Nickels versus Black Swans: Reputation, Trading Strategies and Asset Prices[1]

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Abstract

This paper analyzes a model of fund managers' reputation concerns. It explains why "Nickel strategies" (strategies that earn small positive returns most of the time but occasionally lead to dramatic losses) are more popular among managers than the opposite "Black Swan strategies," (strategies that generate small losses most of the time but occasionally lead to large profits). A novel insight from the model is the fragile nature of the equilibrium with reputation concerns: The interaction between managers' reputation concern and investors' perception of managers' strategy choices may lead to multiple self-fulfilling equilibria. When the economy is in one equilibrium, managers have no incentive to change their strategies unless investors change their perceptions, and vice versa. This coordination problem implies slow-moving capital and may leave profitable opportunities unexploited for an extended period of time. Once the coordination problem is broken, however, the economy switches to the other equilibrium, leading to drastic capital relocation and price movements in the absence of news on fundamentals. This model sheds light on a number of stylized facts documented in the literature and also provides some new testable implications.

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1 Introduction

Many popular hedge fund strategies have been compared to "picking up nickels in front of a steamroller" because they appear to earn small positive returns most of the time but occasionally lead to dramatic losses. For expositional convenience, we refer to them as *Nickel strategies*. One example is the currency carry trade, where speculators borrow currencies with low interest rates to purchase currencies with high interest rates. As two recent articles in *Economist* noted, "this produces a positive return most months, but the risk is that the high-rate currency will devalue, resulting in a heavy loss."[1] This carry trade strategy has been so popular that "no comment on the financial markets these days is complete without mention of the 'carry trade'." However, the opposite strategy of betting against the carry "looks a far less attractive business proposition. Such a strategy would lose money most months, only to make big gains when devaluation...occurred. That kind of return would look very 'risky'..." Despite being much less popular, this strategy is not without its supporters. Nassim Taleb, a former fund manager and popular book writer, argues in a recent book that people tend to underestimate the probability of rare events (e.g., finding a black swan) and so strategies betting on their occurrence are attractive.[2] We refer to those strategies as *Swan strategies*.

Why are Nickel strategies more popular than Swan strategies? What kind of managers might be interested in Swan strategies? How does the popularity of strategies evolve? What are the consequences of these choices made by fund managers? We try to address these questions in a model of managers' reputation concerns.

The main idea is that when a manager's ability is unobservable, he may be fired if his reputation falls below a certain level, and this concern naturally influences his strategy choice. We capture this idea in a simple one-period model of reputation concern: An investor does not have access to investment opportunities but can delegate his capital to a manager, who can choose to invest in a Nickel strategy or a Swan strategy. After the investment return is realized, the investor updates his belief about the manager's ability based on the performance. We assume the investor is sophisticated enough to find out which strategy was implemented and rationally update his belief. The manager is rewarded based on his performance according to an exogenous compensation contract. The key ingredients of our model are that the manager will be fired once his reputation (i.e., perceived ability) falls below a certain

[1] *Instant Returns*, October 7 2006; *Carry on Speculating*, February 22nd 2007. More formally, Brunnermeier, Nagel and Pedersen (2008) document that the return distributions for carry trade strategies are negatively skewed, Plantin and Shin (2008) provide a model in which the equilibrium exchange rate dynamics lead to a negatively skewed return distribution for carry trades.

[2] *The Black Swan: The Impact of the Highly Improbable*, Random House, 2007.

threshold and that being fired is costly to a manager.[3] Naturally, the manager has the incentive to adjust his strategy choice in response to this reputation concern. Our model is focused on the investor's perception formation, the manager's responses, and more importantly, the interaction between the two. Despite its simple structure, the model delivers a rich set of implications, which fall into the following two categories.

First, the model shows that, because of reputation concerns, managers may prefer Nickel strategies over Swan strategies, even when Nickel strategies offer lower expected returns. Intuitively, if a manager chooses a Swan strategy, then he is likely to incur some losses before earning the large but infrequent profits. Since reputation suffers following losses, he faces the risk of being fired before the profits arrive. To the extent that the manager is concerned about this risk, he may choose to forgo the Swan strategy even if it offers a higher expected return. This concern has a stronger impact on managers with modest reputations, who may be fired after a few losses, than on those with very high reputations. One consequence is that, holding managers' ability constant, the managers with less reputation concern would outperform. Therefore, even persistent differences in returns over time are not necessarily reliable indicators of differences in managers' ability. They may simply reflect the differences in their reputation concerns.

It is important to note that our result has an important difference from the casual argument in the previously quoted *Economist* article, which hints that Swan strategies are not attractive to managers because they "look very risky" to investors who do not understand the nature of Swan strategies. This casual argument implies that when a profitable Swan strategy arises, managers should be able to exploit it by raising capital from sophisticated investors who understand that they should expect a series of losses before big gains. Our model, however, focuses on sophisticated investors only and hence sends a stronger message: When their reputation is at stake, fund managers may have a hard time exploiting Swan strategies even if they can raise capital from sophisticated investors who understand the nature of the strategy. This is because, upon seeing a loss, sophisticated investors still downgrade their perception of the manager's ability, although to a lesser extent relative to naïve investors who do not understand the strategy. So, the reputation concern is alleviated but cannot be completely eliminated and introducing naïve investors into our model would make our result even stronger.

While a systematic empirical examination of this implication is beyond the scope of this paper, some anecdotes during the recent subprime crisis are suggestive: Despite repeated warnings of the housing

[3]For example, Brown, Goetzmann and Park (2001) find that a series of lackluster returns tend to lead to the termination of a hedge fund manager and that once a manager is fired, it is hard for him to restart his career as a manager.

bubble before 2007,[4] consistent with our model, most market participants did not find fighting the housing bubble appealing. In fact, many institutions took the other side of the trade, suffering losses of over 400 billion dollars collectively.[5] Fighting the housing bubble is similar to a Swan strategy: Suppose someone was convinced that the subprime crisis was emerging in 2005. He could buy credit default swaps (CDS) on assets backed by subprime mortgages. This is a Swan strategy since one would expect to incur repeated losses (i.e., pay the premium for the CDS) for a long period of time before the housing bubble bursts. This strategy is therefore more attractive to investors with less reputation concern. Indeed, a casual look at the *ex post* high profile winners in this crisis suggests this might be the case: They either implemented the strategy using their personal wealth or made an extra effort to convince their investors.[6] Similarly, Brunnermeier and Nagel (2004) document that during the technology bubble in late 1990s, many hedge funds did not find fighting the bubble appealing and, instead, were heavily invested in technology stocks. Interestingly, they also document a case in which Tiger Fund, a well known hedge fund, refused to follow the trend to buy into the technology bubble, but suffered heavy capital redemption and eventual liquidation.

Second, a novel insight from our model is the fragile nature of the equilibrium with reputation concerns: The interaction between investors' perceptions and managers' reputation concerns may lead to multiple self-fulfilling equilibria. Suppose investors believe a strategy is unpopular among talented managers. Then investors are "intolerant" of poor returns in that strategy, i.e., upon seeing poor performance in that strategy, investors believe that the manager is unlikely to be talented, since they believe most of the talented managers will have avoided this strategy in the first place. As a result, talented managers avoid that strategy and investors' perception is supported in equilibrium. Similarly, suppose investors believe that a strategy is popular among talented managers. This strategy then becomes more attractive since investors will be more "tolerant" of poor performance from it. Talented managers then prefer this strategy and, again, investors' perception is supported in equilibrium.

When the economy is in an equilibrium, the manager has no incentive to change his strategy unless the investor changes his perception, while the investor has no incentive to change his perception unless the manager changes his strategy. This coordination problem leads to slow-moving capital and may leave profitable opportunities unexploited for an extended period of time. Once the coordination problem is

[4]See, e.g., *The Bubble's New Home*, Barron's, June 20, 2005, *Be Warned: Mr Bubble's Worried Again*, New York Times, August 21, 2005.

[5]*How High Will Subprime Losses Go?*, Wall Street Journal, December 27, 2007.

[6]For examples of investing with personal wealth, see *Tiger's Julian Robertson roars again*, CNNMoney.com, January 29 2008; *In Beverly Hills, A Meltdown Mogul Is Living Large*, Wall Street Journal, January 15, 2008. For the case of a hedge fund dealing with its investors' pressure while betting on the crash of the housing bubble, see *Trader Made Billions on Subprime*, Wall Street Journal, January 15, 2008.

broken, however, the economy may switch to the other equilibrium, leading to drastic capital relocation and price movements in the absence of news on fundamentals. These results fit well with the empirical evidence documented in Mitchell, Pedersen and Pulvino (2007): Before the end of 2004, convertible bond arbitrage funds were quite popular and collectively managed around $40 billion of assets. After a series of disappointing returns, however, this strategy quickly ran out of fashion in 2005 and the total assets under management fell by half. Interestingly, the authors also note that the typical convertible bond arbitrage strategy appeared to be *more* profitable in 2005 and this seemingly profitable opportunity appeared to last well into 2006 (the end of their sample). This extensive delay for capital to move back is puzzling. In the light of our model, however, this is a natural phenomenon: It points to the possibility that the economy had switched to the other equilibrium, in which investors were "intolerant" to convertible bond arbitrage strategies, making fund managers wary about investing in this strategy.

Our model also provides a number of empirically testable implications. In the context of the convertible bond arbitrage case, our analysis suggests that, all else being equal, poor performance from convertible bond arbitrage funds should lead to larger outflows during 2005 and 2006 (when investors were intolerant) than comparably poor performance before 2004 when investors were tolerant. More generally, our model implies that after a large amount of capital fleeing away from a strategy, the expected return of this strategy tends to become higher for an extended period of time, during which poor performance in this strategy tends to generate larger-than-usual capital outflows.

There is a growing literature that focuses on the impact of managers' reputation concerns. Allen and Gorton (1993) and Dow and Gorton (1997) show that reputation concerns can lead managers to engage in churning. More recently, Dasgupta and Prat (2006, 2007) and Dasgupta, Prat and Verardo (2007) study the impact of reputation concerns on information aggregation and asset prices. Like these studies, our paper also focuses on the impact of managers' reputation concerns on portfolio choices and asset prices. However, to the best of our knowledge, our paper is the first to demonstrate the fragile nature of the equilibrium with reputation concerns. The ensuing multiple equilibria highlight potential profound impacts of reputations on capital relocations and asset prices.[7]

Our paper is also closely related to Stein (2005). Both papers analyze the impact of manager reputation concerns to emphasize the "dark side" of competition. Stein (2005) focuses on fund managers' organizational choice and highlights that competition may lead funds to inefficiently adopt an open-

[7]More broadly, our paper is also related to the literature on delegated asset management on portfolio choices (e.g., Carpenter (2000), Ross (2004), Basak, Shapiro and Tepla (2006), Basak, Pavlova and Shapiro (2007)) and on equilibrium prices (e.g., Cuoco and Kaniel (2001), Vayanos (2004), He and Krishnamurthy (2007)). These studies, however, abstract away from modeling managers' reputation concerns.

ended structure. Our paper focuses on fund managers' strategy choices and shows that reputation concerns may force managers to under-invest in Swan strategies but over-invest in Nickel strategies. Moreover, our model demonstrates that reputation concerns can influence the popularity of trading strategies. Relative to Scharfstein and Stein (1990), this offers a new explanation for herding behavior and a new interpretation for the "sharing the blame" argument. Managers in our model prefer popular strategies because their common choice creates a positive externality for one another. In contrast, in the standard herding mechanism, other market participants' actions induce managers to neglect their private information (see, e.g., Bikhchandani, Hirshleifer, and Welch (1998) for a recent review).

Our paper contributes to the literature on limits to arbitrage (Dow and Gorton (1994), Shleifer and Vishny (1997)). We show that, because of reputation concerns, arbitrage forces are less effective when the Swan strategy is involved (e.g., fighting the housing bubble). On the other hand, the Nickel strategy might attract too much capital and this can become a destabilizing market force (e.g., carry trade). Moreover, these effects do not rely on investors' naïvete. This is important because otherwise, arbitrageurs can get around this reputation concern by resorting to sophisticated investors for capital when attractive opportunities arise. Our model shows that even if all investors are Bayesian and understand the strategies well, reputation concerns can still induce managers to over-invest in some strategies but under-invest in others.

Finally, our paper also complements the literature on the fragility induced by multiple equilibria. This insight was first analyzed by Diamond and Dybvig (1983), who show that self-fulfilling bank runs can arise in equilibrium. Building on this insight, a large literature on financial fragility developed in the last decade around the idea that, due to market incompleteness and inelastic supply and demand of liquidity in the short-run, forced asset sales can have a large impact on many aspects of financial markets (see Allen and Gale (2007) for an overview). More recently, Basak and Makarov (2008) show that multiplicity over investment strategies can occur when managers try to beat the performance of their competitors to win greater inflows, and Aghion and Stein (2008) show that the dual preferences among shareholders for firm growth and sales margins can lead to multiple equilibria, increasing the variance of corporate investment and output. The contribution of our paper is to point out the fragile nature of the equilibrium with reputation concerns, an insight that has not been studied in the literature.

The rest of the paper is organized as follows. Section 2 discusses some motivating facts. Section 3 presents the baseline model and the main results. Extensions of the baseline model involving the price impact of manager trades are discussed in Section 4, and Section 5 concludes. All proofs are provided in the Appendix.

2 Motivating facts

As noted in the Introduction, anecdotal evidence suggests that among hedge funds, Nickel strategies enjoy substantial popularity and Swan strategies are relatively unpopular. In this section, we try to provide systematic evidence for this claim, using hedge fund index return data. One indication of whether a fund is choosing Nickel strategies is the skewness of its returns. By definition, with frequent small gains and rare large losses, Nickel strategies will produce a pattern of negatively skewed returns over time. On the other hand, Swan strategies will produce positively skewed returns over time.

We collect the monthly returns of the constituent indices of the Credit Suisse/Tremont Hedge Fund index, beginning with the inception of the index in January 1994 until April 2008. The index consists of approximately nine hundred member funds, each with a minimum of $50m in assets under management and at least a one-year track record, who voluntarily report monthly return information. There are ten style-based constituent indices; member funds are assigned to a particular style based on self-reported information. Style index returns are an asset-weighted combination of individual fund returns. Because some constituent indices did not report returns until April of the first year, we drop the first three months of data for our calculations. This leaves 169 monthly return observations. The construction methodology for the index rules out the backfill bias and minimizes survivorship bias.[8]

Table 1 summarizes the primary findings. The evidence suggests that Nickel strategies are very popular among hedge fund managers: four out of the ten style indices, representing more than 40% of the assets of Hedge Fund Index member funds, are negatively skewed at the five percent level. It is particularly interesting to note that the "multi-strategy" index is negatively skewed, suggesting that when a fund does not restrict its strategy choice, managers tend to select Nickel strategies. On the other hand, Swan strategies appear much less popular. Only one index, "Dedicated short bias", representing only 0.6% of hedge fund assets, is significantly positively skewed.[9]

Note that because these calculations are performed using indices rather than individual fund returns, there is a strong bias *against* finding significance: If strategy returns were independent across the individual component funds, then by the law of large numbers, the aggregate of these returns would display little or no skewness. This suggests two things. First, it is likely that the realized skewness in an individual fund's return is even larger than that presented in the table. Second, it is likely

[8] See *Credit Suisse/Tremont Hedge Fund Index Rules*, available at `http://www.hedgeindex.com`.

[9] The skewness of certain trading strategies has been noticed in the literature. For example, Mitchell and Pulvino (2001) find that returns to merger arbitrage are similar to those from selling put options, and Duarte, Longstaff, and Yu (2007) show some fixed income arbitrage strategies can produce positively skewed returns.

Table 1: The Skewness of Hedge Fund Indices

Credit Suisse/Tremont Hedge Fund Index	Sector Weight	Skewness
Convertible Arbitrage	1.90%	−1.59 (0.33)
Fixed Income Arb.	4.70%	−3.35 (0.75)
Multi-Strategy	10.40%	−1.06 (0.30)
Event Driven	24.40%	−3.27 (1.42)
Emerging Markets	8.50%	−0.79 (0.72)
Global Macro	13.80%	0.05 (0.51)
Managed Futures	4.00%	0.02 (0.18)
Long/Short Equity	26.40%	0.19 (0.62)
Equity Market Neutral	5.30%	0.34 (0.20)
Dedicated Short Bias	0.60%	0.83 (0.38)

Numbers in parentheses are bootstrap standard errors, calculated with 10,000 draws.

that the pattern in the data would not exist unless individual fund returns were highly correlated with one another. This suggests that the funds choosing Nickel strategies are also following similar implementations of these strategies.

3 Model

We first present the baseline model in Section 3.1 and analyze it in Sections 3.2–3.4. A number of generalizations are considered in Section 3.5.

3.1 The Baseline Model

Consider a one-period economy, $t = 0, 1$. There is a continuum of investors, which is normalized to 1. At $t = 0$, each investor is endowed with one manager and decides whether to delegate \$W to the manager to invest. A manager may be either a "good" type g, or a "bad" type b, and the type is only observable to the manager himself. A manager's *reputation* ρ_t is defined as investors' perceived likelihood at time t that the manager is type g. We assume all managers have the same initial reputation ρ_0 at $t = 0$.

Both types of managers, but not the investors, have access to two trading strategies, whose returns will be realized at $t = 1$. In this section, the returns are exogenously given and are assumed to have a binary distribution.[10] Within each strategy, type g managers can generate higher returns than type b ones. More specifically, if a type g manager invests in the first strategy, Nickel strategy N, he obtains a return r_n at $t = 1$:

$$r_n = \begin{cases} r_n^+ & \text{with a probability } p_n, \\ r_n^- & \text{otherwise.} \end{cases} \tag{1}$$

If a type g manager invests in the second strategy, Swan strategy S, he gets a return r_s at $t = 1$:

$$r_s = \begin{cases} r_s^+ & \text{with a probability } p_s, \\ r_s^- & \text{otherwise.} \end{cases} \tag{2}$$

We assume $r_n^- \ll r_s^- < r_n^+ \ll r_s^+$ and that p_n is close to 1 and p_s is close to 0. That is, the first strategy is similar to carry trade or merger arbitrage, which tend to generate frequent small gains (r_n^+) or otherwise suffer rare large losses (r_n^-): a payoff profile often likened to "picking up nickels in front of a steamroller". On the contrary, the second strategy is a bet on a small probability event (the appearance of a "Black Swan") and it leads to small losses (r_s^-) most of the time but generates large profits (r_s^+) when the small probability event occurs. One vivid example of a Swan strategy is hedge fund Paulson & Co.'s recent bet against the housing bubble in 2006 and 2007. By holding credit default swaps (CDS) on assets backed by subprime mortgages, Paulson incurred losses (paying the premium on the CDS) every month until house prices collapsed, at which point they reportedly made a 600% return.[11] Type b managers generate lower returns because they have lower probabilities to achieve the high returns for both strategies, r_n^+ and r_s^+. For simplicity, we assume type b managers have 0 probability to obtain r_n^+ or r_s^+. We show later in Section 3.5 that this simplifying assumption is not crucial for our main results below. Finally, for expressional convenience, we say that a manager *fails* a strategy if he gets the low return from the strategy (r_s^- or r_n^-), and that a manager *succeeds* in a strategy if he gets the high return (r_s^+ or r_n^+).

After getting the capital \$W from his investor at $t = 0$, the manager chooses whether to invest the capital into the Nickel strategy or the Swan strategy. That is, we assume that the manager cannot borrow or lend, and must focus on one strategy to reflect the fact that the manager may need to set up the infrastructure for trading in the strategy and can only keep personnel specialized in one strategy. Moreover, our timing choice (capital delegation before strategy choice) shuts down the standard signalling mechanism where in order to attract capital, good managers choose a strategy *ex ante*, at a cost, to signal that they have a high ability. While this signalling mechanism is important in some economic environments, we believe that, by shutting it down, our modeling choice captures some important

[10] In Section 4, we endogenize asset prices to study the price impact induced by managers' trading strategies.
[11] *Trader Made Billions on Subprime*, Wall Street Journal, January 15, 2008

aspects of the hedge fund industry, where managers take extra efforts to hide their trading strategies.[12]

The compensation contract is taken as given in our model: At $t = 1$, the strategy return r is realized and the manager gets a fraction ϕ of the profit or loss, Wr. Based on the realized return, the investor rationally updates the manager's reputation $\rho_1 \equiv \Pr(g|r)$. Note that from the realized return r, the investor can infer the strategy chosen by his manager. That is, we essentially assume that the investor is sophisticated and informed enough to figure out the manager's strategy after checking the manager's book *ex post*. This assumption reflects the sophistication of typical big hedge fund investors—endowments, pension funds, or funds of funds. As will become clear, relaxing this assumption by introducing less sophisticated investors is likely to *amplify* the impacts in our model. Moreover, we assume that the manager shares a constant fraction of the profit or loss. This assumption perfectly aligns the interests of the manager and the investor, so we can isolate and focus on the impact from reputation concerns only. We will also show in the Appendix that modifying this assumption to incorporate the popular option-like compensation structure does not affect our main results.

To simplify the investors' decision problem, we assume that all investors have the same outside option, such that investors would keep a manager whenever the manager's reputation is not lower than $\underline{\rho}$, with $\underline{\rho} < \rho_0$. This implies that investors find it optimal to delegate their capital to their managers at $t = 0$. At $t = 1$, however, an investor would keep his manager if $\rho_1 \geq \underline{\rho}$ and fire the manager otherwise.

To capture the idea that being fired is costly to the manager, we model it here in a reduced form: We assume that if a manager is kept at $t = 1$, he gets an extra "bonus" V and so his total compensation is $\phi Wr + V$. If the manager is fired at $t = 1$, however, he will not get this bonus and so his total compensation is ϕWr. The bonus V is meant to capture the present value of the manager's loss of income over the rest of his career when he is fired. This formulation helps to make the analysis transparent. We also endogenize V in a two-period model but omit this generalization since it leads to the same insights as those in the baseline model.

We simplify calculations by assuming that any manager will be fired for sure, no matter what his prior reputation is, if he fails the Nickel strategy, i.e., suffers the dramatic loss r_n^-. As will be shown later, one of the main themes in our analysis concerns the popularity of the Nickel strategy. The assumption that a manager will always be fired on r_n^- makes the Nickel strategy less appealing. The possibility that

[12]See Stein (2005) for a model where mutual fund managers choose the inefficient open-end structure to signal they are talented managers. This mutual fund organizational structure certainly can be a credible and important signal. Hedge fund managers, however, are considered to be generally reluctant to disclose their trading strategy *ex ante*, making the trading strategy much less credible and effective as a signal. See Lowenstein (2000) for detailed stories on LTCM's reluctance in disclosing their strategies to their investors.

the manager might be kept even after posting a huge loss r_n^- would make the Nickel strategy all the more popular and so reinforce our results.

Managers are risk neutral and so a manager's objective is to choose a strategy ($a \in (N, S)$) to maximize his expected overall payoff

$$\max_{a \in (N,S)} E\left[\phi W r + \Pr(\text{kept}) \times V\right], \tag{3}$$

where $\phi W r$ is the compensation at $t = 1$, and $\Pr(\text{kept})$ is the probability for the manager to be kept, in which case the manager also gets the bonus V. For notational clarity, without loss of generality, we normalize $\phi W \equiv 1$. The tendency for a risk neutral agent to take an infinite position is curbed by our earlier assumption that the manager cannot borrow or lend and has to focus on one strategy. This modeling choice is similar to that in Abreu and Brunnermeier (2002), who point out that limits to positions can be attributed to, among other things, wealth constraints, asymmetric information and risk aversion. Finally, we make the following technical assumption: For any $x \in \{p_s, 0, 1\}$,

$$p_s r_s^+ + (1 - p_s) r_s^- + xV \neq p_n r_n^+ + (1 - p_n) r_n^- + p_n V. \tag{4}$$

Intuitively, this assumption rules out the zero-measure special cases in which a type g manager finds both strategies equally attractive and so doesn't have a preference.

3.2 Investors' belief

Investors are assumed to be rational, so they follow Bayes' rule to update their managers' reputations. Suppose a manager with reputation ρ_0 fails the Swan strategy. An investor will update the manager's reputation to

$$\rho_1 = \Pr(g | r_s^-) = \frac{\Pr(r_s^- | g) * \rho_0}{\Pr(r_s^- | g) * \rho_0 + \Pr(r_s^- | b) * (1 - \rho_0)}, \tag{5}$$

where $\Pr(r_s^- | g)$ is investors' perceived probability for a type g manager to generate a return r_s^-, i.e., the type g manager chooses the Swan strategy *and* fails; $\Pr(r_s^- | b)$ is the perceived probability for a type b manager to generate a return r_s^-, i.e., the type b manager chooses the Swan strategy *and* fails. Note that $\Pr(r_s^- | b) = 1$, i.e., type b managers always prefer the Swan strategy and also always fail. This is due to the assumptions that (1) type b managers always fail their strategies and (2) that the Swan strategy offers type b managers a relatively higher return ($r_s^- > r_n^-$) and the possibility to keep their jobs (recall that a manager is always fired on r_n^-).

Moreover, $\Pr(r_s^- | g)$, the perceived probability for a type g manager to get the outcome r_s^-, can be written as

$$\Pr(r_s^- | g) = (1 - p_s) \times I_S, \tag{6}$$

where I_S is investors' perceived likelihood for a type g manager to choose the Swan strategy in the first place. An alternative interpretation of I_S is based on the frequentist view of probability: I_S refers to the fraction of type g managers choosing the Swan strategy. Hereafter, we will use these two interpretations interchangeably.

Equation (6) reveals that investors' perception I_S plays a key role in their belief updating: the probability for a type g manager to fail a Swan strategy is determined not only by the probability of failure *if* a type g manager chooses the Swan strategy, but also by investors' perceived likelihood for a type g manager to choose the Swan strategy in the first place. Equations (5)-(6) naturally lead to the following result.

Lemma 1 *If a manager fails the Swan strategy, his reputation cost* $\rho_0 - \rho_1$ *decreases in* I_S*, i.e.,* $\frac{\partial(\rho_0-\rho_1)}{\partial I_S} < 0$.

This lemma shows how investors' perception affects the manager's reputation: If investors believe that the Swan strategy is unpopular among type g managers (i.e., I_S is low), then they would be "intolerant" to failures from the Swan strategy, i.e., the reputation cost $\rho_0 - \rho_1$ would be large. The intuition is simple: Suppose I_S is very close to 0, that is, investors believe that type g managers are very unlikely to choose the Swan strategy. Upon seeing a loss r_s^-, investors view this as a strong signal that the manager is type b, since a type g manager most likely would have avoided the Swan strategy in the first place. Similarly, if investors believe that the Swan strategy is popular among type g managers (i.e., I_S is high), they would be "tolerant" to the failure from the Swan strategy, i.e., the reputation cost $\rho_0 - \rho_1$ would be small.

3.3 Multiplicity

The above shows that investors' perception plays a crucial role in their belief formation. However, investors' perception is not without discipline: it has to be supported in the equilibrium. That is, I_S is an *endogenous* variable: Suppose investors believe a fraction I_S of the type g managers choose the Swan strategy. For this to be an equilibrium, the belief has to be sustained, i.e., a fraction I_S of type g managers should actually make this choice.

Knowing that investors' perception I_S has a significant impact on their reputation, managers would respond to it in their strategy choices. This interaction between investors' perception and managers' choices opens up the possibility of multiple self-sustaining equilibria: Suppose I_S is low, that is, investors believe the Swan strategy is unpopular among type g managers. A type g manager then has a strong incentive to avoid the Swan strategy even if it offers a higher expected return, since a failure from the Swan strategy, which happens with a very high probability $1 - p_s$, would bring him a large reputation penalty. As a result, the Swan strategy is unpopular among type g managers and investors' perception is sustained. On the other hand, suppose investors believe that I_S is high. This makes the Swan strategy more attractive to the managers and, as a result, many type g managers may indeed choose the Swan strategy and so sustain the belief that I_S is high.

Lemma 2 *Only $I_S = 0$ and $I_S = 1$ can be sustained in equilibrium.*

Suppose $0 < I_S < 1$. For a type g manager with a reputation ρ_0, there is a knife-edge case in which the manager finds the two strategies indifferent. This case is ruled out by assumption (4). For all other cases, however, type g managers would either all prefer one strategy or the other. This does not support any perception that I_S is between 0 and 1. Note that this result arises also because of the assumption that strategy returns are not affected by managers' choices. We show, in Section 4, that once we incorporate managers' price impact, an I_S between 0 and 1 can also be sustained in equilibrium.

3.4 Equilibrium with reputation concerns

For expositional convenience, we introduce the following notations:

$$\underline{r} \equiv \frac{p_n r_n^+ + (1-p_n)r_n^- - (1-p_s)r_s^- + (p_n - 1)V}{p_s}, \tag{7}$$

$$\overline{r} \equiv \frac{p_n r_n^+ + (1-p_n)r_n^- - (1-p_s)r_s^- + (p_n - p_s)V}{p_s}, \tag{8}$$

$$\rho^* \equiv \frac{\underline{\rho}}{1 - p_s(1-\underline{\rho})}. \tag{9}$$

Note that ρ^* is a key parameter of investors' firing decision when they believe all type g managers choose the Swan strategy (i.e., $I_S = 1$): If $\rho_0 \geq \rho^*$, the manager's initial reputation is high enough that even if he fails the Swan strategy, his updated reputation ρ_1 is still higher than $\underline{\rho}$, and he will not be fired. If $\rho_0 < \rho^*$, however, the manager will be fired if he fails the Swan strategy. Note also that r^* and $\overline{r}$ are the break even points for managers: If $r_s^+ = \underline{r}$, a manager finds the Swan strategy and the Nickel strategy equally attractive if he can be assured that he will not be fired upon a failure in the Swan strategy. If $r_s^+ = \overline{r}$, however, the Swan strategy offers such a high expected return that a manager finds it as attractive as the Nickel strategy even if he will certainly be fired upon a failure in the Swan strategy.

Definition 1 The *equilibrium* is defined by the pair (I_S, a), investors' perception I_S and managers' action a, such that given the perception I_S, managers find their action a solves (3), and given the managers' action a, investors' perception I_S is supported.

Proposition 1 *For the economy defined above, the equilibrium can be characterized by the following four cases.*

1. *If $r_s^+ < \underline{r}$, there is a unique equilibrium with $I_S = 0$ and $a = N$;*

2. *If $r_s^+ > \overline{r}$, there is a unique equilibrium with $I_S = 1$ and $a = S$;*

3. *If $\underline{r} < r_s^+ < \overline{r}$ and $\rho_0 < \rho^*$, there is a unique equilibrium with $I_S = 0$ and $a = N$;*

4. *If $\underline{r} < r_s^+ < \overline{r}$ and $\rho_0 \geq \rho^*$, there are two equilibria: In one equilibrium, $I_S = 0$ and $a = N$, while in the other equilibrium, $I_S = 1$ and $a = S$.*

Proposition 1 can be visualized in Figure 1. The four cases describe how the resulting equilibrium changes as a function of the manager's reputation and of the attractiveness of the Swan strategy. In case 1, the Swan strategy offers such a low return that a manager would not choose it even if he were assured that he would not be fired upon a failure. Knowing this, investors correctly expect that $I_S = 0$. In case 2, however, the Swan strategy offers such a high return that a manager would choose it even if he would certainly be fired once he fails. Understanding this, investors correctly expect $I_S = 1$.

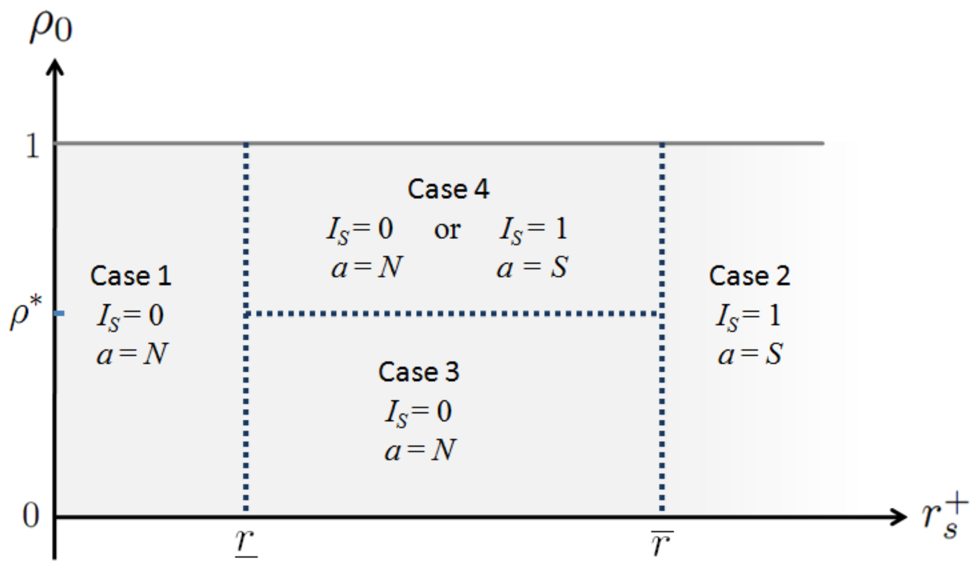

Figure 1: Equilibrium perceptions and strategy choices.

The reputation concern plays a more important role in cases 3 and 4, where the Swan strategy offers a higher expected return than the Nickel strategy, though not high enough to dominate the cost of being fired. Case 3 explains why the Nickel strategy is popular: when the manager's reputation is modest, he knows that his job is not secure and one failure in the Swan strategy is enough to cost him his job. As a result, the manager would choose to forgo the more profitable Swan strategy since it is associated with a high probability of failure $1 - p_s$. Anticipating this, investors correctly expect that no type g manager would choose the Swan strategy, i.e., $I_S = 0$.

In case 4, the impact of reputation concern is more subtle and its interaction with investors' perception leads to multiple equilibria. Suppose investors believe that the Swan strategy is very popular among type g managers, i.e., I_S is high, then, as noted in Lemma 1, a failure in the Swan strategy only leads to a small reputation loss. Since the managers in case 4 have a high initial reputation ($\rho_0 \geq \rho^*$), they will not be fired after a small downgrade in reputation. As a result, type g managers would be happy to invest in the more profitable Swan strategy, which supports investors' perception that I_S is high. On the other hand, if investors believe that the Swan strategy is unpopular among type g managers (i.e., I_S is low), a failure in the Swan strategy would lead to a large downgrade in reputation and cost the manager his job. Hence, type g managers will avoid the Swan strategy, which again sustains investors' perception. Proposition 1 leads to a number of implications as follows.

3.4.1 Reputation and performance

This proposition shows that reputation concerns can make the Nickel strategy popular among managers even if it offers a lower expected return. This naturally implies that reputation concerns can have a significant impact on a manager's performance. When a Swan opportunity arises, the managers with more reputation concerns – higher career value V or lower reputation ρ_0 – are more reluctant to exploit it. As a result, holding managers' skill constant, the ones with fewer reputation constraints would outperform. Even persistent differences in returns over time are not necessarily reliable indicators of differences in managers' ability. They may simply reflect the differences in reputation concerns. This result complements the insight in Berk and Green (2004) that performance might not be a good measure of ability because high ability managers attract more assets and, due to decreasing returns to scale, do not necessarily deliver better performance.

This result also suggests that the overall return from the hedge fund industry is likely to be less impressive going forward. After the explosive growth of the hedge fund industry in the last few decades,[13] it is likely that more and more managers with mediocre reputation (ρ_0 being close to $\underline{\rho}$) joined the industry. Due to their less convincing track records, these managers are more likely to forgo more

[13] For example, Fung and Hsieh (2006) document at least a ten-fold increase in assets under management, and a four-fold increase in number of funds, over the decade 1994–2004.

profitable opportunities to avoid risking their career. This naturally leads to less impressive performance.

3.4.2 Slow-moving capital and fads in hedge fund strategies

A number of implications arise from the multiple self-fulfilling equilibria. First, there are times when some strategies are excessively popular and others are unfashionable. Moreover, capital appears to be slow-moving from one strategy to another, leaving seemingly profitable opportunities unexploited. Once investors' perception begins to shift, however, it can lead to quick relocation in capital and have large impacts on the markets, even in the absence of fundamental news.

As noted earlier, multiple self-fulfilling equilibria are caused by the interaction between investors' perceptions and managers' choices. Once an equilibrium is established, neither the manager nor the investor has the incentive to unilaterally change his action. Suppose we are in a Nickel equilibrium. Even if the Swan strategy becomes more profitable (i.e., r_s^+ increases) a manager may still be unwilling to switch to the Swan strategy due to the risk of being fired. On the other hand, an investor doesn't have any incentive to unilaterally change his belief either (i.e., keep his manager after a failure r_s^-) since only type b managers choose the Swan strategy in this equilibrium. This coordination problem between managers and investors may make a strategy remain popular for an extended period of time. Capital would appear to be slow-moving and profitable opportunities may not be able to attract capital right away.

Once the coordination problem is broken, however, the economy may quickly shift to the other equilibrium and the previously popular strategy hence suddenly goes out of fashion, replaced by a new one. One mechanism that can break the coordination problem is the attractiveness of alternative strategies. For example, if the Swan strategy now becomes sufficiently attractive (i.e., $r_s^+ > \overline{r}$) managers would be willing to choose the Swan strategy despite the risk of being fired. This will shift investors' perception and quickly bring the economy to the other equilibrium. Another possibility is that a series of dramatic losses in one strategy might be able to coordinate investors and managers so that the equilibrium would shift to the other strategy.

One example is the rise and fall of the convertible arbitrage strategy. According to the estimates in Mitchell, Pedersen and Pulvino (2007), convertible bond arbitrage funds had around $40 billion in assets under management in the 4th quarter of 2004. After a series of disappointing returns, however, this strategy quickly ran out of fashion in 2005 and the total assets under management fell by half. Interestingly, they also noted that the typical convertible arbitrage strategy appeared to be *more* profitable in 2005 and this seemingly profitable opportunity appeared to remain present through September 2006 (the end of their sample period). While it is hard to understand the extended shortfall of capital in this strategy based on standard market frictions, our model offers a natural explanation. It is possible that the poor performance in 2004 served to coordinate investors and managers, moving the economy into the equilibrium in which investors were "intolerant" to convertible bond arbitrage strategies and making fund managers wary about investing in this strategy. One empirically testable implication is that, all else being equal, poor performance from convertible bond arbitrage funds during intolerant times (2005 and 2006) should lead to larger outflows than comparably poor performance in the more tolerant times before 2004. Another example is the convergence trading strategy. When LTCM was enjoying its early success, convergence trading became very popular. This strategy, however, quickly lost its appeal after the LTCM crisis and the capital devoted to this strategy is estimated to have fallen by 90% (see, e.g., MacKenzie (2005)). As in the case of convertible bond arbitrage, one testable implication is that, all else being equal, poor performance from convergence trading strategies should lead to larger capital outflows after the LTCM crisis than comparably poor performance before the crisis.

3.5 Discussions on the model

3.5.1 Lock-up

The previous analysis takes the compensation contract as given. However, one might imagine that a properly designed contract might be able to eliminate the impact of managers' reputation concerns. For example, a longer lock-up period would allow the manager to have several chances to try the Swan strategy before investors could withdraw capital. This is essentially equivalent to making the strategy less like a bet on a small probability event. As a result, lock-up can mitigate the distortion caused by reputation concerns and the manager would be more willing to take the Swan strategy as long as it offers a higher expected return.[14] However, lock-ups may not be completely effective in solving the problems induced by reputation concerns because, as analyzed in Stein (2005), managers may have the incentive to signal their ability by voluntarily choosing a contract with a short or no lock-up.

3.5.2 Communication between the investor and his manager

The model illustrates that multiple equilibria arise due to the coordination problem between the manager and the investor. It is, however, silent on which equilibrium should arise. One can imagine that communication between the investor and the manager can break the multiplicity and select the equilibrium. Depending on the parameter values, the investor may prefer one of the equilibria. If we interpret

[14] A parallel argument concerns the "tenure clock" in academia. It is often argued that a longer "tenure clock" would encourage junior faculty to take on more ambitious, but risky, research projects.

the investor in our model literally as one individual, then it is possible that he can credibly communicate with the manager to make sure that his preferred equilibrium is obtained. For example, if the investor prefers the equilibrium with $I_S = 1$, he can commit not to fire the manager if he fails the Swan strategy, i.e., offer the manager a contract with a lock-up. If the investor prefers the equilibrium with $I_S = 0$, however, he can offer the manager a contract that fires the manager if he fails the Swan strategy.

While this is a feasible mechanism to select equilibrium, it also has its limitations. For example, it would be less effective if we interpret the investor as a large number of individuals. When each individual has a small fraction of the fund, he cannot credibly communicate with the manager: Even if the investor personally commits that he will not withdraw his capital when the manager fails the Swan strategy, he cannot guarantee that other investors will do the same. We then have the same coordination problem and so obtain the same results as before.

3.5.3 Relaxing simplifying assumptions

In the baseline model, we make a simplifying assumption that type b managers always get the low return no matter which strategy they choose. Two natural concerns about this assumption merit further examination. First, this assumption implies that type b managers always strictly prefer the Swan strategy since it offers a relatively higher return and the possibility of not being fired. This gives type g managers an incentive to choose the Nickel strategy to separate from type b managers. One might suspect that the popularity of the Nickel strategy in the baseline model is driven by this signalling motive induced by our simplifying assumption. The second concern regards the robustness of the intuition for the multiplicity of equilibria: Suppose investors believe that I_S is high. As pointed out early, this makes the Swan strategy more attractive and, as a result, many type g managers may indeed choose the Swan strategy and so sustain the belief that I_S is high. However, a high I_S also makes the Swan strategy more attractive to type b managers. If type b managers also switch to the Swan strategy, it would make the strategy *less* appealing and hence type g managers may choose to avoid the Swan strategy. In the baseline model, this force is not at work because type b managers prefer Swan regardless of I_S, but one might suspect that this may invalidate the intuition in a more general model.

We address these concerns here by showing that removing this simplifying assumption does not appreciably change the results. Suppose we modify the baseline model so that type b managers can now obtain the high Nickel strategy return r_n^+ with a positive probability $p'_n < p_n$, and obtain the high Swan strategy return r_s^+ with a positive probability $p'_s < p_s$. To isolate and address the first concern, we also assume that

$$p'_n r_n^+ + (1 - p'_n) r_n^- = p'_s r_s^+ + (1 - p'_s) r_s^- . \tag{10}$$

That is, type b managers earn identical expected returns from either the Nickel or the Swan strategies. This assumption implies that, in equilibrium, type b managers always copy type g managers to minimize the probability of being fired. This makes it impossible for type g managers to separate themselves out and so shuts down the signalling mechanism in the first concern.

Note that a manager's posterior reputation is now affected not only by the investors' perception I_S, the fraction of the type g managers that choose the Swan strategy, but also by the perception I'_S, the fraction of the type b managers that choose the Swan strategy. The perceived probability for a type b manager to fail the Swan strategy, $\Pr(r_s^-|b)$, is given by

$$\Pr(r_s^-|b) = (1 - p'_s) \times I'_S, \tag{11}$$

When a manager fails the Swan strategy, the reputation cost $\rho_0 - \rho_1$ is affected by both I_S and I'_S. Parallel to Lemma 1, we now have $\frac{\partial(\rho_0 - \rho_1)}{\partial I_S} < 0$ and $\frac{\partial(\rho_0 - \rho_1)}{\partial I'_S} > 0$. If investors believe that the Swan strategy is unpopular among type g managers (i.e., I_S is low), then they would be "intolerant" to the failure, leading to a large reputation penalty, $\rho_0 - \rho_1$. On the other hand, if investors believe that the Swan strategy is unpopular among type b managers (i.e., I'_S is low), then they would be "tolerant" to the failure from the Swan strategy, leading to a small reputation penalty $(\rho_0 - \rho_1)$. Also similar to Lemma 2, only $I_S = I'_S = 0$ and $I_S = I'_S = 1$ can be sustained in equilibrium.

Definition 2 The *equilibrium* for the economy in this subsection is defined by (I_S, I'_S, a, a'), investors' perceptions I_S, I'_S, type g managers' action a and type b managers' action a', such that given the perceptions I_S and I'_S, managers find their action a or a' solves (3), and given the managers' action a and a', investors' perceptions I_S and I'_S are supported.

Proposition 2 *For the economy defined in this subsection, the equilibrium can be characterized by the following four cases.*

1. *If $r_s^+ < \underline{r}$, there is a unique equilibrium with $I_S = I'_S = 0$ and $a = a' = N$;*

2. *If $r_s^+ > \overline{r}$, there is a unique equilibrium with $I_S = I'_S = 1$ and $a = a' = S$;*

3. *If $\underline{r} < r_s^+ < \overline{r}$ and $\rho_0 < \rho^*$, there is a unique equilibrium with $I_S = I'_S = 0$ and $a = a' = N$;*

4. *If $\underline{r} < r_s^+ < \overline{r}$ and $\rho_0 \geq \rho^*$, there are two equilibria: In one equilibrium, $I_S = I'_S = 0$ and $a = a' = N$, while in the other equilibrium, $I_S = I'_S = 1$ and $a = a' = S$.*

This proposition shows that type g managers have the same strategy as in Proposition 1 and type b managers always mimic type g ones. It thus addresses the two concerns raised at the beginning of this subsection. The popularity of the Nickel strategy is driven by the fact that it offers managers a higher probability of success and thus protects their reputation, not entirely by a desire to play a separating strategy. In addition, the fact that type b managers can easily mimic type g managers does not invalidate the intuition that the interaction between investors' perception and managers' reputation leads to multiple self-fulfilling equilibria.

Note that the assumption in (10) simplifies type b managers' choice: since the two strategies offer the same expected return, type b managers always want to mimic type g managers as long as reputation has a positive value. This assumption can be relaxed: as long as the difference between the expected returns of the two strategies is not too large relative to the reputation value V, the equilibrium will remain the same as summarized in Proposition 2. Only in the relatively less interesting case where the reputation value is dominated by the difference in the expected returns of the two strategies, would separating equilibria emerge: Intuitively, if a type b manager can achieve a higher expected return by deviating from type g managers' strategy, he faces the tradeoff between the higher expected return and revealing his type. Type b managers would only be happy to reveal their type if the reputation value is small relative to the higher expected return. Finally, the assumption that a manager will always be fired if he obtains a return r_n^- can also be removed. In fact, removing this assumption complicates the algebra but only leads to minor changes in Proposition 2.[15]

3.5.4 Further discussions on robustness

As one of the main results in this paper, the fragile nature of the equilibrium with reputation concerns is likely to be a general and robust phenomenon. Suppose investors believe that a certain strategy is popular among talented managers. As noted earlier, investors would be tolerant to failures in this strategy. This leads to a self-fulfilling equilibrium in which this strategy is popular among talented managers as long as tolerance attracts more talented managers than untalented managers to this strategy. This condition is satisfied in Section 3.1 since the untalented managers' strategy does not respond to investors' tolerance. Moreover, this condition also holds in the extended model in Section 3.5.3, where both talented and untalented managers' strategies respond to investors' tolerance.

The above intuition suggests that the multiple equilibria result is likely to hold generally as long as investors' tolerance is "more attractive" to talented managers than to untalented managers. For

[15]The results are omitted for brevity and are available upon request.

example, let's now step out of our model and consider the case where managers are not perfectly "moveable", i.e., they don't have complete freedom in choosing their strategies. One can expect the main results in our earlier models to go through if talented managers are more movable; that is, when sensing that investors are tolerant about a certain strategy, talented managers are more likely to be able to implement this strategy. For example, talented manages are more likely to be able to recruit necessary personnel to set up a fund to exploit the strategy. Another, perhaps simpler, interpretation is the following. Suppose there are a small number of untalented managers whose strategies are randomly assigned. All other managers (both talented and untalented) can freely choose their strategies. It is easy to see that this situation is equivalent to assuming talented managers are more movable and that, based on the earlier intuition, multiple equilibria arise.

Finally, note that the intuition for the multiple equilibria result is independent of the distribution of strategy returns, and hence the fragility of the equilibrium with reputation concerns is a general phenomenon and is not restricted to economies with Nickel and Swan strategies.

4 Price impact

4.1 Economic set-up

The baseline model abstracts away from fund managers' impact on market prices, since the strategy returns are exogenously given. In practice, however, it appears that when a large volume of hedge fund capital flows into or out of a given strategy, it would put pressure on the underlying asset prices. For example, Mitchell, Pedersen and Pulvino (2007) show that the expected return from a typical convertible bond arbitrage strategy appears to have increased when many convertible bond arbitrage funds withdrew their capital in 2005. This section generalizes the baseline model to incorporate these price impacts.

We assume there is a continuum of managers, which is normalized to 1. There are α_g type g managers and α_b type b managers, with $\alpha_g + \alpha_b = 1$. All managers have the same initial reputation $\rho_0 = \alpha_g$. In contrast to the baseline model, managers' choices now affect the strategy returns. Motivated by the evidence in Mitchell, Pedersen and Pulvino (2007), we assume that the expected return of a strategy decreases when more managers implement the strategy. In particular, to simplify the analysis, we assume the gross return of the Nickel strategy, $\tilde{R}_n$, is given by

$$\tilde{R}_n = R_n(1 - k_n X_n), \qquad \text{with } 0 \leq k_n \leq 1, \tag{12}$$

where $R_n = r_n + 1$ for r_n given by (1), k_n is a constant, and X_n is the number of managers implementing this strategy. That is, R_n is the gross return of the Nickel strategy without the impact of the managers and the specification (12) implies that the "post-impact" return of the strategy decreases when it is chosen by more managers. This captures the notion that when managers implement their strategies, prices move against them (i.e., prices increase when managers need to buy but decrease when they need to sell) and this lowers the strategy's profitability. The parameter k_n measures the strength of this impact; $k_n = 0$ implies that managers have no price impact and so includes the baseline model as a special case. We can interpret k_n as a measure of the liquidity of the markets on which the Nickel strategy is implemented. The higher the k_n, the more illiquid the underlying markets are. Similarly, we assume the gross return of the Swan strategy, $\tilde{R}_s$, is given by

$$\tilde{R}_s = R_s(1 - k_s X_s), \quad \text{with } 0 \leq k_s \leq 1, \tag{13}$$

with $R_s = r_s + 1$, r_s given by (2), k_s a constant representing the liquidity in the underlying markets, and X_s the number of managers choosing the Swan strategy.

Parallel to the assumption in Section 3.1, we assume that

$$R_n^- \ll R_s^-(1 - k_s) < R_n^+ \ll R_s^+(1 - k_s), \tag{14}$$

i.e., these two strategies offer returns representing the distributions of a Nickel strategy and a Swan strategy. The rest of the economy is unchanged from the baseline model of Section 3.1. In particular, we assume that the distributions of r_n and r_s are given by (1) and (2) for type g managers, and that type b managers always fail their strategies. Hence, as in the argument in Section 3.1, type b managers always prefer the Swan strategy in the equilibrium, since under (14), the Swan strategy offers a relatively higher return and the chance of not being fired. Let's use f_n to denote the fraction of type g managers who choose the Nickel strategy and $f_s = 1 - f_n$ the fraction who choose the Swan strategy. We then have $X_n = f_n \alpha_g$ and $X_s = f_s \alpha_g + \alpha_b$. The equilibrium is similarly defined as follows

Definition 3 The *equilibrium* for the economy in this section is defined by $(I_S, \tilde{R}_n, \tilde{R}_s, f_s)$, so that given the perception I_S and the returns $(\tilde{R}_n, \tilde{R}_s)$, a fraction f_s of type g managers choose the Swan strategy while $1 - f_s$ type g managers choose the Nickel strategy, and that, given the managers' choices f_s, investors' perception I_S and the returns $\tilde{R}_n, \tilde{R}_s$ are supported, i.e., $I_S = f_s$ and $\tilde{R}_n$, $\tilde{R}_s$ are given by (12) and (13).

To construct the equilibrium, it is helpful to decompose the problem into two simpler ones. First, the investors' problem is to form their perception of the managers' strategy choice and, based on this perception, update their managers' reputation and fire their managers at $t = 1$ only if the reputation falls below $\underline{\rho}$. Second, the managers' problem is to take investors' perception and strategy returns as given to maximize their expected financial compensation and reputation value at $t = 1$. These two problems are intertwined: Investors' perception of the managers' choices I_S can only be maintained in equilibrium if it is consistent with the managers' actual choices f_s, which simultaneously affect the equilibrium returns $\tilde{R}_n, \tilde{R}_s$. At the same time, these equilibrium returns are the bases on which the investors form their belief about the managers' choices I_S. We now analyze these two components one by one before turning to the consistency conditions to construct the equilibrium.

4.2 Investors' problem

The investors' problem is to decide whether to fire their manager once the strategy return is realized. In our model, investors always prefer to keep their managers after a favorable outcome r_s^+ or r_n^+ because due to their success, these managers' reputations will have risen even above the level that warranted their initial hiring. When a manager earns the outcome r_n^-, on the other hand, we simplify the analysis by assuming that investors will fire him.[16] Lastly, when a manager earns r_s^-, investors' optimal behavior is summarized in the following Lemma.

Lemma 3 *Denote*

$$I_s^* \equiv \frac{\underline{\rho}(1-\rho_0)}{\rho_0(1-\underline{\rho})(1-p_s)}.$$

If a manager fails the Swan strategy, investors fire him if $I_s < I_s^*$, and retain him if $I_s \geq I_s^*$.

As noted in Lemma 1, investors are more "tolerant" of the failure from the Swan strategy if the strategy is popular among type g managers (i.e., I_S is high). Lemma 3 shows that I_s^* is the threshold popularity for the Swan strategy above which the reputation cost from a failure in the Swan strategy will be small enough that the manager will not be fired.

4.3 Managers' problem

The following Lemma describes type g managers' response to investors' firing decisions.

Lemma 4 *If managers expect that they will not be fired upon a failure in the Swan strategy, $f_s = \overline{f}$;*

[16] As in the baseline model, this assumption is not crucial for our main results. Relaxing this assumption *increases* the attractiveness of the Nickel strategy, amplifying our results.

on the other hand, if they know they will be fired if they fail the strategy, $f_s = \underline{f}$*, where*

$$\underline{f} \equiv \begin{cases} 0 & \text{if} \quad f_1 \leq 0, \\ f_1 & \text{if} \quad f_1 \in (0,1), \\ 1 & \text{if} \quad f_1 \geq 1, \end{cases} \tag{15}$$

$$\overline{f} \equiv \begin{cases} 0 & \text{if} \quad f_2 \leq 0, \\ f_2 & \text{if} \quad f_2 \in (0,1), \\ 1 & \text{if} \quad f_2 \geq 1, \end{cases} \tag{16}$$

and

$$f_1 \equiv \frac{E[R_s](1-k_s\alpha_b) - E[R_n](1-k_n\alpha_g) + V(p_s - p_n)}{E[R_n]k_n\alpha_g + E[R_s]k_s\alpha_g}, \tag{17}$$

$$f_2 \equiv \frac{E[R_s](1-k_s\alpha_b) - E[R_n](1-k_n\alpha_g) + V(1 - p_n)}{E[R_n]k_n\alpha_g + E[R_s]k_s\alpha_g}. \tag{18}$$

It is easy to see that $\underline{f} \leq \overline{f}$, that is, more managers would choose the Swan strategy when they are assured that they won't be fired upon a failure. Given investors' firing decisions, the more appealing strategy will attract more type g managers, which in turn will reduce the expected return of the strategy. In equilibrium, type g managers will only be present in both strategies if the two strategies offer identical value (i.e., the expected financial compensation plus reputation value) to a manager. In extreme cases, all type g managers may concentrate on one strategy if it offers such a high value that even after the price impact of all type g managers it still dominates the other strategy.

Suppose, for instance, investors' perceptions about the popularity of the Swan strategy lead them to fire their managers who fail the Swan strategy. Then, the Swan and Nickel strategies are indifferent to type g managers if and only if

$$E[\tilde{R}_s] + p_s V = E[\tilde{R}_n] + p_n V. \tag{19}$$

The above is a linear equation of f_s. The left hand side, representing the value of the Swan strategy, decreases in f_s and the right hand side, representing the value of the Nickel strategy, increases in f_s. It is easy to verify that the solution of equation (19) is given by f_1 in (17). If $f_1 \in (0,1)$, then in equilibrium, a fraction f_1 of type g managers choose the Swan strategy and $1 - f_1$ of them choose the Nickel strategy and these two strategies are indifferent to them. If $f_1 \geq 1$, it implies that the Swan strategy is so attractive that even if all type g managers implement this strategy (and decrease its profitability), it still dominates the Nickel strategy. Hence, all type g managers choose the Swan strategy. If $f_1 \leq 0$, however, it implies that the Swan strategy is so unattractive that it is dominated by the Nickel strategy even if all type g managers choose the Nickel strategy. Hence, all type g managers choose the Nickel strategy. This leads to the results in (15). From a similar argument, we obtain the results in (16).

4.4 Equilibrium with price impact

With the results on the investors' firing decisions (Lemma 3) and the managers' responses (Lemma 4), we can now construct the equilibrium as the following.

Proposition 3 *For the economy defined above, the equilibrium can be characterized by the following three cases.*

1. *If $\overline{f} < I_S^*$, there is a unique equilibrium with $I_S = f_s = \underline{f}$, where investors fire their managers who fail the Swan strategy;*

2. *If $I_S^* \leq \underline{f}$, there is a unique equilibrium with $I_S = f_s = \overline{f}$, where investors keep their managers who fail the Swan strategy;*

3. *If $\underline{f} < I_S^* \leq \overline{f}$, there are two equilibria: In one equilibrium, $I_S = f_s = \underline{f}$ and investors fire their managers who fail the Swan strategy, while in the other equilibrium, $I_S = f_s = \overline{f}$ and investors keep their managers who fail the Swan strategy;*

In all three cases the strategy returns, $\tilde{R}_n$ and $\tilde{R}_s$, are given by (12) and (13), with the corresponding f_s substituted in.

As in the baseline model, cases 1 and 2 are straightforward. The Swan strategy return in case 1 is so unattractive that even if managers were assured that they would not be fired when they failed the Swan strategy, only $\overline{f}$ of type g managers would have chosen this strategy. Since $\overline{f} < I_S^*$, i.e., the Swan strategy is not sufficiently popular among type g managers, Lemma 3 implies that investors would actually fire managers who fail the strategy. Understanding this, Lemma 4 implies that an even smaller fraction $\underline{f}$ of type g managers would choose the Swan strategy. Therefore, in equilibrium, investors believe only $\underline{f}$ of type g managers would choose the Swan strategy and fire the managers who fail it. Similarly, in case 2, the Swan strategy return is so appealing that it can attract more than I_S^* of type g managers even if investors fire managers who fail the Swan strategy. Since the Swan strategy is so popular among type g managers, Lemma 3 implies that investors would prefer not to fire the managers who fail the Swan strategy. Knowing this, as implied by Lemma 4, $\overline{f}$ type g managers would actually choose the Swan strategy in equilibrium.

For the same intuition as in the baseline model, the interaction between managers' reputation concerns and investors' perceptions leads to multiple equilibria in case 3. If investors believe that the Swan strategy is popular among type g managers, the reputation penalty from a failure in the Swan strategy is low and so won't cost the manager his job. This makes the Swan strategy more attractive and popular among type g managers (i.e., $\overline{f}$ type g managers choose the Swan strategy), sustaining investors' belief. Similarly, if investors believe instead that the Swan strategy is unpopular among type g managers, the high reputation penalty from failing the Swan strategy means only $\underline{f}$ type g managers would choose the strategy, again sustaining investors' perception.

In addition to illustrating the robustness of the main implications from the baseline model, the set-up in the current section also leads to a number of new insights. The first is that a shift in investors' perception can lead to a different equilibrium, which means drastic capital relocation and price changes without any news about the fundamentals. As noted in case 3 of Proposition 3, when the Swan strategy is popular it attracts $\overline{f}$ of type g managers. Hence, the expected return of this strategy is

$$E[\tilde{R}_s] = E[R_s](1 - k_s(\overline{f} \times \alpha_g + \alpha_b)).$$

A shift in investors' perception can abruptly make the Swan strategy unpopular. The drop in demand increases the expected return of the strategy to

$$E[\tilde{R}_s] = E[R_s](1 - k_s(\underline{f} \times \alpha_g + \alpha_b)).$$

That is, the change in the expected return of the underlying asset is

$$\Delta \equiv E[R_s](1 - k_s(\underline{f} \times \alpha_g + \alpha_b)) - E[R_s](1 - k_s(\overline{f} \times \alpha_g + \alpha_b)). \tag{20}$$

This implication fits well with the convertible bond arbitrage example mentioned earlier: Convertible bond arbitrage strategies became unpopular in late 2004. This not only led to drastic capital outflow but also *increased* the expected return of convertible bond arbitrage strategies for an extended period of time. Our model offers a natural explanation: The poor performance in 2004 served to coordinate investors and managers, moving the economy into the equilibrium in which investors were "intolerant" to convertible bond arbitrage strategies and making fund managers wary about investing in this strategy. The increase in the expected return is perhaps due to the price impact when a large amount of assets flee away from the strategy.

Moreover, our model also offers an empirically testable implication. Poor performance from convertible bond arbitrage funds during intolerant times (2005 and 2006) should lead to larger outflows than comparably poor performance in the more tolerant times before 2004. The same argument can be applied to the convergence trading strategy example mentioned earlier. Our model implies that, after the LTCM crisis, the expected returns of convergence trading strategies should increase and capital flows should be more sensitive to losses in these strategies. That is, generally, our model implies that after a large amount of capital fleeing away from a strategy, the expected return of this strategy tends to become higher for an extended period of time. Meanwhile, poor performance in this strategy tends to generate larger-than-usual capital outflows.

The second insight concerns the impact of liquidity on the price jump induced by the switch in equilibrium. The price of the underlying asset for the Swan strategy changes when the strategy becomes unpopular. The magnitude of the price jump, approximately measured by Δ, depends on not only the liquidity in the market from which the capital is fleeing, but also the liquidity in the market where the capital is flying to, as summarized in the following corollary.

Corollary 1 *When* $\overline{f}, \underline{f} \in (0,1)$, $\frac{\partial \Delta}{\partial k_n} < 0$ *and* $\frac{\partial \Delta}{\partial k_s} > 0$.

This corollary states that when the Swan strategy becomes unpopular and managers flee the strategy, the impact on the expected return of the underlying asset increases with its illiquidity. This is intuitive: When managers try to sell the Swan asset, the price impact will be larger if the market is less liquid. Moreover, the corollary also shows that the price impact is larger if the liquidity of the Nickel strategy is higher. The intuition is the following. Suppose the underlying asset for the Nickel strategy is illiquid. When managers enter the Nickel strategy, they move the price of the underlying asset against them significantly. This discourages other managers from fleeing the Swan strategy, mitigating the impact on the price of the Swan strategy's underlying asset. If the Nickel strategy is very liquid, however, it will have the capacity to absorb more managers from the Swan strategy, leading to a larger price impact on the underlying asset of the Swan strategy. These results suggest that the existence of liquid assets can amplify the impact of "flight to liquidity", leading to larger capital relocation and bigger price impacts.

The final insight is that the earlier analysis of the role of investors' perception I_S can be generalized. In the baseline model, I_S can only take the extreme values 0 and 1, making the earlier analysis susceptible to concerns that it might be driven by the specialty of the extreme cases. The model in the current section directly addresses this concern by showing that the intuition in Section 3 also holds when investors' perceptions are not extreme.

5 Conclusions

We have analyzed an equilibrium model of reputation concerns. Despite the simple structure, it leads to a rich set of implications. It offers a reason why Nickel strategies are popular among fund managers; why capital sometimes appears to move slowly to profitable strategies; why some strategies can quickly become popular while others swiftly go out of fashion, leading to drastic capital relocation and price changes without news on the fundamentals.

One novel insight from our model is the fragile nature of the equilibrium with reputation concerns. The interaction between managers' reputation concerns and investors' perceptions may lead to multiple self-fulfilling equilibria. As an initial step to understanding the impact of this mechanism, we build a simplest possible model to capture it. This leaves many important questions unanswered: How is one equilibrium chosen over the other? How do investors form and change their perceptions? How does this mechanism affect the aggregate real economy? We leave these questions to future research.

Appendix

Proof of Lemmas 1–2

Lemma 1 directly follows from equations (5)-(6). Lemma 2 can be proved by contradiction: Suppose $0 < I_S < 1$. Under assumption (4), type g managers would either all prefer one strategy or the other since managers are *ex ante* identical. This does not support any perception that I_S is between 0 and 1.

Proof of Proposition 1

Case 1: Recall that we normalized $\phi W = 1$. If $r_s^+ < \underline{r}$, it is clear from (3) that the Swan strategy return is so low that all type g managers prefer the Nickel strategy even if they are assured they will not be fired if they fail the Swan strategy. This leads to the equilibrium of $I_S = 0$ and $a = N$.

Case 2: Similarly, if $r_s^+ > \overline{r}$, (3) implies that all type g managers prefer the Swan strategy regardless of whether they will be fired when they fail the Swan strategy, leading to the equilibrium with $I_S = 1$ and $a = S$;

Case 3: We now have $\underline{r} < r_s^+ < \overline{r}$ and $\rho_0 < \rho^*$. Suppose $I_S = 1$. It is easy to verify that $\rho_0 < \rho^*$ implies that $\rho_1 < \underline{\rho}$, i.e., a manager will be fired if he fails the Swan strategy. Therefore, (3) implies that all type g managers prefer the Nickel strategy and $I_S = 1$ cannot be supported in equilibrium. If $I_S = 0$, however, all type g managers prefer the Nickel strategy, supporting the equilibrium with $I_S = 0$ and $a = N$.

Case 4: We now have $\underline{r} < r_s^+ < \overline{r}$ and $\rho_0 \geq \rho^*$. Suppose $I_S = 1$. It is easy to verify that $\rho_0 \geq \rho^*$ implies that $\rho_1 \geq \underline{\rho}$, i.e., a manager will not be fired if he fails the Swan strategy. Therefore, (3) implies that all type g managers prefer the Swan, supporting the equilibrium with $I_S = 1$ and $a = S$. If $I_S = 0$, however, all type g managers prefer the Nickel strategy, supporting the equilibrium with $I_S = 0$ and $a = N$.

The obvious choice for off-equilibrium beliefs is that in the equilibrium with $I_S = 1$ (Cases 2 and 4), if a manager chooses the Nickel strategy and succeed, he must be of type g. There is no need to specify the belief for the failure in the Nickel Strategy due to our simplifying assumption that a manager is fired when he fails the Nickel strategy.

Corollary 2 *Suppose a hedge fund manager is compensated by a fraction of the profit but does not share the loss, i.e., the manager's objective function is* $\max_{a\in(N,S)} E\left[\phi W \max(r, 0) + \Pr(kept) \times V\right]$.

The equilibrium is the same as that in Proposition 1, with equations (8) and (7) being replaced by

$$\overline{r} = \frac{p_n r_n^+ + (p_n - p_s)V}{p_s},$$
$$\underline{r} = \frac{p_n r_n^+ + (p_n - 1)V}{p_s}.$$

Proof. If the manager has a convex compensation contract so that he suffers no loss after a failure in a strategy, then his compensation is identical to the case where his compensation contract is linear and r_s^- and r_n^- both equal zero. Substituting zero for these terms gives the equations above. ■

Proof of Proposition 2

If type b managers choose a different strategy from type g managers, then type b managers will be fired regardless of success or failure. From assumption 10, type b managers have identical expected returns from either strategy and therefore maximize their objective function by mimicking type g managers. It is then sufficient to calculate the optimal strategy of the type g managers only. The proofs of Cases 1–4 parallel those of Proposition 1. The off-equilibrium belief is that, for cases 1–4, if a manager chooses an off-equilibrium, his $\rho_1 \geq \underline{\rho}$ if he succeeds and $\rho_1 < \underline{\rho}$ if he fails. It is easy to verify that this off-equilibrium belief satisfies the intuitive criterion of Cho and Kreps (1987).

Proof of Lemma 3

Following the Bayes rule, $\rho_1 = \frac{(1-p_s)I_S\rho_0}{(1-p_s)I_S\rho_0+(1-\rho_0)}$. Solving for I_S gives that $\rho_1 \geq \underline{\rho}$ iff $I_S \geq I_S^*$.

Proof of Lemma 4

Suppose managers expect that they will not be fired upon a failure in the Swan strategy and a fraction f_s of type g managers choose the Swan strategy. If $c < f_s < 1$, then it implies (19), from which we can solve for f_s. Moreover, if the f_s implied by (19) is greater than or equal to 1, it implies $f_s = 1$. That is, even if all type g managers choose the Swan strategy and reduce the profitability of the strategy to the minimum, the Swan strategy is still more appealing than the Nickel strategy. Similarly, $f_s = 0$ if the solution of (19) is less than or equal to 0. Hence, we obtain (16). Based on a similar argument, we can obtain (15).

Proof of Proposition 3

From Lemma 4, a fraction $\underline{f}$ of type g managers choose the Swan strategy if they expect to be fired after r_s^-; a fraction $\overline{f}$ choose Swan otherwise. Hence, in equilibrium, either $I_S = f^*$ or $I_S = \overline{f}$. Note that $f^* \leq \overline{f}$.

If $\overline{f} < I_S^*$, then we have $I_S < I_S^*$ and, from Lemma 4, a fraction $\underline{f}$ of type g managers choose the Swan strategy. This leads to the results in Case 1. Similarly, $I_S^* \leq \underline{f}$ implies $I_S \geq I_S^*$. From Lemma 4, a fraction $\underline{f}*$ of type g managers choose the Swan strategy, leading to the results in Case 2. If $\underline{f} \leq I_S^* < \overline{f}$, both $I_S = f^*$ and $I_S = \overline{f}$ can be supported in equilibrium leading to the results in Case 3.

Proof of Corollary 1

Substituting (15) and (16) into (20), under the $\overline{f}, \underline{f} \in (0,1)$, we obtain $\Delta = \frac{E[R_s]Vk_s(1-p_s)}{E[R_n]k_n+E[R_s]k_s}$. Taking partial derivatives of Δ with respect to k_s and k_n, we obtain the result in Corollary 1.

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