Trading on Short-Term Information

Preliminary version. Comments welcome

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Abstract

In this paper we address the question as to why fund managers may trade on short-term information in a financial market that offers more profitable trading on long-term information. We consider a setting in which a fund manager's ability is unknown and an investor uses performance observations to learn about this ability. We show that an investor learns less efficiently about the ability of a fund manager when he trades on long-term information compared to trading on short-term information. This is the case, because the information on which a manager bases his trades is less precise the longer the information horizon, and thus performance observations contain more noise. Moreover, under trading on long-term information, performance observations become available after a short period only if the manager unwinds his position early. Such performance observations, however, are generally contaminated with additional noise, because unwinding prices only reveal underlying asset value imperfectly. When the informational efficiency of short-term prices increases, this effect becomes less pronounced, because a long-term trader who unwinds his position after a short time can convey an increasing amount of information concerning his ability to the investor. At the same time, trading on short-term information becomes less profitable, and therefore the investor's incentive to induce short-term trading weakened. Nevertheless, we show that short-term trading may be induced even when prices fully reveal short-term information.

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1. Introduction

There has been considerable debate among economists and practitioners alike, concerning short-termism in financial markets. In this debate, short-termism by fund managers is frequently held responsible for the mispricing of long-term assets and the resulting underinvestment by firms in such assets. This, in turn, is alleged to result in low growth rates of ‘short-termist’ economies.[1]

Short-termism refers to a situation in which factors concerning the near future carry an excessive weight in decision making compared to factors regarding the longer term. Excessive is here defined relative to a first-best benchmark prevalent in a frictionless economy. In the context of financial markets, short-termism is typically understood to mean that investors or traders put too much emphasis on short-term information, such as short-term profits and cash-flows, when valuing an asset.

In this paper we argue that incomplete information concerning the fund manager’s inherent ability, may lead investors to prefer a deviation from the first-best information horizon, resulting in trade on short-term information as a second best outcome. In contrast to much of the existing literature on short-termism, we explore the role of the trading horizon in allowing an investor to learn about the unknown ability of a fund manager.

One of the reasons for short-termism frequently put forward is that fund managers act under intense short-term pressures, leading them to neglect longer-term objectives (see Marsh, 1990, Froot, Scharfstein, and Stein, 1992, Dow and Gorton, 1994). A number of theoretical contributions have shown that due to agency problems, firm or fund managers may indeed take a decision that exhibits a short-term bias, although this is undesirable from an investor’s point of view.[2]

While agency problems associated with fund and firm management may share a number of commonalties, one has to distinguish clearly between these two settings when attempting to explain short-termism. Firm managers have the choice of investment projects which may pay off in the more or less distant future. Inefficient investment in short-term projects may occur, because a manager cannot convey his ability quickly to an investor by choosing the long-term project (v.Thadden, 1995). A major difference between a firm’s investment decision and a fund’s portfolio choice is that there is typically no (or only a very illiquid) market for investment projects. Therefore, no market price for investment projects exists, which makes it hard for an outsider to assess the value of such projects before their payout date. As a result, a firm manager

[1] See Marsh (1990) for a comprehensive appraisal of this debate.

cannot signal superior investment skill in the short-run by selling a long-term investment project. Instead, he might choose an investment project that pays off in the short run.

In contrast to this, the market value of a portfolio of liquid securities changes over time as additional information gets incorporated into prices. A portfolio manager who trades on long-term information can thus signal superior ability early on, by unwinding his position after a short period, when prices reflect more of the information on which he originally based his trade. Therefore, it is not obvious that the often cited short-term pressures under which fund managers act, are a satisfactory explanation for short investment horizons. As Demirag (1995) writes:

> "It is ... reasonable to argue that pressures to maximise short-run returns ... are in principle compatible with a willingness to ignore short-term cash flows, profits, and dividends in favour of long-term prospects. A fund manager who consistently recognised such prospects and invested accordingly, shortly before others did, would 'perform' extremely well in the short-term."

In this paper we consider a setting in which the price of an asset becomes informationally more efficient as its liquidation date is approached and thus short-run prices reflect some long-term information. A fund manager can either trade in an asset that is liquidated in the near future (trade on short-term information) or the more distant future (trade on long-term information). If he trades on long-term information he can unwind his position after a short period. The investor who is unaware of the manager's inherent ability, uses the information contained in a manager's past performance, in order to learn about his ability and possibly to switch funds to a different manager if his performance is bad.[3] In this context we show that trade on short-term information may be preferred by the investor, because it allows her to learn more efficiently about the ability of the manager. This is the case, although trade on long-term information would be chosen in the first-best benchmark case.

Trading on long-term information leads to less efficient learning about the manager's ability for two reasons. Firstly, the quality of information on which the manager trades, worsens as the time horizon of information increases. This reflects the idea that it is easier for a fund manager to predict an event in the near future than in the distant future. Trading on less precise information, however, implies that performance observations contain less information about the

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[2] For short-termism by firm managers see for example Narayanan (1985), Stein (1989), Shleifer and Vishny (1990) and von Thadden (1995). For short-term biases by fund managers due to agency problems see Shleifer and Vishny (1997). These papers are reviewed in more detail in Section 6F.

[3] This may happen in the form of individual investors switching out of badly performing and into well performing funds or by funds firing their manager after bad performance. Empirical evidence suggests that both of this is

ability of the manager, because bad performance is more likely to be attributable to bad luck, rather than low ability. Therefore, trading on long-term information allows less efficient learning about a manager's ability compared to trading on short-term information.

Secondly, when a manager trades on long-term information and unwinds his position early, the price achieved through unwinding is itself a garbled signal of the underlying liquidation value of the asset. This adds a further layer of noise to the performance observations available when trade occurs on long-term information. In our setting early unwinding of long-term positions is never inferior to a buy-and hold strategy. Expected trading profits are the same under either strategy (buy-and-hold or early unwinding), but under a buy-and-hold strategy, performance observations become available later, which is undesirable for the investor.

The efficiency of learning that results from observing a long-term trader's short-run performance clearly depends on the short-term informational efficiency of prices. When prices become perfectly informative at the time of unwinding (shortly before the asset is liquidated), observing the manager's short run performance is as informative as observing the actual asset value. Since the manager's trading decision is based on his assessment of underlying asset value, the investor can best judge the performance of the manager, when prices reveal most information at the time of unwinding, i.e. when prices are most informationally efficient at an interim date before liquidation. The less informationally efficient these short-term prices are, the harder it becomes for the investor to learn from performance observations.

The short-term informational efficiency of prices affects the principal's choice of trading horizon for another reason. The profitability of trading on short-term information depends on the degree to which information is incorporated into the price upon submission of the manager's order. When more information is incorporated into this price, trading becomes less profitable. Therefore, an increase in short-term informational efficiency reduces the principal's payoff from inducing trade on short-term information.[4] We thus establish a link between an investor's incentive to induce trading on long-term information and the short-term informational efficiency of prices.

We show that even in the extreme case when prices fully reveal short-term information, an investor may wish to induce short-term trading in a manager of unknown ability as this allows more efficient screening.

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happening. For evidence on fund switching see Chevalier and Ellison (1997) and for firing of fund managers, see Chevalier and Ellison (1998) and Khorana (1996).

[4] This decline in the economic value of information corresponds to findings of Grinold (1997) who demonstrates that the profitability of trading on a particular piece of information decreases as the date of public revelation of the information draws nearer. It also corresponds to the treatment of Dow and Gorton (1994) and Vives (1995), where

The remainder of the paper is organised as follows. Section 2 lays out the basic model. In Section 3 the expected profits are derived for long-term and short-term trading, and the first-best outcome is calculated. In Section 4 it is shown that the payoff to the investor is increasing with the degree of short-term informational efficiency of prices when trade occurs on long-term information. Section 5 gives the main result concerning the desirability of trading on short-term versus long-term information. Section 6 is a discussion of the results and Section 7 concludes. The Appendix contains the proofs.

2. The model

We consider a setting in which there is one investor that hires a fund manager that can either acquire long-term or short-term information. Depending on his type, the quality of his information is high or low. After acquiring information the manager can trade in risky securities, where trades are executed by a market maker. As in Kyle (1985) the market maker is in Bertrand competition with other market makers and therefore sets a price that is equal to the expected discounted value of the security, given total order flow. Total order flow consists of the order submitted by one informed trader (the fund manager) and an order submitted by noise traders. Trades are (optimally) unwound after one period and the resulting prices and profits are observable by the investor who uses this information to update her belief concerning the manager's ability. Subsequently, the investor decides whether to retain the manager for another trading period, or to fire the manager and hire a new manager from a pool of indistinguishable types.

We model a financial market in discrete time with infinitely many dates $t \in T = \{0,1,2,...\}$. At each date there is a riskless security with rate of return r and two risky securities $k_t \in \{A_t, B_t\}$. The risky security k_t pays an uncertain dividend $d_{k,t} \in \{0,1\}$ only once, at date t, and no dividend at any other date. Either realisation of the dividend payment is equally probable and independent of the other securities' dividend payments.[5]

There are two types of agents in the economy. A risk neutral investor who delegates portfolio management to a risk neutral manager with limited liability. The manager can acquire information about the uncertain dividend payment of securities of the same vintage, i.e. information that concerns the dividend payment of two risky securities at the same date. In particular, at date t, a manager can acquire a noisy signal for dividend payments one period from

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traders subsequently trade on information concerning a particular point in time, making prices more efficient as the event date is approached.

now ($d_{A,t+1}$, $d_{B,t+1}$) or two periods from now ($d_{A,t+2}$, $d_{B,t+2}$). This choice is denoted by $a_t \in \{a_s, a_l\}$. For $a_t = a_l$, the manager receives a long-term signal $l_t \in \{DD, DU, UD, UU\}$ at date t for $d_{A,t+2}$, $d_{B,t+2}$. In this signal, D stands for 'down' (low dividend realisation) and U for 'up' (high dividend realisation).The first letter in the signal indicates the dividend for asset A_{t+2}, while the second indicates that for asset B_{t+2}. For $a_t = a_s$ the manager receives a short-term signal $s_t \in \{DD, DU, UD, UU\}$ for $d_{A,t+1}$, $d_{B,t+1}$. At any date the manager can acquire one of the two signals at zero cost, while it is prohibitively costly to acquire both signals at the same time.[6]

There are two types of fund manager $m \in \{L, H\}$ and neither the principal nor managers know the type. Depending on his type, the information acquired by a manager is of different quality. In particular, if a manager is a high type, the signal l_t (s_t) is correct for both assets of that vintage with probability m (n), is correct for one asset but incorrect for the other with probability $\frac{1-m}{2}$ ($\frac{1-n}{2}$), and is never incorrect for both assets. For a low type manager on the other hand, a signal is always correct for one asset and incorrect for the other, and it is unknown for which asset it is correct. Moreover, it is assumed that $n>m$, i.e. it is harder to predict dividends two periods into the future than one period into the future. Tables 1 and 2 below show the probabilities of a particular realisation of dividends (in the columns) conditional on a particular long-term signal received (in the rows) for a high and a low type manager. The analogous distribution applies to short-term signals, where m is replaced by n everywhere and ($d_{A,t+2}$, $d_{B,t+2}$) is replaced by ($d_{A,t+1}$, $d_{B,t+1}$).

($d_{A,t+2}$, $d_{B,t+2}$)	(0,0)	(0,1)	(1,0)	(1,1)
l_t				
DD	μ	(1-μ)/2	(1-μ)/2	0
DU	(1-μ)/2	μ	0	(1-μ)/2
UD	(1-μ)/2	0	μ	(1-μ)/2
UU	0	(1-μ)/2	(1-μ)/2	μ

Table 1: The high type's probability of receiving a particular signal is given depending on the underlying state of nature.

[5] Instead of dividend payments one could also think of the uncertain payoff as the liquidation value of an asset.
[6] Since we are concerned with the problem of a choice of time horizon here, we allow managers to choose the time horizon of their information, while not addressing the issue of a choice of a particular asset (*A* or *B*).

$(d_{A,t+2}, d_{B,t+2})$	(0,0)	(0,1)	(1,0)	(1,1)
l_t				
DD	0	1/2	1/2	0
DU	1/2	0	0	1/2
UD	1/2	0	0	1/2
UU	0	1/2	1/2	0

Table 2: The low type's probability of receiving a particular signal is given depending on the underlying state of nature.

One way to think about the link between true asset value and signal received is the following. Fund managers often acquire information concerning both specific assets and general economic conditions that affect the value of assets. In our setting one could understand the manager as acquiring information concerning a particular time horizon, such as the interest rate set by the central bank in say six months time. He then tries to understand how a particular value of that interest rate will affect a large number of assets in the economy, where different assets are affected differently. One could then think of the low type manager as being unable to interpret this information correctly in a consistent manner. He therefore trades some of the assets in the correct and some others in the wrong direction. With a large number of assets, this amounts to practically always levelling out the number of wrong and the number of correct investments, which is exactly what happens in this simplified two asset economy. [7]

The high type manager on the other hand, is sometimes able to trade more than half the assets in the correct direction (when he is lucky), while sometimes he performs badly and trades some correctly and some not. His probability of trading more than half the assets in the correct direction depends on the information horizon, reflecting the idea that it is harder to predict far away events correctly than events in the nearer future.

Note that although the model exhibits more than one asset that may pay a dividend at any given date, this paper is not concerned with issues such as diversification across assets. Introducing more than one asset allows us to model the evolution of a manager's reputation over time in a particularly simple manner. This allows us to obtain analytical solutions to a problem that is only tractable numerically in a more general setting.

The two asset setting yields a simple learning structure for the following reason. Essentially there are two distinct outcomes from trade. Either the manager performs badly (trades one asset in the wrong the other in the correct direction), or he performs well (trades both assets in the correct direction). A low ability manager always performs badly, while a high ability

[7] I wish to thank Robert Waldmann for the original stimulus behind the two asset structure employed here.

manager sometimes performs badly and sometimes well. Thus a high ability manager may be identified after just one round of trade. In a one asset economy, always performing badly means always trading the one asset in the wrong direction. This, however, implies that the low ability manager has perfect information, because he could just do the opposite of what the signal suggests. In a two asset setting it is unknown which of the two assets he will trade correctly, and thus he genuinely cannot trade profitably. Still, the simple reputation updating structure is retained.[8]

There is an infinitely large pool of managers and all agents have the correct prior g that a randomly selected manager is a high type (m=H).[9] The principal can decide at any date whether or not to retain the present manager. Denote this choice by $e_t \in \{0,1\}$, where e_t=1 means that at date t the manager is retained from the previous period. If a manager is fired (e_t=0) the principal picks a new manager at random from the pool without incurring any costs. Denote by m_t the type of manager that is employed at date t after the employment decision e_t has been taken. Moreover, denote by u_t the probability that a manager is a high type just *before* the employment decision e_t is taken and q_t the probability just *after*. This probability is also referred to as the reputation of a manager and depends on the managers employment and performance record.

The fund manager receives a private benefit b in every period he is employed. Doing so is a short-hand way of saying that he receives a constant wage payment every period, so that he prefers being employed by a fund over not being employed. Such a constant wage payment corresponds to most contracts found in real world arrangements, where the manager is typically rewarded on the basis of net asset value under management. This type of wage contract yields incentives mainly implicitly, as investors may withdraw funds from the manager when performance is bad. On the other hand, a manager whose performance is good, will typically be able to attract more funds and thus increase wage payments. This corresponds to the firing/retainment decision of the investor in our model.

Moreover, the structure of the model is sufficiently simple to ensure that a manager will take the best trading decision for the investor, merely because he wishes to remain employed.

[8] Note that instead of assuming that there are two different assets, one could arrive at the same reputation updating structure by assuming that the liquidation value of a security consists of two components about which a manager receives a signal that is correlated in the same way as described in the text. However, when managers submit an order the market maker has less information about the manager's signal in some states of the world. This results in very complicated formulae for trading profits, which is why this approach was not taken here.

[9] One could think of the fund managers in the pool as agents without work experience. It then seems plausible to assume that they do not yet know how apt they are for the job of a fund manager.

Therefore, we do not need to consider the provision of incentives through complicated wage contracts.[10]

Following Kyle (1985), we model the financial market as being informationally semi-strong efficient. Therefore, we assume that beside the informed traders there are also noise traders who have an exogenous demand for the security (e.g. an unmodelled hedging need). At date t they submit a random and serially uncorrelated order $\tilde{n}_{k,t,t} \in \{-n, n\}$ for asset k_t, where $t \in \{t+1,\ t+2\}$.[11] Either realisation of $n_{k,t,t}$ is equally probable and independent of $d_{k,t}$. We assume that noise traders hold their positions until the date of the uncertain dividend payment.[12]

At date t the market maker receives a total order for asset k_t, denoted by

$$Q_{k,t,t} = n_{k,t,t} + q_{k,t,t}$$

where $q_{k,t,t}$ denotes the (market) order submitted by the informed trader. Market makers are in Bertrand competition, and therefore make zero profits in expectation. The price $p_{k,t,t}$ for asset k_t at date t is therefore set so as to equal the asset's expected present value given the market maker's information set I_t. Hence,

$$p_{k,t,t} = 1/(1+r)^{t-t} E[\, d_{k,t} \mid I_t].$$

Since we are interested in exploring a financial market that exhibits more profitable long-term than short-term trading opportunities, while preserving the natural property that long-term information is no better than short-term information, we require that prices become informationally more efficient as the event date draws nearer. This is achieved by assuming that for each security k_{t+1} the market maker receives a noisy *short-term* signal $w_{k,t} \in \{0,1\}$ at date t about $d_{k,t+1}$.[13] The information content of the signal is defined as

$$\omega \equiv prob(w_{k,t} = 1 \mid d_{k,t+1} = 1) = \text{prob}(w_{k,t} = 0 \mid d_{k,t+1} = 0) \geq 1/2.$$

Another way of achieving increased informational efficiency of short-term prices would be to introduce a second informed trader who exogenously trades on short-term information. This would leave the main insights of the paper unchanged, while complicating the analysis considerably, which is why this approach was not taken here.

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[10] Papers exploring the provision of incentives through optimal wage contracts for delegated portfolio managers include Bhattacharya and Pfleiderer (1985), Stoughton (1993) and Heinkel and Stoughton (1994).

[11] Note that the actual order size n is irrelevant here as it depends entirely on the scale used for measuring order size. Without loss of generality we can set n=1. We will do this later when calculating trading profits, but for the time being we retain the notation in order to avoid confusion with other variables.

[12] For a discussion concerning the behaviour of noise traders and their role in our model, see Section 6.C and 6.D.

[13] In order to explain why a long-term arbitrage opportunity may remain unexploited, we need to consider a situation in which a long-term arbitrage opportunity *should* be exploited in a first-best setting (otherwise 'short-termism' would not be an issue). The assumption is essentially made, so that a situation can arise in which it is not first-best to trade on short-term information.

All the signals l_t, s_{t+1}, and w_{t+1} are assumed to exhibit minimal correlation, so that

$$prob(w_{A,t}=x,\ w_{B,t}=y,\ s_t=X|d_{A,t+1},d_{B,t+1})$$
$$= prob(w_{A,t}=x|\ d_{A,t+1})\ prob(w_{B,t}=y|\ d_{B,t+1})prob(s_t=X|d_{A,t+1},d_{B,t+1}),$$

where $x,y\in\{0,1\}$ and $X\in\{DD, DU, UD, UU\}$. Similarly for the long-term signal:

$$prob(w_{A,t+1}=x,\ w_{B,t+1}=y,\ l_t=X|d_{A,t+2},d_{B,t+2})$$
$$= prob(w_{A,t+1}=x|\ d_{A,t+2})\ prob(w_{B,t+1}=y|\ d_{B,t+2})prob(l_t=X|d_{A,t+2},d_{B,t+2}),$$

Moreover we assume that short-term and long-term signals display minimal correlation:

$$prob(s_{t+1}=Y\ ,\ l_t=X|d_{A,t+2},d_{B,t+2}) = prob(s_{t+1}=Y|\ d_{A,t+2},\ d_{B,t+2})\ prob(l_t=X|d_{A,t+2},d_{B,t+2}).$$

It is assumed that the market maker knows the manager's reputation, denoted by q_t. The market maker's information set at a given date t thus consists of the observed total order flow in all assets, his private signal $w_{k,t}$ and the choice of a trading horizon a_t, which can be inferred from observed order flows. Hence, the information set is $I_t = \{ Q_{A,t,t}, Q_{B,t,t}, a_t, q_t, w_{A,t}, w_{B,t}\}$.

Since noise traders submit buy or sell orders of size n, the informed trader has to submit orders of the same size ($q_{t,t} \in \{-n, 0, n\}$), as any other order size would certainly reveal the manager's order to the market maker. Since the market maker knows that the manager only submits a buy (sell) order after receiving a signal that indicates that the dividend payment for that asset will be high (low), the price would be set so as to reflect this information and trading could not be profitable.[14]

We moreover assume that the manager can unwind a long-term position before a new round of trade begins. This yields an unwinding price at t+1 for an asset k_{t+2}, denoted by $P_{k,t+2}$ which is used by the principal to update her belief about the manager's type. The principal can observe which trading positions a manager takes. From this follows that if the principal wishes to induce the manager to trade on, say long-term information, the principal can threaten to fire the manager if he then trades in the asset that pays out a dividend in the next period.[15] Similarly, the

[14] It is straightforward to specify the market maker's out of equilibrium beliefs for total order sizes other than -2n, 0, 2n, such that it is not profitable for the manager to deviate from equilibrium. For a treatment of this issue see Dow and Gorton (1994), Section VI.

[15] In Section 6.E we discuss incentive compatibility of the trading horizon in a setting where the investor cannot observe the types of assets a manager trades in.

unwinding of long-term positions is enforceable, since the principal can directly observe whether or not a manager unwinds a long-term position.

Summary table of variables

$k_t \in \{A_t, B_t\}$	Security that pays off uncertain dividend at date t
$d_{k,t} \in \{0,1\}$	Dividend payment of security k_t
$a_t \in \{a_s, a_l\}$	Horizon of information acquired at date t
l_t	Signal when long-term information is acquired
s_t	Signal when short-term information is acquired
$w_{k,t}$	Market maker's signal for $d_{k,t+1}$
m	Probability that long-term signal is correct for both assets
n	Probability that short-term signal is correct for both assets
w	Probability that $w_{k,t}$ is correct
$m_t \in \{L, H\}$	Type of manager trading at date t
$e_t \in \{0,1\}$	Investor's employment decision (for e_t=0 the manager is fired)
q_t	Reputation of manager after employment decision
u_t	Reputation of manager before employment decision
$n_{k,t,t} \in \{-n, n\}$	Order for asset k_t submitted by noise trader at date t
$q_{k,t,t}$	Order for asset k_t submitted by informed trader at date t
$Q_{k,t,t}$	Total order for asset k_t submitted at date t
$p_{k,t,t}$	Price for asset k_t at date t
$P_{k,t}$	Unwinding price for asset k_t (at date t-1)

Table 3: Summarises the variables of the model.

The last remaining 'real' choice variable is then whether or not the manager trades on information or simply trades at random. We make the assumption that $\gamma\nu \geq 1/4$. This implies that a manager picked from the pool is more likely to trade both assets in the correct direction by following the signal than by trading at random. For the generality of our main result, we do not assume that $\gamma\mu \geq 1/4$. This means that for some 'admissible' parameter values, the manager may have an incentive to trade on noise instead of long-term information. Note, however, that in this case a principal certainly does not have an incentive to induce trade on long-term information.

Throughout, we assume that when $\gamma\mu<1/4$, the manager will nonetheless trade on his information instead of trading at random. As will become apparent later on, this implies that the set of parameter values for which the principal wishes to induce trade on short-term information is larger when the manager is allowed to trade at random, than when he is not. Hence, we identify a subset of parameter values for which trade on short-term information is chosen by the principal compared to the set that would result if managers were allowed to not trade on their long-term information.[16]

Given that at any date the principal can costlessly enforce her desired action concerning the time horizon of the manager's information and the unwinding decision, the agency problem effectively reduces to a pure decision problem for the principal. There remains a conflict of interest concerning the decision of the investor to retain the present manager, or to fire him and hire a new manager.[17] Since the manager receives a private benefit of being employed and has limited liability, he always wishes to be employed. Therefore, we can simply set the wage payment to the manager equal to zero in every period.

The timing of events

1. The holders of security k_t receive a dividend $d_{k,t}$.
2. The market maker observes $w_{k,t}$ about $d_{k,t+1}$.
3. If the informed trader held a long-term position in asset k_{t+1} ($q_{k,t+1,t-1}\neq 0$), he can unwind the position.
4. The principal updates her belief about the type of manager employed from observing $d_{k,t}$ and/or the profit due to unwinding.
5. The principal takes a firing/ retainment decision e_t.
6. The principal chooses a new trading horizon a_t.
7. The manager observes a signal s_t if $a_t=a_s$ (l_t if $a_t=a_l$).
8. The manager submits an order $q_{k,t+1,t}$ ($q_{k,t+2,t}$) and noise traders submit $n_{k,t+1,t}$ ($n_{k,t+2,t}$).
9. The market maker observes $Q_{k,t+1,t}$ ($Q_{k,t+2,t}$), sets prices $p_{k,t+1,t}$ ($p_{k,t+2,t}$) and trades are executed.

[16] The main reason for restricting attention to this subset, rather than the full set without the restriction on the manager's behaviour is that we do not believe that churning on long-term information is an interesting argument in favour of trade on short-term information.

[17] Some models of career concerns and learning about an agent's type (e.g. Holmstrom, 1982) assume that an agent's wage fluctuates with his reputation, rendering the principal indifferent between retaining and firing the agent. This approach assumes that agents have all the bargaining power, i.e. that the labour market is not competitive. Our approach is compatible with a competitive labour market and finds empirical support e.g. in Chevalier and Ellison (1999) and Khorana (1996). Both papers find that a fund manager's probability of being fired is negatively correlated with past performance.

10. Restart at 1.[18]

Define $p_{t+1}(a_t, q_t) \equiv W_{t+1}(a_t, q_t) - W_t(1+r)$ as the trading profit that accrues when a manager of reputation q_t trades on information a_t rather than investing all wealth in the riskless security. The principal maximises the expected present value of future wealth subject to the stochastic transition of the manager's reputation. The evolution of reputation depends on the principal's actions and is captured by constraints (2), (3) and (4) of the optimisation problem below. The optimisation problem below is a general formulation, which will be made more specific later on.

At date t:

$$V(h_t, u_t) = \max_{a_t, e_t} \frac{1}{1+r} E\left[p\left(a_t, q_t\left(u_t, e_t\right)\right) + V\left(h_{t+1}\left(a_t, a_{t-1}, e_t\right), \tilde{u}_{t+1}\right)\right] \qquad (1)$$

s.t. $$q_t(u_t, e_t) = \begin{cases} u_t & \text{if} \quad e_t = 1 \\ g & \text{if} \quad e_t = 0 \end{cases} \qquad (2)$$

$$\tilde{u}_{t+1} \sim h\left(h_t, a_t, q_t\right) \qquad (3)$$

$$h_{t+1} = \begin{cases} 1 & \text{if} \quad a_t = a_{t-1} = a_l, e_t = 1 \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

If the manager gets fired (e_t=0), the reputation of the following manager will just be g, as managers from the pool are picked at random. If the manager is retained, his next period reputation is a random variable described by the distribution function $h(*)$. The stochastic properties of next period's reputation depend on the previous reputation q_t, the trading horizon a_t induced and the realisation of the indicator function $h_t \in \{0,1\}$. We will characterise the distribution function $h(*)$ below. The indicator function is set to 1 if the manager employed at date t-1 was also employed at t-2 (e_{t-1}=1) *and* traded on long-term information ($a_{t-1}=a_{t-2}=a_l$). The variable h_{t-1} is important, because it captures the asymmetry between learning about a manager who trades on long-term information for the first time or repeatedly. Its significance will be discussed in detail in Section 4 and the Appendix.

[18] Note that in this statement of timing, at t=0 the points 1 and 3-5 do not apply.

3. Asset prices and trading profits

In this Section results concerning the trading profits accruing from trade on short-or long-term information are presented. The purpose of the section is to illustrate how trading can be profitable in this setting and how the market maker's private information affects trading profits. Moreover, Proposition 1 gives a necessary and sufficient condition for trading on long-term information to be first-best.

3.1 Asset prices and trading profits under short-term trading

First, consider prices and trading profits under short-term trading (a_t=a_s). Since the manager submits orders of size n, total order flow in each asset A_{t+1} and B_{t+1} can take the values $Q_{k,t+1,t} \in \{-2n, 0, 2n\}$. The manager can either receive a signal that indicates that the dividend payment for, say, asset A_{t+1} will be high (i.e. $s_t = UU$ or $s_t = UD$), in which case he submits a buy order ($q_{A,t+1,t} = n$), or he receives a bad signal for asset A_{t+1} (i.e. $s_t = DU$ or $s_t = DD$) and sells the asset short ($q_{A,t+1,t} = -n$).[19] Orders for asset B_{t+1} are determined similarly. This leads to the possible total order flows

$Q_{k,t+1,t} = 2n$: Both, the manager and the noise trader submit an order.
$Q_{k,t+1,t} = 0$: The manager submits a buy order and the noise trader a sell order, or vice versa.
$Q_{k,t+1,t} = -2n$: Both manager and noise trader submit a sell order.

Apart from the order flow, the market maker also receives a direct signal $w_{k,t} \in \{0,1\}$ for the next dividend payment $d_{k,t+1}$. Correspondingly, the price $p_{k,t+1,t}$ depends on the total order flow *and* the market maker's private signal. Prices can be calculated by Bayesian updating from

$$p_{k,t+1,t}(\mathcal{I}_t) = 1/(1+r)\, E[d_{k,t+1}|\mathcal{I}_t] = 1/(1+r) prob(d_{k,t+1}=1|\mathcal{I}_t) \qquad (5)$$

Since the actual price of an asset depends on the realisations of $Q_{A,t+1,t}$, $Q_{B,t+1,t}$, $w_{A,t}$, $w_{B,t}$, we get $3\times3\times2\times2=36$ possible prices for each asset. For the computation of trading profits, however, not all of these prices are relevant, because the manager can only expect to make a profit if it so

[19] We assume that $\gamma\nu\geq1/4$, i.e. the manager trading on short-term information is most likely to trade in the 'correct' direction when following his signal, rather than guessing or doing the opposite of what the signal suggests. If the principal believes that the manager does trade on his information in the way described above, the manager has no incentive to deviate from doing so, as this would only reduce his probability of being retained. We do not consider possible equilibria in which the manager trades in the 'wrong' direction and the principal believes that this is what he is doing. For the generality of the argument in the Theorem of Section 5, we cannot restrict $\gamma\mu\geq1/4$. However, all

happens that total order flow does not reveal his order (i.e. when $Q_{k,t+1,t}$=0). These 'relevant' prices are given in the proof of the following lemma, contained in Appendix A.

Lemma 1: The expected trading profits when a manager of reputation q_t trades on short-term information at date t are given by:

$$Ep_{t+1}\,(a_t=a_s,\, q_t) = 2q_t n\,\omega(1-\omega) \tag{6}$$

Proof see Appendix A.

Note that expected trading profits are decreasing in ω, for ω>1/2. This is the case, because an increase in the quality of the market maker's private information ω, results in informationally more efficient prices. Hence, the manager's informational rents from trading decrease. In the limiting case when the market maker has perfect information about next period's dividend payments (ω=1), prices fully reflect this information and the manager makes zero profits.

3.2 Asset prices and trading profits under long-term trading

Next, consider the price setting behaviour of the market maker, when the manager trades on long-term information at date t, i.e. a_t=a_l. In that case he submits an order $q_{k,t+2,t}$ for asset k_{t+2}. Again, total order flow in each asset can take the values -2n, 0, or 2n. However, when trading on long-term information, the manager submits an order for assets for which the market maker has not yet received private information. Hence, the price only depends on the realisations of $Q_{k,t+2,t}$, which implies nine possible different prices for each asset.

Again, the price of asset k_{t+2} at date t (denoted by $p_{k,t+2,t}$) can be calculated by Bayesian updating. Since an asset pays out at most one dividend, we can write

$$p_{k,t+2,t}(\mathcal{I}_t) = 1/(1+r)^2\, E[d_{k,t+2}|\mathcal{I}_t] = 1/(1+r)^2 prob(d_{k,t+2}=1|\mathcal{I}_t) \tag{7}$$

After one period the manager can unwind his position with the market maker, after the latter received his private signal $w_{k,t+1}$, but before the next round of trading begins. As in the case of short-term trading this implies 36 different possible unwinding prices. The proof of Lemma 2 in Appendix A contains the details of how prices are formed. We can now state the following result concerning the trading profits under long-term information acquisition.

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the arguments go through under either assumption: that the long-term trader does or does not follow his signal when $\gamma\mu$<1/4.

***Lemma* 2**: Suppose a manager of reputation q_t trades on long-term information at date t and unwinds the position at t+1. Expected trading profits are then given by:

$$Ep_{t+1}\,(a_t=a_l,\, q_t) = \frac{q_t m}{2(1+r)}\,. \tag{8}$$

Moreover, expected discounted trading profits from following a 'buy and hold' strategy are the same as under the 'unwinding' strategy.

Proof see Appendix A.

It is important to notice that by observing the prices at which the manager unwinds his positions, the principal learns the realisation of the market maker's private information. This in turn is a noisy signal for the true value of the future dividend payments $d_{k,t+2}$, which is used by the principal to assess whether or not the manager traded in the correct direction at date t. This is important for the principal's decision concerning the choice of an information horizon for her fund manager.[20]

3.3 The first-best benchmark

Consider as a benchmark the case where the investor is able to distinguish high and low type managers and thus employs a high type.

***Proposition* 1**: *For*

$$m > m^* \equiv 4nw(1-w)(1+r) \tag{9}$$

a high type manager trades more profitably in expectation when acquiring the long-term signal a_l *than when acquiring the short-term signal* a_s.

Moreover, if and only if

$$1/4 > w(1\text{-}w)(1+r), \tag{10}$$

is it possible to find parameter values n, m, r, *such that* $n > m > m^*$, *i.e. trading on long-term information is more profitable even though the long-term signal is less informative than the short-term signal.*

Proof see Appendix A.

[20] Note that the quality ω of the market maker's signal w_t does not affect the expected profitability of trading under long-term information, although the individual prices do depend on ω. This is the case because an increase in ω leads to an increase in expected profits, when trades are unwound at a favourable price. This increase in expected profits is exactly matched ex ante by a decrease in expected profits, when trades are unwound at an unfavourable price. As a result expected profits are independent of ω.

In the remainder of the paper we are mainly interested in the case where $n > m > m^*$. Note that when $\omega = 1/2$, condition (10) can never be satisfied. This is obvious, since for $\nu > \mu$, short-term information is better than long-term information, and at $\omega = 1/2$, short-term prices are intrinsically not more informationally efficient than long-term prices. As a result trading on short-term information is always first-best. For all values of $\omega > 1/2$, there exists an r small enough such that (10) is satisfied. In the extreme case, where $\omega = 1$, the condition is satisfied for all values of $r < \infty$.

4. Informational efficiency of short-term prices and trading on long-term information

In the previous section it was shown that the direct profit from trading on long-term information is independent of the informational efficiency of short-term prices, denoted by ω. Is it therefore the case that the principal's payoff when the manager trades on long-term information is independent of ω? Note that the principal's payoff consists not only of the direct trading profit, but also of the benefit from learning about the manager's ability. When a manager trades on long-term information at date t and unwinds his positions at t+1, the manager learns the market maker's private information $w_{A,t+1}$ and $w_{B,t+1}$ by observing the prices at which trades are unwound. Since $w_{A,t+1}$ and $w_{B,t+1}$ are indicative of the true value of the securities A_{t+2}, B_{t+2}, the principal receives some information about whether or not the manager traded in the correct direction, *before* the true asset value is revealed. It is intuitively clear that when ω increases, i.e. unwinding prices become a more reliable source of information for true asset value, the principal is better able to assess the manager's performance. Hence, one would expect the principal's payoff from inducing trade on long-term information to be non-decreasing in ω.

More formally, denote by $W_l(h_t,u_t)$ the principal's discounted expected payoff from always inducing long-term trade, when the currently employed manager (before employment decision e_t is taken) has reputation u_t and an optimal employment decision is taken at every date from t onwards. The state variable h_t denotes whether or not a manager who trades on long-term information did so for the first time (h_t=0) or not (h_t=1). To see why this is important consider the following.

At date t+1 the principal receives the following information: l_t (by observing the positions $q_{k,t+2,t}$ that were taken), $w_{k,t+1}$ (by observing at which prices $P_{k,t+2,t+1}$ positions are unwound) and actual dividend payments $d_{k,t+1}$. Signal l_t and $w_{k,t+1}$ are directly informative about the ability of the manager since the market maker's signal $w_{k,t+1}$ is informative about next period's dividend payments $d_{k,t+2}$ and thus about whether or not the manager traded assets A_{t+2} and B_{t+2} in the correct direction at date t. On the other hand, $d_{k,t+1}$ reveals whether or not trades two periods ago (trade $q_{k,t+1,t-1}$ at date t-1) were correct. This, however, is only of interest to the principal if the manager who traded in t-1 is still employed. Hence, the variable h_{t+1} indicates whether or not the principal should take into account the information contained in $d_{k,t+1}$ for the reputation update. Note that h_{t+1} also affects the value function, because learning about a manager who trades on long-term information is not 'linear' in the sense that every period yields the same amount of information to the investor. As explained above, whenever $\omega<1$, the investor learns less after the first period of employment compared to after the second.

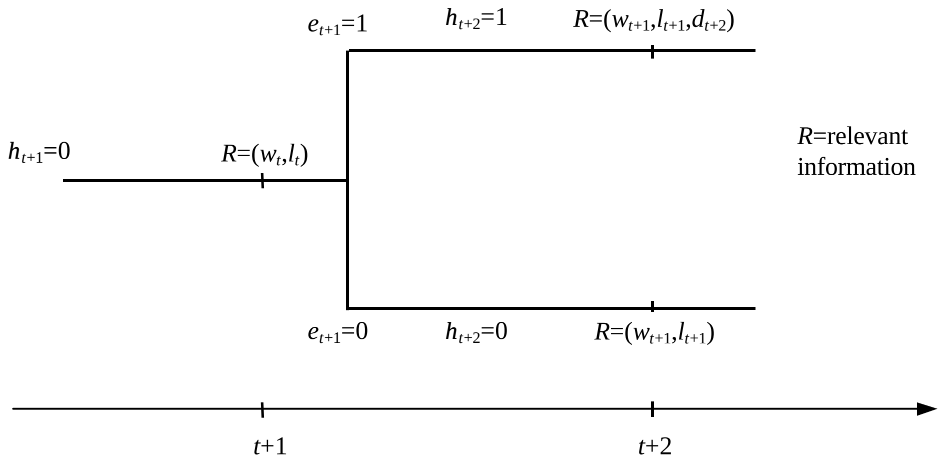

Figure 1 shows the evolution of the state variable h_t depending on the employment decision e_t under long-term information acquisition (i.e. $a_t=a_l$ and $a_{t+1}=a_l$) and the associated 'relevant' information to carry out the belief update about a manager's type. If a manager is fired at t+1 (e_{t+1}=0) the dividend payment d_{t+2} is uninformative about the new manager's type (R=(w_{t+1}, l_{t+1})). When a manager is retained at date t+1 and traded on long-term information at date t (h_{t+2}=1), d_{t+2} is informative about his type (R=(w_{t+1}, l_{t+1}, d_{t+2})).

This allows us to write the expected discounted payoff under the optimal employment decision as

$$W_l(h_t, u_t) = \max_{e_t} \frac{q_t(u_t, e_t)m}{2(1+r)^2} + \tfrac{1}{1+r} E\left[W_l\left(h_{t+1}(e_t), \tilde{u}_{t+1}(h_t, q_t)\right)\right] \tag{11}$$

s.t. constraints (2), (3), and (4)

Depending on the value of w, the optimal employment policy may differ and hence the maximised expected discounted payoff. Denote by $W_l^*(w, h, u)$ the maximised payoff for a given value of w, h and u. Then, we can state the following result:

***Proposition* 2:** *The principal's expected discounted payoff* $W_l^*(w, 0, g)$ *when always inducing long-term trading and choosing an optimal employment policy is non-decreasing in w, and for* $0 < g < 1$ *strictly increasing in w for some value* $w^* \in [1/2,1]$.

Proof see Appendix A.

Proposition 2 establishes that the investor's expected payoff from letting a manager trade on long-term information is increasing in the short run efficiency of prices. This is the case although short run price efficiency has no direct effect on the profitability of trade on long-term information.

To see why this is true, consider the extreme case where ω = 1/2, i.e. the market maker receives no private information. In that case the unwinding prices $P_{k,t+2}$ do not reveal any information about the future dividend that was not already known by the principal from observing the orders that a manager submitted. Therefore, the principal does not learn anything about whether or not the manager received a correct long-term signal from observing the manager's trading profits and instead has to wait until the dividend payment actually occurs. For a newly employed manager this means that the first information about his ability is observed two periods after he is first employed. The principal thus has to retain a potentially bad manager for at least one more period than under perfectly efficient short-term prices ($w = 1$). It is essentially this delay in learning that causes long-term trading to become less attractive as the informational efficiency of short-term prices decreases.

5. Short-term versus long-term trading

In this Section the main result is presented, followed by a discussion of its driving forces. Some implications of the result are explored. The proof is contained in Appendix B.

Our main interest in this paper is to find out whether or not short-term trading may be induced with a manager picked randomly from the pool. We are interested in the set of parameter values r, m, n, g, for which this may be the case, in particular when trading on long-term information is first-best. Denote the set on which the basic parameters are defined by

$$Z=\{(r, m, n, g)|(r, m, n, g)\in \{R^+\times[\tfrac{1}{4}, 1]^2\times[0,1]\}, gn \geq 1/4\}.$$

Denote by $S(\omega) \subseteq Z$ the set for which short-term trading is induced when a manager picked from the pool is first employed. Moreover, using Proposition 1, we can denote the set of parameters for which long-term trading is first-best, while the short-term signal is more informative, by

$F(\omega)=\{(r, \mu, \nu, \gamma)|(r, \mu, \nu, \gamma)\in B, \nu>\mu>\mu^*\}$.

We would then like to know whether or not $S(\omega)$ is a non-empty set, how it depends on ω, and whether we can have a situation where long-term trading is first-best, while short-term trading is induced by the principal, i.e. $F(\omega) \cap S(\omega) \neq \emptyset$. All of this is stated in the following Theorem.

Theorem:

(i) For all values of w∈(1/2,1]*, there exists a non-empty set S(w) Í Z of parameter values (r, m, n, g), such that the principal prefers to induce trading on short-term information with a manager who is randomly picked from the pool. This is the case even when trading on long-term information is first-best, i.e. S(w) Ç F(w) ¹ Æ . Moreover, a subset of S(w)ÇF(w) is given by SF(w) Í S(w)ÇF(w) with*

$$SF(w)=\{(r, m, n, g)|(r, m, n, g)\, Î\, F(w),\ \frac{n-m}{r+gn} > \frac{m-4nw(1-w)(1+r)}{m-4gnw(1-w)(1+r)}\}. \qquad (12)$$

(ii) S(w') Ì S(w'') for w'>w''.

Proof see Appendix B.

The Theorem above states the following.

(1) Even when long-term trading is first-best, the principal may want to induce a newly employed manager to trade on short-term information, for *any* degree w>1/2 of the informational efficiency of short-term prices.

(2) A sufficient condition on the parameter values for short-term trading to be chosen by the investor who employs a new manager, when long-term trading is first-best, is given by (12).

(3) The higher the informational efficiency ω of short-term prices, the lower the incentive for the principal to induce short-term trading. Hence, the set of parameters $S(\omega)$ for which short-term trading is induced by the principal becomes smaller as ω increases.

In order to illustrate the mechanism at work in this model, it is most convenient to consider the case where w=1, i.e. prices are fully revealing one period before the uncertainty concerning dividend payments is resolved. In this case the evolution of reputation takes a simple form. Remember that when a manager trades on long-term information at date t ($a_t=a_l$), he unwinds his positions at t+1, at prices $P_{k,t+2}$. As mentioned above, unless w = 1/2, $P_{k,t+2}$ reveals the market maker's private signals $w_{k,t+1}$. For w = 1, the realisation of $w_{k,t+1}$ is perfectly informative about $d_{k,t+2}$. By indirectly observing $w_{k,t+1}$ at date t+1 the principal knows whether or not the manager received a correct long-term signal l_t in the previous period. As a result, the reputation update u_{t+1} can take two values: a high value if the manager received a correct signal and a low value if he received a wrong signal. From Bayesian updating we get the distribution $h(h_t, a_t = a_l, q_t)$[21] as

$$u_{t+1} = \begin{cases} 1 & \text{with probability} \quad q_t m \\ \dfrac{(1-m)q_t}{1-q_t m} & \text{with probability} \quad 1 - q_t m \end{cases} \tag{13}$$

Under short-term trading, the principal observes directly the relevant dividend payments $d_{k,t+1}$ at date t+1 and thus whether or not the manager received a correct signal. Again, the reputation update for a retained manager can take one of two values: a high value if the signal was correct for both assets and a low value if it was wrong for one asset and correct for the other. We can thus characterise
$h(h_t, a_t = a_s, q_t)$ by

$$u_{t+1} = \begin{cases} 1 & \text{with} \quad q_t n \\ \dfrac{(1-n)q_t}{1-q_t n} & \text{with} \quad 1 - q_t n \end{cases} \tag{14}$$

From (13) and (14) it is clear that reputation deteriorates after bad performance. If a manager trades for the first time (and hence $q_t = \gamma$) and performs badly, his reputation falls below the reputation of managers in the pool. Since hiring and firing is costless, the principal fires a manager whose reputation is below that of a manager picked from the pool. Therefore, at any point in time and under either trading strategy, the principal employs a manager either of reputation q=1 (if she was able to identify a high type manager) or of reputation $q=\gamma$ (if she has not yet been able to identify a high type manager). Under this optimal employment policy, we can calculate the expected reputation $E[q_{t+1}|q_t=\gamma,a_t]$ for trading on short- or long-term information. It is easy to verify that

$$E[q_{t+1}|q_t=\gamma,a_t=a_s] = \gamma(1+\nu(1-\gamma))$$
$$> \gamma(1+\mu(1-\gamma)) = E[q_{t+1}|q_t=\gamma,a_t=a_l] \quad \Leftrightarrow \quad \nu > \mu \text{ and } 0 < \gamma < 1.$$

This is the case, because the screening value of a particular trading horizon is directly linked to the quality of information on which the manager trades. If a high ability manager trades on short-term information he is more likely to receive a correct signal than when he trades on long-term information. Since a manager can only be identified as a high type when he happens to

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[21] For ω=1, the variable η_t is irrelevant.

receive a correct signal, the principal is more likely to become aware of a high type manager's identity when she lets him trade on short-term information. Thus, only when short-term information is of higher quality than long-term information can the principal learn more efficiently from letting the manager trade on short-term information.

An interesting implication of our model is that the sensitivity of firing as a reaction to performance is sensitive to the manager's 'age'. A young (newly employed) manager gets fired after performing badly once. If he is retained he will never be fired although he might perform badly in some periods. On an empirical level, this result is supported by Chevalier and Ellison (1999). They find that the probability of a fund manager being fired after bad performance decreases with the manager's age.

Another interesting result concerns the role of the cost of capital in determining the optimality of short-term trading, which is stated in the following corollary.

***Corollary*:** *When prices fully reveal short-term information, the principal wishes to induce trade on short-term information only if the opportunity cost of capital r, is sufficiently low.*

This result contrasts with conventional wisdom (Marsh, 1990) which associates short investment horizons with strong discounting. Long-term investment projects pay off later than short-term projects. When the discount rate increases, a long-term project loses more in net present value than a short-term project, leading to a short-term bias in the choice of investment horizon.

The above corollary shows that exactly the opposite holds in our setting for the special case w=1. From condition (12) in the Theorem we can see that for w=1, the riskless rate of return r must be sufficiently small for short-term trading to be induced. The riskless rate r determines the principal's (opportunity) cost of capital and thus the rate at which future payments are discounted. By inducing short-term rather than long-term trading, the principal incurs an opportunity cost of screening due to foregoing trading profits in the next period. The gain from doing so only accrues in later periods, as the principal learns more efficiently about the ability of the manager employed. Therefore, only if interest rates are sufficiently low, is a principal willing to induce short-term trading. More generally, the effect is not clear cut, as an increase in r does affect the expected discounted trading profits under long-term trading more strongly than those under short-term trading (see equations (6) and (8)). Therefore, in general, an increase in r has an ambiguous effect on the desirability of short-term trading.

The Theorem also shows that trading on short-term information in a risky security may occur, even if it is equally profitable to invest in the riskless asset. This result resembles Dow and Gorton's (1997) finding that portfolio managers may "churn", i.e. trade in a risky security, although this is not more profitable than trading in the riskless security. Our result, however, is different from other churning results (e.g. Allen and Gorton, 1993) in that our model exhibits trade in the risky asset that is always based on the trader's information about asset value.

6. Discussion of the results

(A) *Agents' planning horizons*

In contrast to most of the literature on short-termism, we do not assume that agents have exogenous limited horizons. We model all agents in the economy as having infinitely long horizons, which is important for two reasons. Firstly, our specification is stationary, unlike other models in the literature. E.g. v. Thadden (1995) presents a model in which both, principal and agent have a two period horizon. It is not obvious in such a model that the agent's incentives and the principal's payoff (taking into account the screening value of long-term versus short-term projects) remain unaltered in an infinite horizon model. Secondly, our results are not driven by exogenous short horizons as for example in Dow and Gorton (1994). In contrast to their results, we find that short-termism may obtain when all agents have infinite horizons.

(B) *Short-termism as a transient feature*

In our model short-termism occurs when a principal first employs a manager, but disappears once she has learned that a manager is a high ability type. The probability of employing a manager under short-term trading decreases over time and goes to zero as $t \to \infty$. One could therefore argue that short-term trading occurs only in a very small number of periods compared to the time in which long-term trading occurs. It would be straightforward to get "more" short-term trading by assuming (realistically) that managers had finite lives, or a constant probability of separation from the principal in each period. Then investors would have to start searching for a new manager in regular intervals and short-term trading would occur more often. Such a modelling approach, however, would have introduced an element of limited horizons that, as explained above, we wished to avoid.[22]

[22] An alternative modification might be to let a manager's type be non-constant over time. This approach is followed by Benabou and Laroque (1992) who find that some participants in a financial market do not find out an

(C) *Exogenous liquidity trade*

We present a model in which the source of noise trade is exogenous. Some models using noise traders argue that they are irrational traders who participate in the stock market despite making a loss consistently due to misperceptions concerning asset value (see De Long et al., 1990). Another way of modelling noise trade is to assume that trade originates from rational agents who face a wage shock that is negatively correlated with asset value. For this reason they submit orders for an asset, despite losing money on average. This approach is explored by Spiegel and Subrahmanyam (1992) and used for example in Dow and Gorton (1994, 1997).

In principle, our model allows for the introduction of rational agents that act as liquidity traders because they have a hedging need. This would, however, complicate the analysis somewhat, because the orders submitted by these liquidity traders will typically depend on the reputation of the informed trader, as the latter affects the cost of insurance for the hedger. As a result the model would become analytically less tractable. Nonetheless, we like to think of our model as not essentially driven by the presence of irrational agents.

(D) *Early unwinding of long-term positions*

In order to model unwinding of long-term positions in a simple manner, we assume that noise traders do not unwind their positions. Therefore, a market maker knows that only informed traders unwind their positions and thus does not need to infer from the previous price whether a noise trader or an informed trader is unwinding a position. This simplifies the treatment considerably, because unwinding prices are then unconditional on the price in the previous period. It seems plausible that noise traders hold their positions until the date of liquidation, if their demand for the asset originates from a need to insure wage risk. If wage is correlated with the dividend payment of an asset, it is clearly better to wait until the dividend payment occurs than to unwind the position before this payment occurs.

We moreover assume that unwinding of long-term positions is carried out before new trades in the asset occur. In other papers (e.g. Hirshleifer, Subrahmanyam, and Titman, 1994, and Froot, Scharfstein, and Stein, 1992) unwinding occurs at the same time as new orders for the asset are submitted. This approach is not taken here, because it would imply that a principal could only observe interim performance of a long-term trader, after the next trading round was completed. Thus, firing a manager would impose a cost on the principal as she would have to wait for one period, before a new manager could participate in the stock market. As a result,

informed trader's type even asymptotically, and therefore anomalies due to asymmetric information may persist infinitely.

inducing long-term trading for a manager of unknown ability would become even costlier, which reinforces our result. Since we do not believe that this effect is relevant in the real world, we preferred not to let it affect the results of the model.

In our setting early unwinding of long-term positions is as profitable as keeping a position (long or short) until the liquidation date. Nonetheless, the principal prefers early unwinding of the position, because this supplies her with some information about the manager's ability (for $w>1/2$). Compared to short-term trading, the information contained in short run performance is nonetheless lower (for $\omega<1$). This additional layer of noise under long-term trading is due to the fact that information gets reflected imperfectly in the unwinding price (depending on the parameter ω). In Hirshleifer, Subrahmanyam, and Titman (1994) the unwinding decision by risk averse traders is also affected by the information contained in unwinding prices. In their model traders prefer to unwind a position in an interim period, because the interim price does not yet reflect a public information shock. Hence, in contrast to Hirshleifer et al., in our model early unwinding is preferred, *because* some of the public information is already contained in the unwinding price.

(E) *Incentive compatibility and the trading horizon*

In our setting the choice of assets reveals to the investor on which type of information a manager trades. There is thus no problem of a fund manager taking a hidden action in the choice of information horizon, as in some of the literature on short-termism. In a different setting where random variables do not follow a binary distribution and assets are not distinguished by their liquidation date, the choice of information horizon may no longer be inferrable for the investor. The design of incentive compatible contracts for the choice of information horizon thus becomes an issue.

As shown in v. Thadden (1995) incentive compatibility problems arise when the principal wants to induce the long-term strategy. This is also the case in our setting. To see this, suppose that the principal cannot contract on the trading horizon and is unable to infer from prices which trading horizon was chosen by the manager. If the principal wishes to induce trading on short-term information, she could simply offer a zero wage in every period. Since the manager receives a private benefit from being employed he chooses the trading strategy that maximises the probability of being retained.

Consider the simple case in which short-term prices are perfectly efficient and the manager gets fired after one bad performance. Then the probability of being retained is gm under trading on long-term information, and gn under trading on short-term information. By assumption, $n>m$ and hence the manager prefers to trade on short-term information. Under more complicated employment rules, essentially the same argument applies, so that generally trading on short-term information is incentive compatible, even if it is impossible to contract on the trading horizon.

A problem may arise if the principal wishes to induce long-term trading with an agent whose reputation is lower than one ($q<1$). Even under an appropriate incentive contract it may then not be optimal for the manager to trade on long-term information. This, however, is exactly the case dealt with in v.Thadden who shows that short-termism may result when it is not desired by the principal due to incentive compatibility problems.

(F) *Relation to the literature*

Short-termism is typically seen as undesirable, because of its adverse effect on the efficiency of stock markets and firms' investment decisions. Froot, Scharfstein, and Stein (1992) for example show that short trading horizons may lead to serious mispricing of assets. Vives (1995) finds that informational efficiency of prices may increase or decrease under short trading horizons, depending on whether or not information arrival is concentrated or dispersed over time. Dow and Gorton (1994) argue that arbitrageurs' limited trading horizons may lead to a failure of long-term arbitrage and thus stock prices may not reflect the long run value of an asset. Shleifer and Vishny (1997) point to the failure of long-term arbitrage in the context of delegated portfolio management.[23]

Regarding firms' investment decisions, Shleifer and Vishny (1990) argue that if speculators prefer short-term arbitrage over long-term arbitrage, long-term assets will be more strongly mispriced by the market than short-term assets. This, in turn, may lead firm managers who are averse to mispricing, to underinvest in long-term assets. Similarly, v. Thadden (1995), Stein (1989) and Narayanan (1985) argue that firm managers may boost short-term earnings at the expense of long-term earnings, if short-term performance affects their wage or reputation.

Shleifer and Vishny (1997) focus on incentive problems for portfolio managers and consider the effect of performance sensitive fund flows on the efficiency of stock prices. They argue that performance sensitive fund flows may lead to the failure of delegated arbitrageurs to exploit long-term arbitrage opportunities. When mispricing of an asset might deepen before the arbitrage opportunity pays off, the arbitrageur may be forced to unwind a position when it is least

[23] Despite extensive empirical research, the question whether or not financial markets exhibit significant mispricing, remains unresolved. For an overview of the debate on market efficiency see for example Fama (1991) and Lo (1997).

profitable to do so. In anticipation of this possibility, the arbitrageur may not engage sufficiently in long-term arbitrage, and assets remain mispriced.

In Shleifer and Vishny the interim price risk associated with long-term arbitrage is due to the possibility of an interim worsening of noise traders' misperceptions concerning asset value. Thus, their argument is based on the assumption that short-term prices are inefficient and, in particular, that they may be even more inefficient than the long-term price. Although our model also exhibits the property that more efficient short-term prices make long-term arbitrage more attractive, we find that even with perfectly informative short-term prices, long-term arbitrage opportunities may remain unexploited.

Holden and Subrahmanyam (1996) consider a model where the investment horizon is endogenous (long or short) and traders are risk averse. They argue that long-term arbitrage carries a higher risk, as more public information gets accumulated into the price of the asset. Risk averse agents may thus prefer short-term over long-term arbitrage, reducing the informational efficiency of long-term compared to short-term prices.

7. Conclusion

In this paper we show that incomplete information concerning the ability of a fund manager, may lead to short-term trade by the manager. This is the case, although with complete information it is first-best to trade on long-term information. If the investor does not know the ability of the manager employed, she uses past performance in order to learn about the ability, and possibly to switch funds to another manager if his performance is bad. Our starting point is the observation that often cited short-run performance pressures that may arise in this relationship of delegation, may not be a sufficient explanation for possible short-termism, because even long-term traders can consistently earn profits in the short-run, when they are able to unwind their positions profitably after a short period of time. Instead of focusing on possible incentive problems involved in implementing a particular trading horizon, we explore the effect of different trading horizons of the manager on the efficiency with which the investor can learn about the manager's unknown type.

We show that trading on short-term information allows more efficient learning about the manager's ability for two reasons. (i) A high ability manager can produce more precise information about an event in the near future, compared to the more distant future, which means that bad performance under long-term trading is more likely to be attributable to bad luck rather than low ability. As a result, the performance observations contain less information under long-term trading. (ii) Under long-term trading, information about a manager's ability becomes available later, because the principal can only evaluate the manager once the information on which trade occurred becomes public. This is the case even though the manager can unwind the long-term position profitably after one period. The information content of this immediately available performance observation depends on the informational efficiency of short-term prices: the more informative the prices concerning the short-term, the more informative the immediately available performance observation. We show that, even in the polar case, where short-term prices are perfectly informative, (i) is sufficient to guarantee that short-term trading is preferred by the principal for a non-empty set of parameter values.

APPENDIX A

Proof of Lemma 1:

In general expected trading profits can be calculated from

$E[W_{t+1}|a_t=a_s,\ q_t]$

$= E[(W_t - q_{A,t+1,t}p_{A,t+1,t} - q_{B,t+1,t}p_{B,t+1,t})(1+r) + q_{A,t+1,t}d_{A,t+1} + q_{B,t+1,t}d_{B,t+1}\ |a_t=a_s,\ q_t]$

$= W_t(1+r) + E[q_{A,t+1,t}(d_{A,t+1} - p_{A,t+1,t}(1+r)) + q_{B,t+1,t}(d_{B,t+1} - p_{B,t+1,t}(1+r))\ |a_t=a_s,\ q_t]$,

where $E[p(a_t=a_s,\ q_t)] = E[W_{t+1}|a_t=a_s,\ q_t] - W_t(1+r)$.

When calculating the expected profits from trading on short-term information, we only need to consider one particular realisation of a signal s_t and calculate prices for the possible order flows from that realisation. This is the case, because of the symmetry in possible dividend realisations and resulting trading behaviour. Consider w.l.o.g. the case $s_t=UU$.

When the manager receives the signal UU, he submits a buy order for both assets. Resulting total order flows can therefore be $(Q_{A,t+1,t},\ Q_{B,t+1,t}) \in \{(2n,2n),\ (2n,0),\ (0,2n),\ (0,0)\}$. Each realisation occurs with probability 1/4. When total order flow is $(2n,2n)$ the market maker can infer that the signal must have been UU. The market maker's information is thus the same as the manager's. This means that prices will be set such that the manager makes zero trading profits in expectation.

If total order flow is (0,0), the market maker does not know in which direction the manager traded either asset. In that case straightforward Bayesian updating yields prices

$p_{k,t+1,t}((Q_{A,t+1,t},\ Q_{B,t+1,t}) = (0,0),\ w_{k,t}=1) = w/(1+r)$

$p_{k,t+1,t}((Q_{A,t+1,t},\ Q_{B,t+1,t}) = (0,0),\ w_{k,t}=0) = (1-w)/(1+r)$

Expected trading profits can be calculated as

$E[p(a_s,\ q)|\ (Q_{A,t+1,t},\ Q_{B,t+1,t}) = (0,0),\ s_t=UU]$

$= q\nu\{2-2\omega^2\omega-2\omega(1-\omega)(\omega+1-\omega)-2(1-\omega)^2(1-\omega)\}$

$- 2(1-q\nu)/2*\{1-\omega^2(\omega+1-\omega)-(1-\omega)^2(\omega+1-\omega)-\omega(1-\omega)2\omega - \omega(1-\omega)2(1-\omega)\}$

$= 4q\nu\omega(1-\omega)$.

Now consider the case $(Q_{A,t+1,t},\ Q_{B,t+1,t}) = (2n,0)$. Again prices can be calculated from Bayesian updating, which results in prices for asset A_{t+1} that are independent of $w_{B,t}$ and prices for B_{t+1} are independent of $w_{A,t}$. In particular we find:

$p_{A,t+1,t}((Q_{A,t+1,t}, Q_{B,t+1,t}) = (2n,0), w_{A,t}=1)= \frac{1}{1+r} w \frac{qn + \frac{1-qn}{2}}{qnw + \frac{1-qn}{2}}$

$p_{A,t+1,t}((Q_{A,t+1,t}, Q_{B,t+1,t}) = (2n,0), w_{A,t}=0)= \frac{1}{1+r} (1-w) \frac{qn + \frac{1-qn}{2}}{qn(1-w) + \frac{1-qn}{2}}$

and

$p_{B,t+1,t}((Q_{A,t+1,t}, Q_{B,t+1,t}) = (2n,0), w_{B,t}=1)= \frac{1}{1+r} w$

$p_{B,t+1,t}((Q_{A,t+1,t}, Q_{B,t+1,t}) = (2n,0), w_{B,t}=0)= \frac{1}{1+r} (1-w)$

From this it is straightforward to calculate expected trading profits as

$E[p(a_s, q)| (Q_{A,t+1,t}, Q_{B,t+1,t}) = (2n,0), s_t=UU]=2qnw(1-w).$

By symmetry the case $(Q_{A,t+1,t}, Q_{B,t+1,t}) = (0, 2n)$ yields identical expected trading profits. Hence, we have overall trading profits given by

$$E[p(a_s, q)| s_t=UU]=1/4\{0 + 2qnw(1-w) + 2qnw(1-w) + 4qnw(1-w)\}.$$
$$= 2qnw(1-w).$$

As mentioned above, by symmetry we have $E[p(a_s, q)| s_t]$ is independent of s_t, and hence

$E[p(a_s, q)]=2qnw(1-w).$

q.e.d.

Proof of Lemma 2:

Note that when the market maker sets prices at date t he has no private information concerning the value of the assets A_{t+2} and B_{t+2}. Since asset values are independent and managers are ex ante equally likely to receive a wrong signal concerning either asset, the price for asset A_{t+2} is independent of order flow in asset B_{t+2} and vice versa. Using Bayesian updating, prices can be calculated as

$$p_{k,t+2,t}(Q_{k,t+2,t} = 2, a_l, q_t, w_t) = 1/(1+r)^2\ prob(d_{k,t+2}=1| Q_{k,t+2,t} = 2, a_l, q_t, w_t)$$

$$= 1/(1+r)^2 \frac{prob\left(Q_{k,t+2,t} = 2 \middle| d_{k,t+2} = 1\right) prob\left(d_{k,t+2} = 1\right)}{prob\left(Q_{k,t+2,t} = 2 \middle| d_{k,t+2} = 1\right) prob\left(d_{k,t+2} = 1\right) + prob\left(Q_{k,t+2,t} = 2 \middle| d_{k,t+2} = 0\right) prob\left(d_{k,t+2} = 0\right)}$$

$$= 1/(1+r)^2 \; \frac{\frac{1}{2}\left(q_t\left(m+\frac{1-m}{2}\right)+\frac{1}{2}\left(1-q_t\right)\right)}{\frac{1}{2}\left(q_t\left(m+\frac{1-m}{2}\right)+\frac{1}{2}\left(1-q_t\right)\right)+\frac{1}{2}\left(q_t\,\frac{1-m}{2}+\frac{1}{2}\left(1-q_t\right)\right)} = \frac{1}{\left(1+r\right)^2}\cdot\frac{1+q_t m}{2}$$

Similarly the prices for $Q_{k,t+2,t} = 0$ and $Q_{k,t+2,t} = -2$ can be calculated as

$$p_{k,t+2,t}(Q_{k,t+2,t} = 0, a_l, q_t, w_t) = 1/(1+r)^2 \cdot 1/2$$

and

$$p_{k,t+2,t}(Q_{k,t+2,t} = -2, a_l, q_t, w_t) = \frac{1}{\left(1+r\right)^2}\cdot\frac{1-q_t m}{2}.$$

In order to calculate the expected trading profits of the long-term trading strategy, we need to know the price at which the market maker is willing to unwind the manager's position. This price does not depend on the previous price $p_{k,t+2,t}$, because when the manager unwinds, the market maker knows on which information he traded, since noise traders never unwind their positions prematurely. This renders the market maker's previous belief (reflected in price) about the manager's information irrelevant.

The unwinding price, denoted by $P_{k,t+2}(q_{A,t+2,t}, q_{B,t+2,t}, u_{t+1}, w_{A,t+1}, w_{B,t+1})$, thus depends on the orders $q_{k,t+2,t}$ submitted at date t and the signals $w_{k,t+1}$ received by the market maker. The variable u_{t+1} denotes the manager's reputation at the time of unwinding. The reputation u_{t+1} may be different from q_t and q_{t+1}, because a dividend payment d_{t+1} occurs *after* the order is originally submitted and *before* the principal takes her employment decision e_{t+1}. Since the realisation of d_{t+1} may contain information about the manager's ability, his reputation at the time of unwinding may be different from q_t.

The unwinding prices can be calculated by Bayesian updating:

$$prob(d_{A,t+2}=1|\, Q_{A,t+2,t}, Q_{B,t+2,t}, w_{A,t+1}, w_{B,t+1}, u_{t+1}) ==$$

$$\frac{\sum_{x=0}^{1} prob\left(Q_{A,t+2,t}, Q_{B,t+2,t}, w_{A,t+1}, w_{B,t+1} \middle| u_{t+1}, d_{A,t+2}=1, d_{B,t+2}=x\right) prob\left(d_{A,t+2}=1, d_{B,t+2}=x\right)}{\sum_{y=0}^{1}\sum_{x=0}^{1} prob\left(Q_{A,t+2,t}, Q_{B,t+2,t}, w_{A,t+1}, w_{B,t+1} \middle| u_{t+1}, d_{A,t+2}=y, d_{B,t+2}=x\right) prob\left(d_{A,t+2}=y, d_{B,t+2}=x\right)}$$

.

When calculating expected trading profits under long-term information acquisition, only some of all possible unwinding prices are relevant. Recall the structure of the model: dividend payments are either zero or one with equal probability and noise traders either submit a buy or sell order of equal size and with equal probability. Moreover, all random variables are independent of one another and managers can either buy or short-sell the asset. From this follows that expected trading profits are the same for any realised value of the dividend payments $d_{A,t+2}$ and $d_{B,t+2}$. Hence, in order to calculate expected trading profits it is sufficient to calculate possible asset prices and resulting trading profits for one particular realisation, say $d_{A,t+2} = 1$ and $d_{B,t+2} = 1$.

The expectation of wealth at date t+1 can be written as

$$\begin{aligned} & E_t[W_{t+1}|a_t=a_I,q_t] \\ = \; & E_t\,[(W_t - q_{A,t+2,t}p_{A,t+2,t} - q_{B,t+2,t}p_{B,t+2,t})(1+r) + q_{A,t+2,t}P_{A,t+2,t+1} + q_{A,t+2,t}P_{A,t+2,t+1}|a_t=a_I,q_t] \\ = \; & W_t(1+r) + E_t\,[q_{A,t+2,t}(P_{A,t+2,t+1}-p_{A,t+2,t}(1+r)) + q_{B,t+2,t}(P_{B,t+2,t+1}-p_{B,t+2,t}(1+r))|a_t=a_I,q_t]. \end{aligned}$$

Substituting prices and probabilities given in table 4 and simplifying the resulting term yields:

$$E_t[W_{t+1}|a_t=a_I,q_t] = W_t\left(1+r\right)+\tfrac{1}{2(1+r)}m\left(2E_t u_{t+1}-q_t\right).$$

Note that since u_{t+1} denotes reputation before an employment decision is taken, the expectation of u_{t+1} satisfies $E_t[u_{t+1}]=q_t$. Hence, expected wealth at date t+1 is

$$E_t[W_{t+1}|a_t=a_I,q_t] = W_t\left(1+r\right)+\tfrac{1}{2(1+r)}q_t m .$$

Moreover, it is straightforward to show that discounted trading profits from trade on long-term information, when holding the asset until the date of the dividend payment, are identical to those under early unwinding.

q.e.d.

The following table gives the relevant unwinding prices for the case $d_{A,t+2}$ = 1 and $d_{B,t+2}$ = 1 as a function of $q_{A,t+2,t}$, $q_{B,t+2,t}$, $w_{A,t+1}$, and $w_{B,t+1}$, w.l.o.g. for u_{t+1}=g.

	$q_{A,t+2,t}$	$q_{B,t+2,t}$	$w_{A,t+1}$	$w_{B,t+1}$	$(1+r)P_{A,t+2}$	$(1+r)$ $P_{B,t+2}$[24]	*prob*
(1)	1	1	1	1	$\frac{wgm+(1-w)\frac{1-gm}{2}}{wgm+(1-w)(1-gm)}$	(1)	$\omega^2\gamma\mu$
(2)	1	1	1	0	$w\frac{(1-w)gm+w\frac{1-gm}{2}}{w(1-w)gm+\left(w^2+(1-w)^2\right)\frac{1-gm}{2}}$	(3)	$\omega(1-\omega)\gamma\mu$
(3)	1	1	0	1	$(1-\omega)\frac{wgm+(1-w)\frac{1-gm}{2}}{w(1-w)gm+\left(w^2+(1-w)^2\right)\frac{1-gm}{2}}$	(2)	$\omega(1-\omega)\gamma\mu$
(4)	1	1	0	0	$\frac{(1-w)gm+w\frac{1-gm}{2}}{(1-w)gm+w(1-gm)}$	(4)	$(1-\omega)^2\gamma\mu$
(5)	1	-1	1	1	$\omega\frac{(1-w)gm+w\frac{1-gm}{2}}{w(1-w)gm+\left(w^2+(1-w)^2\right)\frac{1-gm}{2}}$	(9)	$\omega^2\frac{1-gm}{2}$
(6)	1	-1	1	0	$\frac{wgm+(1-w)\frac{1-gm}{2}}{wgm+(1-w)(1-gm)}$	(11)	$\omega(1-\omega)\frac{1-gm}{2}$
(7)	1	-1	0	1	$\frac{(1-w)gm+w\frac{1-gm}{2}}{(1-w)gm+w(1-gm)}$	(10)	$\omega(1-\omega)\frac{1-gm}{2}$
(8)	1	-1	0	0	$(1-\omega)\frac{wgm+(1-w)\frac{1-gm}{2}}{w(1-w)gm+\left(w^2+(1-w)^2\right)\frac{1-gm}{2}}$	(12)	$(1-\omega)^2\frac{1-gm}{2}$
(9)	-1	1	1	1	$\frac{w^2\frac{1-gm}{2}}{w(1-w)gm+\left(w^2+(1-w)^2\right)\frac{1-gm}{2}}$	(5)	$\omega^2\frac{1-gm}{2}$
(10)	-1	1	1	0	$\frac{w\frac{1-gm}{2}}{(1-w)gm+w(1-gm)}$	(7)	$\omega(1-\omega)\frac{1-gm}{2}$
(11)	-1	1	0	1	$\frac{(1-w)\frac{1-gm}{2}}{wgm+(1-w)(1-gm)}$	(6)	$\omega(1-\omega)\frac{1-gm}{2}$
(12)	-1	1	0	0	$(1-\omega)\frac{(1-w)\frac{1-gm}{2}}{w(1-w)gm+\left(w^2+(1-w)^2\right)\frac{1-gm}{2}}$	(8)	$(1-\omega)^2\frac{1-gm}{2}$

Table 4: Gives all possible combinations of $q_{A,t+2,t}$, $q_{B,t+2,t}$, $w_{A,t+1}$, $w_{B,t+1}$, and the associated prices. The unwinding price for asset B_{t+2} is given by the price for asset A_{t+2} in the row specified by the entry in the column for $P_{B,t+2}$. The probability for a particular realisation of $q_{A,t+2,t}$, $q_{B,t+2,t}$, $w_{A,t+1}$, $w_{B,t+1}$ is given in the last column. The probabilities are conditional on dividends $d_{A,t+2}$=1, $d_{A,t+2}$=1.

[24] By symmetry, the price for asset B_{t+2} is the same as the price for asset A_{t+2} in the corresponding row number.

Proof of Proposition 1: For q=1 a manager's reputation never changes and hence it is optimal to induce the same strategy in every period. The expected discounted wealth from trading on long-term information can be calculated as (w.l.o.g. we consider optimisation at date t=0)

$$EW_\infty(a_l) = W_0 + E\left[\sum_{t=1}^{\infty} \frac{1}{(1+r)^t} p_t(a_{t-1} = a_l, q_{t-1} = 1)\right] = W_0 + \frac{m}{2r(1+r)} \qquad (15)$$

Similarly the expected discounted wealth under short-term trading is given by

$$EW_\infty(a_s) = W_0 + E\left[\sum_{t=1}^{\infty} \frac{1}{(1+r)^t} p_t(a_{t-1} = a_s, q_{t-1} = 1)\right] = W_0 + \frac{2n}{r} w(1-w) \qquad (16)$$

Setting $EW_\infty(a_l) > EW_\infty(a_s)$ yields the inequality (9).
From this it is also obvious that (10) is a necessary condition for $\nu>\mu>\mu^*$.

q.e.d.

Proof of Proposition 2:

Firstly, we show that $W_l^*(\omega, \eta, u)$ is non-decreasing in ω. In order to do so, we prove that the signal received by the principal from observing unwinding prices for some value of $\omega=\omega_1>1/2$ is sufficient for the same signal with smaller $\omega=\omega_2<\omega_1$. This allows us to apply Blackwell's Theorem (see Crémer, 1982) to the principal's decision problem.

The states of the world that affect the principal's expected payoff in a given period are whether or not the manager employed is a high type. The principal receives information about this state of the world from observing whether the manager traded both assets in the correct direction, or whether he traded one asset in the correct and the other in the wrong direction. Once this is known the principal updates her belief concerning the probability that a manager is a high type. At this stage the belief update is independent of $w_{A,t}$, $w_{B,t}$. However, $w_{A,t}$, $w_{B,t}$, which are inferred by the principal from unwinding prices, are informative for whether or not the manager traded both assets in the correct direction. Call x_1 the state of the world in which a manager traded both assets in the correct direction, and x_2 the state in which a manager traded one asset correctly and the other incorrectly. Moreover, define by $\mathbf{w_1}=(w_{A,t}, w_{B,t})$ the market maker's signal when $\omega=\omega_1>1/2$, and similarly $\mathbf{w_2} = (w_{A,t}, w_{B,t})$ when $\omega=\omega_2<\omega_1$.

We will now show that $\mathbf{w_1}$ is sufficient for $\mathbf{w_2}$ with the states of the world being x_1 and x_2. Without loss of generality, suppose that the manager traded quantities $q_{A,t+1,t-1}=1$ and $q_{B,t+1,t-1}=1$, i.e. he received the signal $l_{t-1}=UU$. The conditional probabilities $prob(\mathbf{w_i}|x_1)$ and $prob(\mathbf{w_i}|x_2)$ are then given by

$$prob(\mathbf{w_i}|x_1) = \begin{cases} w_i^2 & \text{for} \quad \mathbf{w_i} = (1,1) \\ w_i(1-w_i) & \text{for} \quad \mathbf{w_i} = (1,0) \\ w_i(1-w_i) & \text{for} \quad \mathbf{w_i} = (0,1) \\ (1-w_i)^2 & \text{for} \quad \mathbf{w_i} = (0,0) \end{cases} \tag{17}$$

and

$$prob(\mathbf{w_i}|x_2) = \begin{cases} w_i(1-w_i) & \text{for} \quad \mathbf{w_i} = (1,1) \\ \frac{1}{2}\left(w_i^2 + (1-w_i)^2\right) & \text{for} \quad \mathbf{w_i} = (1,0) \\ \frac{1}{2}\left(w_i^2 + (1-w_i)^2\right) & \text{for} \quad \mathbf{w_i} = (0,1) \\ w_i(1-w_i) & \text{for} \quad \mathbf{w_i} = (0,0) \end{cases} \tag{18}$$

By the definition of sufficiency (see Crémer, 1982), $\mathbf{w_1}$ is sufficient for $\mathbf{w_2}$, if there exist positive real numbers $prob(\mathbf{w_2}|\mathbf{w_1})>0$ such that

$$\sum_{\mathbf{w_2}} prob(\mathbf{w_2}|\mathbf{w_1}) = 1 \text{ for all } \mathbf{w_1},$$

$$prob(\mathbf{w_2}|x_i) = \sum_{\mathbf{w_1}} prob(\mathbf{w_2}|\mathbf{w_1})\, prob(\mathbf{w_1}|x_i) \tag{19}$$

for i=1,2, and $prob(\mathbf{w_2}|\mathbf{w_1})>0$ for all $\mathbf{w_2}$, $\mathbf{w_1}$.

Construct numbers $prob(\mathbf{w_2}|\mathbf{w_1})$ as given in the following table:

$\mathbf{w_2}$ \ $\mathbf{w_1}$	(1,1)	(1,0)	(0,1)	(0,0)
(1,1)	b^2	$b(1-b)$	$b(1-b)$	$(1-b)^2$
(1,0)	$b(1-b)$	b^2	$(1-b)^2$	$b(1-b)$
(0,1)	$b(1-b)$	$(1-b)^2$	b^2	$b(1-b)$
(0,0)	$(1-b)^2$	$b(1-b)$	$b(1-b)$	b^2

Table 5: Shows the positive real numbers $prob(\mathbf{w_2}|\mathbf{w_1})$ for all $\mathbf{w_2}$,$\mathbf{w_1}$.

For $\beta\in(0,1)$, all numbers in the above table are positive, and satisfy $\sum_{\mathbf{w}_2} prob(\mathbf{w_2}|\mathbf{w_1}) = 1$. It is then straightforward to check that (19) is satisfied for x_1 and x_2, and all $\mathbf{w_2}$. Consider for example the case x_1, and w_2=(1,1). From (17) and table 5 we can write (19) as

$$\omega_2^2 = \beta^2\omega_1^2 + 2\beta(1-\beta)\omega_1(1-\omega_1) + (1-\beta)^2(1-\omega_1)^2$$

which can be written as

$$\beta = \frac{w_1 + w_2 - 1}{2w_1 - 1}$$

For $\omega_1>\omega_2\geq 1/2$ we get $\beta\in(0,1)$. The other cases can be worked out analoguously.

We can now apply Blackwell's Theorem to the principal's decision problem. Blackwell's Theorem states that an agent cannot be made worse off by basing his decision on a signal that is sufficient for another signal. Since the manager has no choice variables available, we are in a situation of a pure decision problem from the principal's point of view. Thus, Blackwell's Theorem applies and it follows that $W_l^*(\omega, \eta, u)$ is non-decreasing in ω.

We now prove that when $0<g<1 \Rightarrow W_l^*(\omega=1,\eta=0,g) > W_l^*(\omega=1/2,\eta=0,g)$. Note that for u=1, the expected payoff $W_l^*(*)$ is independent of ω and η and given by equation (15).[25] In order to show that the payoff to the principal is strictly increasing at some point $\omega^*\in[1/2,1]$, we show that for ω=1 the payoff is strictly greater than for ω=1/2. For w=1, we can write

$$W_l^*(\omega=1,\eta=0,g) = \frac{1}{1+r}\left[Ep(a_l,g) + gmW_l^*(1,1,1) + (1-gm)W_l^*(1,0,g)\right] \quad (20)$$

Solving (20) for $W_l^*(\omega=1,\eta=0,g)$ yields

$$W_l^*(\omega=1,\eta=0,g) = \frac{\frac{gm}{2(1+r)} + gmW_l^*(1,1,1)}{r+gm} \quad (21)$$

Now consider the payoff for w=1/2. For ω=1/2 a newly employed manager who trades on long-term information at date t will have an unchanged reputation at t+1 since no information concerning his ability becomes available (the unwinding prices are uninformative if ω=1/2). This means that the manager should not be fired after the first period. Therefore, $W_l^*(\omega=1/2,\eta=0,g)$ must satisfy

$W_l^*(1/2,0,g)$ =

$$\tfrac{1}{1+r}\left\{Ep(a_l,g)+\tfrac{1}{1+r}\left[Ep(a_l,g)+gmW_l^*\left(\tfrac{1}{2},h_{t+2}=1,u_{t+2}=1\right)+(1-gm)W_l^*\left(\tfrac{1}{2},h_{t+2}=1,u_{t+2}=\tfrac{(1-m)g}{1-mg}\right)\right]\right\}$$

(22)

Moreover, it is clear that $W_l^*(1,1,\gamma) \geq W_l^*\left(\tfrac{1}{2},h_{t+2}=1,u_{t+2}=\tfrac{(1-m)g}{1-mg}\right)$.

Replace $W_l^*\left(\tfrac{1}{2},h_{t+2}=1,u_{t+2}=\tfrac{(1-m)g}{1-mg}\right)$ in (22) by $W_l^*(1,1,\gamma)$, known from (21). Then set

$$W_l^*(1,1,\gamma) > \tfrac{1}{1+r}\left\{Ep(a_l,g)+\tfrac{1}{1+r}\left[Ep(a_l,g)+gmW_l^*\left(\tfrac{1}{2},h_{t+2}=1,u_{t+2}=1\right)+(1-gm)W_l^*(1,1,g)\right]\right\}.$$

(23)

After a few steps of calculations one finds that (23) is satisfied $\Leftrightarrow$ $1>\gamma>0$.

q.e.d.

APPENDIX B

Proof of Theorem: The structure of the proof is as follows. First, we show that the condition in (12) indeed is sufficient to make short-term trading optimal for the principal. Then we show that there exist parameter values r, g, m, n such that for all $w>1/2$, the sufficient condition is satisfied and the parameters belong to the set $F(w)$ (Part (i) of the Theorem). Then we show that the set of parameter values $S(w)$ is decreasing in w (Part (ii) of Theorem).

Proof of Part (i)

Let $V(h, u)$ denote the highest possible expected discounted profit from employing a manager who trades in the risky asset. We know from Proposition 1 that when $m>m^*$, in the first-best case (u=1) long-term trading is induced and (15) gives the formula for the expected discounted wealth in that case. Moreover, it is clear that when u=1 the value function does not depend on h_t, because the principal *knows* the manager's type and learning ceases to be an issue. Hence,

$$V(1,1)=V(0,1) = \frac{m}{2r(1+r)} \qquad (24)$$

Moreover denote by $V_s(h, u)$ the payoff when a_s is chosen in the next period and the optimal decision taken ever thereafter. Similarly, define $V_l(h, u)$ as the payoff when a_l is chosen. Thus, the value function can be written as

[25] We neglect W_0 for $W_l^*(*)$, as it is irrelevant for the optimal decision.

$V(h, u)= \max\{V_s(h, u), V_l(h, u)\}$. (25)

First, suppose it is optimal to choose trade on short-term information for a manager of reputation u_t. The distribution of next period reputation u_{t+1} is given by $h(0,a_s,q_t)$:

$$u_{t+1} = \begin{cases} 1 & \text{with} \quad q_t n \\ \dfrac{(1-n)q_t}{1-q_t n} & \text{with} \quad 1\text{-}\, q_t n \end{cases} \tag{26}$$

We can write

$$V_s(0,u_t) = \tfrac{1}{1+r} \max_{e_t}\left[2q_t(e_t)nw(1-w) + q_t(e_t)nV(0,1) + (1-q_t(e_t)n)V\left(0, \tfrac{(1-n)q_t(e_t)}{1-nq_t(e_t)}\right)\right] \tag{27}$$

If u_t=γ, it is better to fire the manager after one bad performance than to retain him. This is the case, because a manager from the pool has a higher reputation and firing the old manager and hiring a new manager is costless. Hence, if a_s is indeed optimal at $u_t=g$, we can write $V\left(0, \tfrac{(1-n)g}{1-ng}\right) = V_s(0, g)$. Substituting this into (27), we can solve for $V_s(0,g)$.

$$V_s(0,g) = \frac{2gnw(1-w) + gnV(0,1)}{r + gn} \tag{28}$$

Now suppose it is optimal to induce trade on long-term information for a newly employed manager. To start with, consider the case where w=1 and the distribution of u_{t+1} is given by (13). As was shown in the proof of Proposition 2 the variable η_t does not matter in the value function, when ω=1, as learning about the manager is independent of how many times a particular manager traded on long-term information. Therefore, when ω=1, there is no implicit cost of firing a manager and hiring a new one. Hence, a manager optimally gets fired after one period if performance is bad. The reputation of a manager employed can therefore only ever take one of two values: either q=1, if the manager traded both assets in the correct direction, or $q=g$, if trade in one asset was in the wrong direction and a new manager gets employed. Moreover, if at $u_t=g$, it is indeed optimal to induce trade on long-term information, it will be optimal to do so, for any u_t in the future, since $u_t \in \{g, 1\}$. Hence, for ω=1, $W_l^*(w=1,h, u=g)=V_l(h, u=g)$.

Suppose now that the principal is able to observe whether or not the choice of trades by a long-term manager was correct after one period, even when $w<1$. This corresponds to giving the principal a signal concerning whether or not the manager traded both assets in the correct direction, that is sufficient for the signal received when w<1.[26] By Blackwell's Theorem, this makes the payoff from inducing trade on long-term information at least as high as the payoff from the actual timing of performance observation prevalent in the model. Thus, W_l^* (w=1, h, q=γ) constitutes an upper bound for the payoff that can be achieved by inducing trade on long-term information with a newly employed manager and following an optimal employment policy. Therefore,

$$W_l^* (\omega=1, \eta=0, g) \geq V_l(h=0, g). \tag{29}$$

From (21), we know that $W_l^*(w=1, \eta=0, g) = \dfrac{\frac{gm}{2(1+r)} + gmW_l^*(1,1,1)}{r+gm}$.

Moreover, at u=1, obviously, $W_l^*(w, h, u=1) = V(h,1) \Leftrightarrow m>m^*$.

Substituting this into (21) allows us to rewrite (29) as

$$V_l(0,g) \leq \frac{\frac{gm}{2(1+r)} + gmV(1,1)}{r+gm} \tag{30}$$

Comparing (28) and (30) yields

$$V_s(0, g) > \frac{\frac{gm}{2(1+r)} + gmV(1,1)}{r+gm}$$

$$\Leftrightarrow \quad rgV(1,1)\,(n-m) > gr\left(\frac{m}{2(1+r)} - 2nw(1-w)\right) + g^2mn\left(\frac{1}{2(1+r)} - 2w(1-w)\right). \tag{31}$$

Substituting (24) into (31) and rearranging the resulting inequality yields the inequality in (12). Moreover, setting m, n, r, w such that $m=m^* + e$, with e>0, we get

$$\frac{n-m}{r+gn} > \frac{e}{m^*(1-g) + e} \tag{32}$$

For m^*>0, the RHS of (32) tends to zero as $e \to 0$, and hence for any n>m an e > 0 can be found such that (32) is satisfied. If m^*=0, the RHS of (30) is equal to 1. Again, parameters can be found such that (32) is satisfied. An example is r=0.01, g=0.5, m=0.29, n=0.62. Note that in the case

[26] See the proof of Proposition 2 for an elaboration on this point.

where $\mu^*=0$, any set of parameters that satisfies (32) implies $\gamma\mu<1/4$. This means that if a manager were to choose between following his signal and trading at random, he would be better off trading at random. In that case, however, the principal would certainly not have an incentive to induce trade on long-term information, as trades woud be uninformative about the type. Hence, by assuming that the manager always follows his signal, we make the payoff from inducing trade on long-term information higher, than it would otherwise be. Thus, the actual set of parameter values for which trade on short-term information is induced by the principal, is larger than the one given by *S*(*w*), which reinforces our result.

Proof of Part (ii)

In order to prove statement (ii) of the Theorem, we show that the principal's payoff is decreasing in *w* when short-term trading is optimal and that it is non-decreasing in *w* when long-term trading is optimal.

Suppose that at (h_t=0, $q_t=\gamma$), $a_t=a_s$ is optimal. From (28) it can be seen that the parameter ω only enters $V_s(0,\gamma)$ through the instantaneous payoff. It is then straightforward to show that for $w \in (1/2, 1]$, $\frac{¶V_s(0,g)}{¶w} < 0$. Only for *w*=1/2, we get $\frac{¶V_s(0,g)}{¶w} = 0$.

Hence, if a_s is optimal at (h_t=0, $q_t=\gamma$), the payoff $V_s(0,\gamma)$ is strictly decreasing in ω>1/2.

Now suppose that at (h_t=0, $q_t=\gamma$), $a_t=a_l$ is optimal. For trading under long-term information, the efficiency of short-term prices does not affect the instantaneous profit (see equation (8)). Instead *w* only affects the belief update of the principal. In particular, an increase in *w* leads to more efficient learning about the manager, because the price $P_{k,t+2}$ is more informative about the true state of the world ($d_{k,t+2}$) and thus about whether or not the manager received a correct signal. Since the principal uses this information optimally, the expected payoff $V_l(0, g)$ must be non-decreasing in *w*.

Remember that the set *S*(*w*) is defined by the set of parameter values *r*, *m*, *n*, *g* for which $V_s(0, g) > V_l(0, g)$. Therefore, if for a given vector $x = (r\ \mu\ \nu\ \gamma)$ short-term trading is induced at *w'* it will also be induced at *w''*<*w'*. On the other hand, there always is a vector $x = (r\ \mu\ \nu\ \gamma)$ that lies sufficiently close to the boundary of *S*(*w''*), that it will not lie in *S*(*w'*) for all *w'*>*w''*. Hence, *S(w') Ì S(w'') for w'>w''.*

q.e.d.

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