the impact of market liquidity on the production of long-term information. In the model, short-termism is related to the existence of a feedback effect between successive managers' contracts. This feedback effect is affected by market liquidity. When markets are very illiquid (e.g. when hedgers are less likely to be present on the market), informed traders are easily spotted, which annihilates their potential profits. If information is costly, illiquid markets deter information acquisition. If investors anticipate at date 1 that market liquidity will deteriorate, they refrain from inducing long-term information acquisition, thereby worsening short-termism. An implication of the model is that short-termism is more present when markets are less liquid. To test this prediction, on could study whether long-term information is more reflected into prices in developed markets compared to less liquid emerging markets. Likewise, we would expect to see more long-term compensation for managers who invest in emerging markets. For instance, pension fund managers or socially responsible fund managers should receive more long-term compensation when they invest in emerging markets, compared to more liquid markets.

5 Robustness

This section explores the robustness of our analysis to changes in the main assumptions of the model.

Consider first the assumption that there is only one investor/manager pair per period. If this was not the case, our results would still hold as long as there is imperfect competition and thus non-null trading profits. Note however that in this case, investors can use the current price to extract information on the effort made by her manager (see Gorton, He, and Huang (2010)).

Next, agents are long-lived. If agents were short-lived, we would be back to Dow and Gorton (1994) who show that asymmetric information might not be incorporated into asset prices despite the existence of a chain of successive traders.

Another assumption of the model is that investors cannot coordinate their investment policies. In our setting, coordination would be useful for investor 1 to compensate investor 2 when $\varphi > \beta^*$, in order to avoid a sharp increase in the expected transfer.

Furthermore, we consider that investor 1's portfolio is chosen at date 1 and held until date 3:

this means in particular that manager 1 cannot buy again at date 2 after buying at date 1.[16] This assumption does not affect our results. Indeed, if price P_1 reveals manager 1's information, there is no expected profit left for him. If $P_1 = \frac{1}{2}$, he anticipates that, if $v = 1$, manager 2 knows it and buys. Therefore, the total demand if manager 1 buys again is 2 or 3. The market maker thus infers that there has been at least one high signal and sets a price strictly greater than φ which eliminates any expected profit for manager 1. When $v = 0$, manager 2 knows it and does not buy. If manager 1 buys again at date 2, the total demand is either 1 or 2. When the demand is 2, the price is greater than φ for the reason explained above. When the demand is 1, the market maker is not aware of the fact that $v = 0$, the price is strictly greater than 0 and manager 1 loses money (he would be subject to the winner's curse). Overall, at equilibrium, manager 1 cannot trade twice on a high signal.

Last, market makers observe buying and selling order flows separately. If this was not the case, managers at equilibrium would not buy after a high signal *and* sell after a low signal. Indeed, their trading would always be identified and prices would be fully revealing.[17] No profit could ever be made. The equilibrium strategies would be either to refrain from selling after a low signal (as it is the case in our equilibrium) or to refrain from buying after a high signal. The reasoning would be similar to ours in that case, and the assumption of separate order flows is simply helpful to focus on one equilibrium.

[16] It is straightforward to see that there is no point in selling the asset at date 2 when manager 1 has observed a high signal.

[17] To see this, observe that the net order flow would be 2 or 1 following a high signal, and 0 or -1 following a low signal.

Appendix

Proof of Proposition 1

Given the distribution of the order flows and prices presented in Figure 2, we have

$$\Pi_1 = \frac{1}{2} \times \left[\varphi - \left(\frac{1}{2} \times \varphi + \frac{1}{2} \times \frac{1}{2}\right)\right] - \sum_t R_t^{1,FB} = \frac{2\varphi - 1}{8} - \sum_t R_t^{1,FB}.$$

Next, given that manager 2's signal is perfect, prices set by market makers according to the observed order flow are $P_2(P_1, q_2 = 2) = 1$, $P_2(P_1, q_2 = 1) = P_1$,$P_2(P_1, q_2 = 0) = 0$.

Note that $\Pr(s_2 = H|P_1) = \Pr(v = 1|P_1) = P_1$ and $E(P_2|P_1, s_2 = H) = \frac{1}{2} \times 1 + \frac{1}{2} \times P_1$. This leads to

$$\Pi_2(P_1) = \frac{1}{2} P_1 (1 - P_1) - \sum_t R_t^{2,FB}.$$

We obtain easily that $\Pi_1 \geq 0 \Leftrightarrow \varphi \geq \varphi^{FB}$, with $\varphi^{FB} = \frac{1}{2} + 4 \sum_t R_t^{1,FB}$. Also, $\Pi_2(P_1) \geq 0 \Leftrightarrow P_1 \in [\underline{\beta}^{FB}, \overline{\beta}^{FB}]$, with $\underline{\beta}^{FB} = \frac{1}{2} - \frac{\sqrt{1-8\sum_t R_t^{2,FB}}}{2}$ and $\overline{\beta}^{FB} = \frac{1}{2} + \frac{\sqrt{1-8\sum_t R_t^{2,FB}}}{2}$. ∎

Proof of Proposition 2

The investor's objective is to minimize the fund manager's expected compensation subject to the constraints (IC_H^1), (IC_L^1), (IC_e^1) and (H_1^1) defined in Section 3.1. Recall that the optimal contract determines the sequence of transfers to the fund manager $\{R_1^1(q_1^m), R_2^1(q_1^m, P_1, P_2), R_3^1(q_1^m, P_1, P_2, v)\}$ according to the price path (P_1, P_2, v). To characterize the optimal contract we use a standard Lagrangian technique. Assume first that $\varphi \leq \overline{\beta}$. The investor's program is:

$$\begin{aligned}
&\min_{R^1} \; R_1^1(1) + \tfrac{1}{4}\varphi \textstyle\sum_{P_1 \in \left\{\frac{1}{2}, \varphi\right\}} \left(R_2^1(1, P_1, 1) + \sum_{P_2 \in \{P_1, 1\}} R_3^1(1, P_1, P_2, 1)\right) + \tfrac{1}{4}\left(R_2^1(1, \varphi, \varphi) + R_2^1\left(1, \tfrac{1}{2}, \tfrac{1}{2}\right)\right) \\
&+ \tfrac{1}{4}(1-\varphi) \textstyle\sum_{P_1 \in \left\{\frac{1}{2}, \varphi\right\}} \left(R_2^1(1, P_1, 0) + \sum_{P_2 \in \{0, P_1\}} R_3^1(1, P_1, P_2, 0)\right) + R_1^1(0) \\
&+ \tfrac{1}{4}\varphi \textstyle\sum_{P_1 \in \left\{1-\varphi, \frac{1}{2}\right\}} \left(R_2^1(0, P_1, 0) + \sum_{P_2 \in \{0, P_1\}} R_3^1(0, P_1, P_2, 0)\right) + \tfrac{1}{4}\left(R_2^1(0, 1-\varphi, 1-\varphi) + R_2^1\left(0, \tfrac{1}{2}, \tfrac{1}{2}\right)\right) \\
&+ \tfrac{1}{4}(1-\varphi) \textstyle\sum_{P_1 \in \left\{1-\varphi, \frac{1}{2}\right\}} \left(R_2^1(0, P_1, 1) + \sum_{P_2 \in \{P_1, 1\}} R_3^1(0, P_1, P_2, 1)\right),
\end{aligned}$$

subject to

$$E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=H\right) \geq \tfrac{1}{4}\varphi\sum_{P_1\in\left\{1-\varphi,\frac{1}{2}\right\}}\left(U\left(R_2^1\left(0,P_1,1\right)\right)+\sum_{P_2\in\{P_1,1\}}U\left(R_3^1\left(0,P_1,P_2,1\right)\right)\right)$$
$$+U\left(R_1^1\left(0\right)\right)+\tfrac{1}{4}\left(U\left(R_2^1\left(0,1-\varphi,1-\varphi\right)\right)+U\left(R_2^1\left(0,\tfrac{1}{2},\tfrac{1}{2}\right)\right)\right)$$
$$+\frac{1}{4}\left(1-\varphi\right)\sum_{P_1\in\left\{1-\varphi,\frac{1}{2}\right\}}\left(U\left(R_2^1\left(0,P_1,0\right)\right)+\sum_{P_2\in\{0,P_1\}}U\left(R_3^1\left(0,P_1,P_2,0\right)\right)\right), \qquad \left(IC_H^1\right)$$

$$E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=L\right)\geq\frac{1}{4}\varphi\sum_{P_1\in\left\{\frac{1}{2},\varphi\right\}}\left(U\left(R_2^1\left(1,P_1,0\right)\right)+\sum_{P_2\in\{0,P_1\}}U\left(R_3^1\left(1,P_1,P_2,0\right)\right)\right)$$
$$+U\left(R_1^1\left(1\right)\right)+\frac{1}{4}\left(U\left(R_2^1\left(1,\varphi,\varphi\right)\right)+U\left(R_2^1\left(1,\frac{1}{2},\frac{1}{2}\right)\right)\right)$$
$$+\frac{1}{4}\left(1-\varphi\right)\sum_{P_1\in\left\{\frac{1}{2},\varphi\right\}}\left(U\left(R_2^1\left(1,P_1,1\right)\right)+\sum_{P_2\in\{P_1,1\}}U\left(R_3^1\left(1,P_1,P_2,1\right)\right)\right), \quad \left(IC_L^1\right)$$

where $E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=H\right)$ and $E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=L\right)$ are computed using the probability distribution presented in Figure 2,

$$U\left(R_1^1\left(1\right)\right)+\frac{1}{8}\left(\sum_{P_1\in\left\{\frac{1}{2},\varphi\right\}}\sum_{P_2\in\{0,1\}}U\left(R_2^1\left(1,P_1,P_2\right)\right)+\sum_{P_1\in\left\{\frac{1}{2},\varphi\right\}}\sum_{P_2\in\{P_1,v\}}\sum_{v\in\{0,1\}}U\left(R_3^1\left(1,P_1,P_2,v\right)\right)\right)$$
$$+\frac{1}{4}\left(\sum_{P_1\in\left\{\frac{1}{2},\varphi\right\}}\sum_{P_2=P_1}U\left(R_2^1\left(1,P_1,P_2\right)\right)\right)\geq$$
$$U\left(R_1^1\left(0\right)\right)+\frac{1}{8}\left(\sum_{P_1\in\left\{1-\varphi,\frac{1}{2}\right\}}\sum_{P_2\in\{0,1\}}U\left(R_2^1\left(0,P_1,P_2\right)\right)+\sum_{P_1\in\left\{1-\varphi,\frac{1}{2}\right\}}\sum_{P_2\in\{P_1,v\}}\sum_{v\in\{0,1\}}U\left(R_3^1\left(0,P_1,P_2,v\right)\right)\right)$$
$$+\frac{1}{4}\left(\sum_{P_1\in\left\{1-\varphi,\frac{1}{2}\right\}}\sum_{P_2=P_1}U\left(R_2^1\left(0,P_1,P_2\right)\right)\right), \quad \left(H_1^1\right)$$

$$\frac{1}{2}\left(E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=H\right)+E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=L\right)\right)-c\geq E_{ne}\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)\right), \quad \left(IC_e^1\right)$$

where $E_{ne}\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)\right)$ is the left-hand side of $\left(H_1^1\right)$,

$$R_\cdot^1\left(.\right)\geq 0.$$

We denote by $\lambda_1^1(q_m)$ the Lagrange multiplier of the constraint $R_1^1(q_m) \geq 0$, by $\lambda_2^1(q_m, P_1, P_2)$ that of $R_2^1(q_m, P_1, P_2) \geq 0$, and by $\lambda_3^1(q_m, P_1, P_2, v)$ that of $R_3^1(q_m, P_1, P_2, v) \geq 0$. Similarly λ_H^1 corresponds to the constraint (IC_H^1), λ_L^1 to (IC_L^1), λ_e^1 to (IC_e^1), and $\lambda_{H_1^1}$ to (H_1^1).

Assume first that the optimal contract entails $R_2^1(1, \varphi, 1) > 0$ and $R_2^1(0, 1-\varphi, 0) > 0$. This implies that $\lambda_2^1(1, \varphi, 1) = 0$ and $\lambda_2^1(0, 1-\varphi, 0) = 0$. FOCs give

$$\frac{\partial \mathcal{L}}{\partial R_2^1(1, \varphi, 1)} = 0 \Leftrightarrow \lambda_{H_1^1} = \frac{\varphi}{\frac{\partial U}{\partial R_2^1(1,\varphi,1)}} - 2\varphi\lambda_H^1 + 2(1-\varphi)\lambda_L^1 + (1-\varphi)\lambda_e^1 \tag{1}$$

$$\frac{\partial \mathcal{L}}{\partial R_2^1(0, 1-\varphi, 0)} = 0 \Leftrightarrow \lambda_e^1 = \frac{\varphi}{2\varphi - 1}K - 2\left(\lambda_H^1 + \lambda_L^1\right), \tag{2}$$

with $K = \frac{1}{\frac{\partial U}{\partial R_2^1(1,\varphi,1)}} + \frac{1}{\frac{\partial U}{\partial R_2^1(0,1-\varphi,0)}}$.

Use Equation (1) into (2) to obtain

$$\lambda_{H_1^1} = \varphi M - 2\lambda_H^1, \tag{3}$$

with $M = \frac{1}{\frac{\partial U}{\partial R_2^1(1,\varphi,1)}} + \frac{1-\varphi}{2\varphi-1}K$.

Plug (3) into $\frac{\partial \mathcal{L}}{\partial R_1^1(1)} = 0$ to find that $\lambda_1^1(1) = \frac{1}{2} - \frac{\partial U}{\partial R_1^1(1)} \times \frac{\varphi}{2} \times \left[\frac{1}{\frac{\partial U}{\partial R_2^1(1,\varphi,1)}} - \frac{1}{\frac{\partial U}{\partial R_2^1(0,1-\varphi,0)}}\right]$. If $\frac{\partial U}{\partial R_2^1(1,\varphi,1)} = \frac{\partial U}{\partial R_2^1(0,1-\varphi,0)}$ (we show in the proof of Proposition 3 that this is true at the optimum), $\lambda_1^1(1) > 0$ and $R_1^1(1) = 0$. Similarly, we can show that $\lambda_1^1(0) > 0$, $\lambda_2^1(1, \varphi, \varphi) > 0$, $\lambda_2^1(0, 1-\varphi, 1-\varphi) > 0$, $\lambda_2^1\left(1, \frac{1}{2}, \frac{1}{2}\right) > 0$, $\lambda_2^1\left(0, \frac{1}{2}, \frac{1}{2}\right) > 0$. This implies that $R_1^1(0) = R_1^1(1) = R_2^1(1, \varphi, \varphi) = R_2^1(0, 1-\varphi, 1-\varphi) = R_2^1\left(1, \frac{1}{2}, \frac{1}{2}\right) = R_2^1\left(0, \frac{1}{2}, \frac{1}{2}\right) = 0$. Intuitively, it is counterproductive to pay the manager according to his trading decision only ($R_1^1(q_m) = 0$) or according to the state of the world, when the latter does not reveal additional information (i.e. when $P_2 = P_1$).

Next, we have that

$$\frac{\partial \mathcal{L}}{\partial R_2^1(1, \varphi, 0)} = 0 \Leftrightarrow \lambda_2^1(1, \varphi, 0) = \frac{1}{8}(1-\varphi) - \frac{\partial U}{\partial R_2^1(1, \varphi, 0)} \times \frac{\varphi}{8} \times \left(M - \frac{K\varphi}{2\varphi - 1}\right). \tag{4}$$

See that $M - \frac{K\varphi}{2\varphi-1} \leq 0$. We thus have $\lambda_2^1(1, \varphi, 0) > 0$, and $R_2^1(1, \varphi, 0) = 0$. Using the same approach, it follows that $R_2^1(0, 1-\varphi, 1) = R_2^1\left(1, \frac{1}{2}, 0\right) = R_2^1\left(0, \frac{1}{2}, 1\right) = R_3^1(0, 1-\varphi, 1, 1) =$

$R_3^1\left(1,\frac{1}{2},0,0\right) = R_3^1(1,\varphi,0,0) = R_3^1\left(0,\frac{1}{2},1,1\right) = R_3^1(0,1-\varphi,1-\varphi,1) = R_3^1\left(1,\frac{1}{2},\frac{1}{2},0\right) = R_3^1(1,\varphi,\varphi,0) = R_3^1\left(0,\frac{1}{2},\frac{1}{2},1\right) = 0$. Intuitively, this reflects the fact that for incentives reasons, the fund manager is not rewarded when his trading decision is contradicted by the interim price or by the final cash flow.

Given these null transfers, (H_1^1) can be written as $Y \geq X$, with

$$X = \sum_{P_1 \in \left\{1-\varphi,\frac{1}{2}\right\}} U\left(R_2^1(0,P_1,0)\right) + \sum_{P_1 \in \left\{1-\varphi,\frac{1}{2}\right\}} \sum_{P_2 \in \{0,P_1\}} U\left(R_3^1(0,P_1,P_2,0)\right),$$

and

$$Y = \sum_{P_1 \in \left\{\frac{1}{2},\varphi\right\}} U\left(R_2^1(1,P_1,1)\right) + \sum_{P_1 \in \left\{\varphi,\frac{1}{2}\right\}} \sum_{P_2 \in \{P_1,1\}} U\left(R_3^1(1,P_1,P_2,1)\right).$$

Similarly, (IC_H^1) can be rewritten as $\frac{\varphi}{4}Y \geq \frac{1-\varphi}{4}X$, (IC_L^1) as $\frac{\varphi}{4}X \geq \frac{1-\varphi}{4}Y$, and (IC_e^1) as $\frac{1}{2}\frac{\varphi}{4}Y + \frac{1}{2}\frac{\varphi}{4}X - c \geq \frac{1}{8}Y \Leftrightarrow \frac{\varphi}{4}X \geq 2c + \frac{1-\varphi}{4}Y$.

It is now straightforward to see that (IC_H^1) is not binding because of (H_1^1), and (IC_L^1) because of (IC_e^1): $\lambda_H^1 = \lambda_L^1 = 0$. Conditions (2) and (3) yield $\lambda_{H_1^1} > 0$ and $\lambda_e^1 > 0$: (H_1^1) and (IC_e^1) are binding. It follows that $X = Y$, and $\frac{\varphi}{8}Y = \frac{\varphi c}{2\varphi - 1}$. Note that

$$\begin{aligned} \frac{\varphi}{8}Y &= E_e\left(U\left(R_2^1(q_1^m = 1, P_1, P_2 = 1)\right) + U\left(R_3^1(q_1^m = 1, P_1, P_2, v = 1)\right)\right) \\ &= E_e\left(U\left(R_2^1(q_1^m = 0, P_1, P_2 = 0)\right) + U\left(R_3^1(q_1^m = 0, P_1, P_2, v = 0)\right)\right). \end{aligned}$$

To complete the proof, one can check that, if one assumes initially that the optimal contract entails $R_2^1(1,P_1,1) > 0$ or $R_3^1(1,P_1,P_2,1) > 0$, and $R_2^1(0,P_1,0) > 0$ or $R_3^1(0,P_1,P_2,0) > 0$, for all admissible price paths (P_1,P_2), one obtains the same characterization for the optimal contract.

At the opposite, starting from $R_2^1(1,P_1,0) > 0$ or $R_3^1(1,P_1,P_2,0) > 0$, and $R_2^1(0,P_1,1) > 0$ or $R_3^1(0,P_1,P_2,1) > 0$, for all admissible price paths (P_1,P_2), leads to a contradiction.

Assume now that $\varphi > \overline{\beta}$. The program is very similar and is written

$$\min_{R^1} \frac{1}{4}\varphi\left(R_2^1\left(1,\frac{1}{2},1\right)+2R_3^1\left(1,\varphi,\varphi,1\right)+\sum_{P_2\in\left\{\frac{1}{2},1\right\}}R_3^1\left(1,\frac{1}{2},P_2,1\right)\right)+\frac{1}{4}\left(2R_2^1\left(1,\varphi,\varphi\right)+R_2^1\left(1,\frac{1}{2},\frac{1}{2}\right)\right)$$

$$+\frac{1}{4}\left(1-\varphi\right)\left(R_2^1\left(1,\frac{1}{2},0\right)+2R_3^1\left(1,\varphi,\varphi,0\right)+\sum_{P_2\in\{0,P_1\}}R_3^1\left(1,\frac{1}{2},P_2,0\right)\right)+R_1^1(1)+R_1^1(0)$$

$$+\frac{1}{4}\varphi\left(R_2^1\left(0,\frac{1}{2},0\right)+2R_3^1\left(0,1-\varphi,1-\varphi,0\right)+\sum_{P_2\in\left\{0,\frac{1}{2}\right\}}R_3^1\left(0,\frac{1}{2},P_2,0\right)\right)+\frac{1}{2}R_2^1\left(0,1-\varphi,1-\varphi\right)$$

$$+\frac{1}{4}R_2^1\left(0,\frac{1}{2},\frac{1}{2}\right)+\frac{1}{4}\left(1-\varphi\right)\left(R_2^1\left(0,\frac{1}{2},1\right)+2R_3^1\left(0,1-\varphi,1-\varphi,1\right)+\sum_{P_2\in\{P_1,1\}}R_3^1\left(0,\frac{1}{2},P_2,1\right)\right),$$

subject to

$$E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=H\right)\geq\frac{1}{4}\varphi\left(U\left(R_2^1\left(0,\frac{1}{2},1\right)\right)+2U\left(R_3^1\left(0,1-\varphi,1-\varphi,1\right)\right)\right)$$

$$+\frac{1}{4}\varphi\sum_{P_2\in\{P_1,1\}}U\left(R_3^1\left(0,\frac{1}{2},P_2,1\right)\right)+\frac{1}{4}\left(2U\left(R_2^1\left(0,1-\varphi,1-\varphi\right)\right)+U\left(R_2^1\left(0,\frac{1}{2},\frac{1}{2}\right)\right)\right)+U\left(R_1^1\left(0\right)\right)$$

$$+\frac{1}{4}\left(1-\varphi\right)\left(U\left(R_2^1\left(0,\frac{1}{2},0\right)\right)+2U\left(R_3^1\left(0,1-\varphi,1-\varphi,0\right)\right)+\sum_{P_2\in\{0,P_1\}}U\left(R_3^1\left(0,\frac{1}{2},P_2,0\right)\right)\right),\quad (IC_H^1)$$

$$E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=L\right)\geq\frac{1}{4}\varphi\left(U\left(R_2^1\left(1,\frac{1}{2},0\right)\right)+2U\left(R_3^1\left(1,\varphi,\varphi,0\right)\right)\right)$$

$$+\frac{1}{4}\varphi\sum_{P_2\in\{0,P_1\}}U\left(R_3^1\left(1,\frac{1}{2},P_2,0\right)\right)U\left(R_1^1\left(1\right)\right)+\frac{1}{4}\left[2U\left(R_2^1\left(1,\varphi,\varphi\right)\right)+U\left(R_2^1\left(1,\frac{1}{2},\frac{1}{2}\right)\right)\right)$$

$$+\frac{1}{4}\left(1-\varphi\right)\left(U\left(R_2^1\left(1,\frac{1}{2},1\right)\right)+2U\left(R_3^1\left(1,\varphi,\varphi,1\right)\right)+\sum_{P_2\in\{P_1,1\}}U\left(R_3^1\left(1,\frac{1}{2},P_2,1\right)\right)\right),\qquad (IC_L^1)$$

$$U\left(R_1^1(1)\right)+\frac{1}{8}\left(\sum_{P_2\in\{0,1\}}U\left(R_2^1\left(1,\frac{1}{2},P_2\right)\right)+2\left(U\left(R_3^1\left(1,\varphi,\varphi,1\right)\right)+U\left(R_3^1\left(1,\varphi,\varphi,0\right)\right)\right)\right)$$
$$+\frac{1}{8}\sum_{P_2\in\{P_1,v\}}\sum_{v\in\{0,1\}}U\left(R_3^1\left(1,\frac{1}{2},P_2,v\right)\right)+\frac{1}{4}\left(2U\left(R_2^1\left(1,\varphi,\varphi\right)\right)+U\left(R_2^1\left(1,\frac{1}{2},\frac{1}{2}\right)\right)\right)\geq$$
$$U\left(R_1^1\left(0\right)\right)+\frac{1}{8}\left(\sum_{P_2\in\{0,1\}}U\left(R_2^1\left(0,\frac{1}{2},P_2\right)\right)+2\left(U\left(R_3^1\left(0,1-\varphi,1-\varphi,0\right)\right)+U\left(R_3^1\left(0,1-\varphi,1-\varphi,1\right)\right)\right)\right)$$
$$+\frac{1}{8}\sum_{P_2\in\{P_1,v\}}\sum_{v\in\{0,1\}}U\left(R_3^1\left(0,\frac{1}{2},P_2,v\right)\right)+\frac{1}{4}\left(2U\left(R_2^1\left(0,1-\varphi,1-\varphi\right)\right)+U\left(R_2^1\left(0,\frac{1}{2},\frac{1}{2}\right)\right)\right)\quad (H_1^1)$$

where $E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=H\right)$ and $E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=L\right)$ are computed using the probability distribution indicated in the objective function,

$$\frac{1}{2}E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=H\right)+\frac{1}{2}E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=L\right)-c\geq E_{ne}\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right),\left(IC_e^1\right)$$

where $E_{ne}\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)$ is the left-hand side of (H_1^1);

$$R_\cdot^1\left(.\right)\geq 0.$$

The only difference with the previous program is that, when $P_1=\varphi$ or $P_1=1-\varphi$, then $P_2=P_1$ with probability 1. The resolution of the program is the same as before and yields the same characterization of the optimal contract in terms of expected utility granted to the fund manager. As we show in Proposition 3, the optimal monetary transfers to achieve the equilibrium expected utility will differ. ■

Proof of Corollary 1

Manager 1's agency rent is written

$$\Pr\left(s_1=H|e\right)E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=1\right)\right)|s_1=H\right)+\Pr\left(s_1=L|e\right)E_e\left(\sum_{t=1}^{t=3}U\left(R_t^1\left(q_1^m=0\right)\right)|s_1=L\right)-c$$
$$=\frac{1}{2}\times\frac{2\varphi c}{2\varphi-1}+\frac{1}{2}\times\frac{2\varphi c}{2\varphi-1}-c$$
$$=\frac{c}{2\varphi-1}.$$

$\blacksquare$

Proof of Proposition 3

When $\varphi \leq \overline{\beta}$, using the proof of Proposition 2, investor 1 has the following program:

$$\min_{R^1_\cdot} \sum_{P_1 \in \left\{\frac{1}{2}, \varphi\right\}} \left(R^1_2(1, P_1, 1) + \sum_{P_2 \in \{P_1, 1\}} R^1_3(1, P_1, P_2, 1) \right) + \sum_{P_1 \in \left\{1-\varphi, \frac{1}{2}\right\}} \left(R^1_2(0, P_1, 0) + \sum_{P_2 \in \{0, P_1\}} R^1_3(0, P_1, P_2, 0) \right),$$

$$\begin{aligned} s.t.\quad & \textstyle\sum_{P_1 \in \left\{\frac{1}{2}, \varphi\right\}} U\left(R^1_2(1, P_1, 1)\right) + \sum_{P_1 \in \left\{\varphi, \frac{1}{2}\right\}} \sum_{P_2 \in \{P_1, 1\}} U\left(R^1_3(1, P_1, P_2, 1)\right) = \frac{8c}{2\varphi - 1}, \\ & \textstyle\sum_{P_1 \in \left\{1-\varphi, \frac{1}{2}\right\}} U\left(R^1_2(0, P_1, 0)\right) + \sum_{P_1 \in \left\{1-\varphi, \frac{1}{2}\right\}} \sum_{P_2 \in \{0, P_1\}} U\left(R^1_3(0, P_1, P_2, 0)\right) = \frac{8c}{2\varphi - 1}, \\ & R^1_\cdot \geq 0. \end{aligned}$$

FOCs imply that marginal utilities are equal across states. It follows that

$$R^1_\cdot = U^{-1}\left(\frac{4c}{3(2\varphi - 1)}\right),$$

and manager 1's optimal expected compensation, denoted $E(R^{1*})$, is

$$E\left(R^{1*}\right) = \frac{3}{2}\varphi U^{-1}\left(\frac{4c}{3\left(2\varphi - 1\right)}\right).$$

When $\varphi > \overline{\beta}$, investor 1's program is

$$\min_{R^1_\cdot} R^1_2\left(1, \frac{1}{2}, 1\right) + 2R^1_3(1, \varphi, \varphi, 1) + \sum_{P_2 \in \{P_1, 1\}} R^1_3\left(1, \frac{1}{2}, P_2, 1\right) + R^1_2\left(0, \frac{1}{2}, 0\right) + 2R^1_3(0, 1-\varphi, 1-\varphi, 0)$$
$$+ \sum_{P_2 \in \{0, P_1\}} R^1_3\left(0, \frac{1}{2}, P_2, 0\right),$$

$$\begin{aligned} s.t.\quad & U\left(R^1_2\left(1, \tfrac{1}{2}, 1\right)\right) + 2U\left(R^1_3(1, \varphi, \varphi, 1)\right) + \textstyle\sum_{P_2 \in \{P_1, 1\}} U\left(R^1_3\left(1, \tfrac{1}{2}, P_2, 1\right)\right) = \frac{8c}{2\varphi - 1}, \\ & U\left(R^1_2\left(0, \tfrac{1}{2}, 0\right)\right) + 2U\left(R^1_3(0, 1-\varphi, 1-\varphi, 0)\right) + \textstyle\sum_{P_2 \in \{0, P_1\}} U\left(R^1_3\left(0, \tfrac{1}{2}, P_2, 0\right)\right) = \frac{8c}{2\varphi - 1}, \\ & R^1_\cdot \geq 0. \end{aligned}$$

This yields

$$R^1_\cdot = U^{-1}\left(\frac{8c}{5(2\varphi - 1)}\right),$$

and manager 1's expected compensation is

$$E\left(R^{1*}\right)=\frac{5}{4}\varphi U^{-1}\left(\frac{8c}{5\left(2\varphi-1\right)}\right).$$

Next, see that

$$\frac{3}{2}\varphi U^{-1}\left(\frac{4c}{3\left(2\varphi-1\right)}\right)<\frac{5}{4}\varphi U^{-1}\left(\frac{8c}{5\left(2\varphi-1\right)}\right)\Leftrightarrow 6U^{-1}\left(\frac{4c}{3\left(2\varphi-1\right)}\right)<5U^{-1}\left(\frac{8c}{5\left(2\varphi-1\right)}\right).$$

U is increasing and strictly concave, which implies that U^{-1} is increasing and strictly convex. Therefore

$$\begin{array}{rc} & \left(\frac{8c}{5(2\varphi-1)}-\frac{4c}{3(2\varphi-1)}\right)U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right)<\frac{4c}{3(2\varphi-1)}\left(U^{-1}\left(\frac{8c}{5(2\varphi-1)}\right)-U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right)\right) \\ \Leftrightarrow & U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right)<5\left(U^{-1}\left(\frac{8c}{5(2\varphi-1)}\right)-U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right)\right), \end{array}$$

which yields i).

Last, let us show that $E\left(R^{1*}\right)$ decreases with φ.

$$\frac{\partial E\left(R^{1*}\right)}{\partial\varphi}<0\Leftrightarrow U^{-1}\left(\frac{4c}{3\left(2\varphi-1\right)}\right)<\frac{8\varphi c}{3(2\varphi-1)^{2}}(U^{-1})'\left(\frac{4c}{3\left(2\varphi-1\right)}\right). \tag{5}$$

Again, use the convexity of U^{-1} to see that

$$U^{-1}\left(\frac{4c}{3\left(2\varphi-1\right)}\right)<\frac{4\varphi c}{3(2\varphi-1)}(U^{-1})'\left(\frac{4c}{3\left(2\varphi-1\right)}\right). \tag{6}$$

Multiply the (RHS) of (6) by $\dfrac{2\varphi}{2\varphi-1}$ to show that (5) holds. ■

Proof of Corollary 2

To prove this corollary, we analyze investor 1's participation constraint. Recall that, with symmetric information, long-term information is acquired if and only if $\varphi\geq\varphi^{FB}=\frac{1}{2}+4\sum_t R^{1,FB}$.

Recall that the expected trading profit is $\dfrac{2\varphi-1}{8}$. φ^* is defined by

$$\varphi^* = \frac{1}{2} + 4\frac{3}{2}\varphi U^{-1}\left(\frac{4c}{3\,(2\varphi-1)}\right).$$

And φ^{**} by

$$\varphi^{**} = \frac{1}{2} + 4\frac{5}{4}\varphi U^{-1}\left(\frac{8c}{5\,(2\varphi-1)}\right).$$

Use the convexity of U^{-1} to see that

$$U^{-1}\left(\frac{4c}{3\,(2\varphi-1)}\right) > \frac{4}{2\varphi-1}U^{-1}(\frac{c}{3}). \tag{7}$$

The (RHS) of (7) is greater than $\frac{2}{\varphi}U^{-1}(\frac{c}{3})$, which implies that $\frac{3}{2}\varphi U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right) > E(R^1_{FB})$ and $\varphi^* > \varphi^{FB}$. It follows immediately that $\varphi^{**} > \varphi^*$. ■

Proof of Proposition 4

Use the proof of Proposition 2 to see that all transfers are null when the portfolio performance is null or negative. Use the proof of Proposition 3 to see that all positive bonuses are equal to $U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right)$ when $\varphi \leq \overline{\beta}$ and are equal to $U^{-1}\left(\frac{8c}{5(2\varphi-1)}\right)$ when $\varphi > \overline{\beta}$. ■

Proof of Proposition 5

When $\varphi \leq \overline{\beta}$, the expected long-term bonus is equal to $\varphi U^{-1}\left(\frac{4c}{3(2\varphi-1)}\right)$. The ratio of long-term expected bonus over total expected bonus is thus $\frac{2}{3}$. Proceed in the same way to show that when $\varphi > \overline{\beta}$, the ratio of long-term expected bonus over total expected bonus is $\frac{4}{5}$, which completes the proof. ■

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