The Consequences of Index Investing on Managerial Incentives*

George C. Nurisso†

April 19, 2025

Abstract

This paper explores how index investing impacts managerial compensation in a moral hazard setting. With index investing, effort is reflected not only in the manager's stock price but also in the stock prices of all other constituent firms through the synchronized asset demands of index investors. Thus, the prices of other constituent firms are positively related to and contain unique information about the manager's effort. The optimal contract puts a positive weight on the index's price to enhance the effort sensitivity of the manager's pay, not to reduce risk. Relative performance evaluation is, therefore, not optimal in this setting. Common ownership does not affect the sign of this contract parameter—it only amplifies the magnitude.

*I thank Philip Bond and Doron Levit for their valuable guidance and feedback on this paper. I also thank participants at the 2022 Finance Theory Group - Bridging Theory and Empirical Research in Finance PhD poster session and 2024 AFA PhD Poster Session.

†University of Washington—Foster School of Business

1 Introduction

Properly incentivizing executives is one of the most important governance decisions faced by shareholders and their representatives on boards of directors. However, optimal compensation schemes derived from academic theory and those observed in practice often diverge. One of the most notable differences concerns relative performance evaluation (RPE): the classic analysis of Holmstrom (1982) states that optimal contracts should filter out common shocks to reduce the volatility of a manager's pay, enabling the implementation of stronger incentives. However, executive contracts implement RPE far less frequently than theory predicts—instead paying managers for good market or industry stock performance—giving rise to the "RPE puzzle" (e.g., Murphy (1999) and Jenter and Kanaan (2015)).[1] Many papers have tried reconciling such "payment for luck" with various extensions to the standard framework,[2] but it is not obvious whether such a compensation scheme is truly rewarding luck rather than performance once one considers one of the most prominent developments in financial markets over the past few decades: the rise of index investing.

Recent work by Chinco and Sammon (2024) estimates that around one-third of the U.S. stock market is held by index investors, underscoring the major shift away from active investing in recent years. Index investors purchase baskets of stocks in fixed proportions, so any information that induces the purchase of an index product should be transmitted to all constituent stock prices, regardless of which firm in the index generates the signal. Consider the recent experience of the "Magnificent Seven" stocks[3]; when discussing record inflows into S&P 500 ETF products in 2024, Vanguard's head of US ETF capital markets

[1] While the use of RPE appears to be growing (Bizjak et al. (2022)), it is still far from universal and many shocks are not filtered out. See the survey by Edmans, Gabaix, and Jenter (2017) for a full discussion on the state of RPE.

[2] See the literature review for a discussion of these papers.

[3] Alphabet, Amazon, Apple, Meta, Microsoft, Nvidia, and Tesla.

said, "People see a lot more in the news about the Magnificent Seven stocks. People want a piece of that, and all these stocks are in the S&P.[4]" Consequently, compensating the Magnificent Seven CEOs for good index performance may not be rewarding luck, but rather, their good performance, as reflected in these other constituent stocks via the synchronized asset demands of index investors. However, whether such a channel is meaningful enough to dominate the traditional RPE contracting motivation in equilibrium is challenging to foresee without a formal model.

In this paper, I develop a joint model of contracting with moral hazard and financial markets with index investors to examine how optimal managerial compensation changes as the fraction of index investors increases. To my knowledge, this is the first paper to study the impact of index investing on managerial compensation. My baseline model contains two ex-ante identical firms (labeled 1 and 2) that make up a stock index. Each firm has a principal who must solve a standard managerial moral hazard contracting problem to maximize the expected payoff of their firm; in particular, the contracts can depend on both firms' stock prices. Stock prices are determined via a noisy rational expectations equilibrium model of financial markets (e.g., Grossman and Stiglitz (1980) or Hellwig (1980)), where some fraction of traders are active, and the rest are indexers. Index investors can only purchase the stocks in some fixed proportion, while active traders have complete portfolio discretion.

My main result is that the optimal contract should put a positive and increasing weight on the stock performance of other index constituents when indexing increases. The key mechanism is as follows. Manager 1's effort increases expectations about the payoffs of Firm 1 and the index (because Firm 1 is part of the index). Index investors then buy more of the index after receiving this good news, which pushes up both stock prices. As a result,

[4]https://www.ft.com/content/4a9b70d7-f956-4ac7-b730-7ee3cafbd9e1

both stock prices reflect the index investors' information about Manager 1's effort but also become more positively correlated. These two results have opposite implications for Manager 1's optimal contract: the increased sensitivity of Firm 2's stock price to Manager 1's effort suggests a positive weight on Firm 2's stock performance (effort sensitivity channel), while the increased correlation suggests a negative weight to hedge out common shocks (RPE or hedging channel). I find that the effort sensitivity channel dominates in equilibrium.

The intuition for this main result follows from how the financial market equilibrium adjusts as the fraction of index investors increases. Following an increase in index investing, fewer active traders remain to supply *relative* liquidity. For example, suppose liquidity demand for Stock 1 is negative, while liquidity demand for Stock 2 is positive. For these markets to clear, active traders must take the opposite side of these trades because indexers cannot trade against relative liquidity demand shocks; index investors can only supply *absolute*, not relative, liquidity. However, since traders are risk-averse, the remaining active traders will require greater compensation (i.e., more favorable prices) to supply this relative liquidity, meaning that liquidity demand has a greater price impact as indexing increases. The equilibrium prices' increased sensitivity to liquidity trades dampens the positive correlation induced by indexing (and thus also the benefit of RPE), which allows the effort sensitivity channel to dominate.

My model also predicts that under most parameters, the sensitivity of the manager's pay to his stock price decreases in the fraction of index investors. This result follows from the insight that as indexing increases, other index constituents' stocks will reflect relatively more of the market's information about the manager's effort—due to the synchronized demands of index investors. Moreover, my model predicts that managerial pay will become more highly correlated across firms as index investing increases. This finding arises naturally from

my previous two results, which show that firms put less weight on their own firm's stock performance and more on other firms' as index investing increases. In fact, all executive pay will be identical in the limiting case with only indexers.

My baseline model assumes that the goal of each firm's principal is to maximize the expected payoff of its firm. However, the common ownership literature (e.g., Azar, Schmalz, and Tecu (2018)) suggests that the growth of indexing may change this objective. Index investors typically invest through an index fund or ETF managed by a large asset manager (e.g., Vanguard, BlackRock, or Fidelity), so stock ownership tends to become more concentrated as indexing increases. These diversified asset managers may then govern their firms to maximize portfolio value, which is not necessarily equivalent to maximizing the value of each firm in their portfolio. I include an extension where a common principal sets each manager's contract to maximize expected index payoffs. The optimal contract parameters with common ownership have the same sign as the separate owner case; all the common owner does is alter the magnitudes. As a result, any empirical evidence showing that the rise of index investing results in more highly correlated CEO pay is not necessarily evidence of anti-competitive common ownership activities; it can also be the optimal contract for separate value-maximizing principals.

Literature Review

My paper contributes to the executive compensation literature on relative performance evaluation as developed theoretically by Holmstrom (1979) and Holmstrom (1982). However, the lack of empirical support for this theory is a well-known puzzle, and several papers have proposed explanations. Jin (2002) and Garvey and Milbourn (2003) argue that RPE may

be redundant if executives can hedge exposure to risk factors on their personal portfolios; Himmelberg and Hubbard (2000) argue that shocks to executive labor demand generate a positive correlation between aggregate stock returns and CEO pay; Oyer (2004) proposes a model where RPE may be sub-optimal when the CEO's outside option covaries positively with aggregate stock returns; Goplan, Milbourn, and Song (2010) argue that not filtering out industry shocks leads to executives choosing more appropriate firm exposure to industry conditions; and DeMarzo and Kaniel (2023) show that RPE may not be optimal when managers have "keeping up with the Joneses" preferences. Lastly, Edmans, Gosling, and Jenter (2023) survey UK directors and investors about executive compensation and find that fairness concerns are the most common explanation for the lack of RPE. I contribute to this literature by demonstrating that RPE can be suboptimal even in a textbook moral hazard framework once one considers the impact of index investing on equilibrium stock prices.

My paper also contributes to the literature on the real effects of financial markets—specifically, how financial market developments impact managerial incentives (see Bond, Goldstein, and Edmans (2012) for a survey). Holmstrom and Tirole (1993) and Diamond and Verrecchia (1982) are two classic papers on this subject. Holmstrom and Tirole (1993) examine whether a firm's stock price can be a useful contracting variable when profits are observable and contractible. They find that stock prices contain additional information, and the value of this information is increasing in market liquidity. Diamond and Verrecchia (1981) examine a moral hazard model where the stock price contains unique information for the principal above and beyond output. My main contribution to this literature is to analyze how well markets can monitor a manager's effort when index traders impact the informativeness of prices.

This paper also addresses the impact of index investing on equilibrium asset prices. Most theoretical papers in this literature rely on noisy rational expectations equilibrium (REE) models of financial markets as developed by Grossman and Stiglitz (1980), Hellwig (1980), Diamond and Verrecchia (1981), and Admati (1985). I use the Admati (1985) framework (a multi-asset version of Hellwig (1980)) for my financial market and add index investors and endogenous cash flows driven by managerial effort.

The three index investing papers most similar to mine are Bond and Garcia (2022), Buss and Sundaresan (2020), and Liu and Wang (2018). Bond and Garcia (2022) use a Diamond and Verrecchia (1981) style financial market to analyze the welfare consequences of a decline in the cost of index investing. They find that as the fraction of index investors increases, the price efficiency of the index declines and the price efficiency of individual stocks increases. The latter result occurs because the marginal trader who switches from active to index investing following a decrease in the cost of index investing is less informed than the remaining active traders. Thus, the average information quality for individual stocks increases when he leaves. Buss and Sundaresan (2020) develop a model with a feedback mechanism between price informativeness and corporate investment. They find that an increase in the fraction of passive investors lowers the firm's cost of capital because active investors hold fewer shares in equilibrium—and thus less risk. A lower cost of capital encourages investment, increasing the volatility of the firm's cash flows and incentivizing active investors to gather more information. Liu and Wang (2018) develop a model of index investors with endogenous information acquisition and find that the effect of index investors on price efficiency depends on how gathering information on one stock affects the costs of gathering information on additional stocks.

As the above papers suggest, there is no theoretical consensus on how an increase in

indexing impacts price efficiency. Other papers on the subject include Lee (2020), who finds a positive relationship between indexing and price efficiency; Baruch and Zhang (2021), who find a negative relationship; and Coles, Heath, and Ringgenberg (2022), who find no relationship. Davies (2021) and Sammon (2022) also contribute to this literature. The latter uses theoretically motivated measures of price informativeness to find that price efficiency has declined over the last 30 years. This result suggests a negative relationship between index investing and price efficiency. My simple model of index investors also implies a negative relationship between index investing and price efficiency, but that is not the focus of my paper. One of my main contributions to this literature is endogenizing stock payoffs with a managerial moral hazard problem.

Finally, I contribute to the common ownership literature by examining an extension where a common owner sets contracts to maximize index value. Prior work (e.g., Gordon (1990), Aggarwal and Samwick (1999), Liang (2016), and Anton et al. (2022)) has shown that common owners may find RPE suboptimal. However, I take a step back and show that index investing—the primary driver of common ownership—endogenously alters asset prices, making RPE suboptimal even in the absence of common ownership. This finding suggests that common ownership may only be correlated with—as opposed to causing—the absence of RPE, with both phenomena driven by the rise of index investing.

2 Toy Model

I start by setting up and solving a simple contracting problem that demonstrates the intuition behind my optimal contract. There are two firms ($k \in \{1, 2\}$) whose outputs (x_k) depend on their manager's effort (e_k) and noise (η_k). Formally, $x_k = e_k + \eta_k$ with

$\eta_1, \eta_2 \sim N(0,1)$ and $corr(\eta_1, \eta_2) = 0$.

Firms cannot contract directly on output but must rely instead on a performance measure $P_k = e_k + \alpha e_j + \eta_k + \phi_k$ with $\alpha \in [0,1]$, $\phi_k \sim N(0,1)$, and $corr(\phi_1, \phi_2) = \rho$. Assume ϕ_k is independent of η_1 and η_2. Firm 1's performance measure equals its output plus a term that depends on the effort of Manager 2 (αe_j) and an additional noise term that is correlated across performance measures (ϕ). Thus, even though outputs are uncorrelated, the two firms' performance measures are linked by effort (through α) and a correlated noise term (with correlation ρ).

The principal is risk-neutral, the manager is risk-averse (specifically, CARA utility[5]), and contracts are linear in the two performance measures. For Firm 1, the contract is $w_1 = l_1 + m_1 P_1 + n_1 P_2$. The formal contracting problem for Firm 1 is:

$$\max_{l_1, m_1, n_1} E(x_1 - w_1)$$

$$\text{s.t. } E(w_1) - \frac{1}{2}e_1^2 - \frac{1}{2}Var(w_1) \geq 0 \qquad \text{(IR)}$$

$$e_1 \in \underset{\tilde{e_1}}{\operatorname{argmax}} E(w_1) - \frac{1}{2}\tilde{e_1}^2 - \frac{1}{2}Var(w_1) \qquad \text{(IC)}$$

The principal maximizes the expectation of output minus the manager's wage. The manager requires non-negative expected utility to participate and chooses effort to maximize his expected utility given the contract. The manager's expected utility equals the expected wage minus a quadratic cost of effort term and a risk-aversion term. I will drop the firm subscripts in the following discussion because the solutions are the same for both firms.

Lemma 1. *When $\alpha = 0$, the optimal contract sets $m^* > 0$ and sets n^* to have the opposite sign of $\rho = corr(\phi_1, \phi_2)$.*

[5] I set the manager's coefficient of absolute risk aversion to 1 for simplicity.

We can interpret Lemma 1 as the classic RPE result. The positive sign on m^*—the contract weight on the firm's own performance measure—is straightforward, but the sign of n^* is the main RPE result; we set the sign of n^* to be opposite that of ρ to hedge common noise in the performance measures. By doing so, we reduce the volatility of the risk-averse manager's pay, which allows the principal to implement stronger incentives.

Lemma 2. *When $\alpha > \frac{\rho}{2}$, the optimal contracts sets $m^* > 0$ and $n^* > 0$.*

We still get $m^* > 0$ when $\alpha > 0$. However, we are now guaranteed to get $n^* > 0$ when $\alpha > \frac{\rho}{2}$. Note that α can be interpreted as the sensitivity of Firm 1's performance measure to Manager 2's effort divided by the sensitivity of Firm 1's performance measure to Manager 1's effort. We can also interpret $\frac{\rho}{2}$ as the covariance of the two performance measures divided by their common variance: $Var(P) \equiv Var(P_1) = Var(P_2) = 2$.

$$\alpha = \left(\frac{dP_k}{de_j}\right) / \left(\frac{dP_k}{de_k}\right) \text{ and } \frac{\rho}{2} = \frac{cov(P_1, P_2)}{Var(P)}$$

In the RPE model, we always set $n^* < 0$ when $\rho > 0$, but now we set $n^* > 0$ whenever $\alpha > \frac{\rho}{2} > 0$ even though doing so increases the manager's risk. The benefits of increasing the effort sensitivity of the manager's pay outweigh the costs of increased pay volatility.

In my full model, I endogenize the parameters α and ρ through a model of financial markets with index investors. We can then interpret my heretofore generic performance measures as stock prices, and as we will see, the synchronized asset demands of index investors create both the correlation between the two performance measures (ρ) and the presence of the other manager's effort (α) in each firm's performance measure. I then demonstrate conditions that result in the magnitudes of these parameters being such that $\alpha > \frac{\rho}{2}$ so $n^* > 0$.

3 Full Model

3.1 Firms

There are two firms: 1 and 2.[6] Each firm is controlled by a risk-neutral principal and managed by a risk-averse manager. The manager privately exerts costly effort to increase the mean cash flow of his firm. Denote firm $k's$ cash flow as x_k. The manager of firm k is paid a wage w_k as compensation for his effort. Each firm pays out the entirety of its cash flow net of managerial compensation (i.e., $x_k - w_k$) to its shareholders as a dividend. Financial market participants trade shares of each firm at the equilibrium price P_k. Assume each firm has one share outstanding. The details of the contracting problem and financial market will be explained in the following subsections.

3.2 Contracting Problem

Each firm's principal faces a moral hazard problem. The risk-neutral principal wants to maximize the expected dividends of the firm: $E(x_k - w_k)$. Each risk-averse manager chooses his firm's mean cash flow e_k at a personal cost of $\frac{1}{2}e_k^2$. The manager's choice of e_k is his private information. I assume the cash flows of the two firms are normally distributed, independent, and have identical variances. Specifically, let $x_k \sim N(e_k, 1)$.[7]

The principal induces effort with a contract. I focus on linear incentive schemes of the following form:

$$w_k = l_k + m_k P_k + n_k P_j$$

[6] All results generalize to an arbitrary number N firms. See Section 6.1 for details.

[7] When the cash flow's variance gets too small, market clearing restricts the principal to contracts that make the stock resemble a risk-free asset. This restriction generates all sorts of bizarre results such as putting a negative contract weight on the firm's own stock price. To avoid these unrealistic complications, I normalize the variance of the cash flow to one.

That is, the contract has a fixed component (l_k), a component based upon the firm's stock price (m_k), and a component based upon the other firm's stock price (n_k). I assume that the principal cannot contract on the actual cash flow x_k. This assumption can be rationalized by supposing that the payoffs are for a long-term project and the manager must be paid immediately for current consumption.

The manager has CARA utility over $w_k - \frac{1}{2}e_k^2$ with risk aversion coefficient 1. He also requires an expected utility of at least 0 to participate. Therefore, the principal of firm k chooses (l_k, m_k, n_k) to maximize expected dividends subject to the manager participating and choosing the effort level that maximizes his expected utility (given the contract).

3.3 Financial Market

The financial market consists of three assets: a risk-free asset, the stock of Firm 1, and the stock of Firm 2. I assume the risk-free asset has a guaranteed price and payoff of \$1. There is an infinite supply of the risk-free asset and one share of each stock outstanding.

There exist a unit mass of agents $i \in [0, 1]$ with CARA utility over terminal wealth and a common coefficient of absolute risk aversion 1. All agents have the same starting wealth W_0. Agents choose portfolios to maximize their expected utility. I also assume there are noise traders whose aggregate demand for each asset (z_1, z_2 respectively) are i.i.d random variables with distribution $N(0, \tau_z^{-1})$. These random variables are independent of every other random variable in the model.

However, for mathematical convenience, I follow Bond and Garcia (2022) and analyze the financial market in terms of two synthetic assets rather than the original stock prices.

Define the following synthetic asset prices:

$$\begin{bmatrix} P_{IN} \\ P_{LS} \end{bmatrix} = T \begin{bmatrix} P_1 \\ P_2 \end{bmatrix}, \text{with } T = \frac{1}{\sqrt{2}} * \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \tag{1}$$

I divide by $\sqrt{2}$ to keep the variances of the synthetic cash flows and noise demands equal to the originals. P_{IN} is the price of an index asset (proportional to $P_1 + P_2$) and P_{LS} is the price of a long-short asset (proportional to $P_1 - P_2$). We can similarly transform all other variables in the model: variables with subscript IN are for the index asset and variables with subscript LS are for the long-short asset. Also, observe that $Cov(x_{IN}, x_{LS}) = 0, Cov(z_{IN}, z_{LS}) = 0$, and $Cov(x_{IN}, z_{LS}) = Cov(x_{LS}, z_{IN}) = 0$. As a result, the two synthetic asset prices are uncorrelated.

The purpose of this transformation in Bond and Garcia (2022), and here, is to simplify the traders' asset demands. Index investors generate multiple sources of correlation in the original stock prices, which makes each trader's information set quite large. However, because the two synthetic assets have zero correlation, focusing on them simplifies the calculations considerably.

I assume an exogenous fraction of traders λ are active, and the remaining $1 - \lambda$ are indexed. I endogenize this fraction in Appendix 2, but it does not impact my results. Active traders can purchase as much of the index and long-short assets as they want, while index investors are constrained to only trade the index asset. This restriction is equivalent to letting active traders freely trade the two original stocks while constraining index investors to purchase them in a fixed proportion.

Active traders receive independent noisy signals about both the index and long short assets. For example, let $s_{i1} = x_1 + \epsilon_{i1}$ be a signal for the Stock 1 and $s_{i2} = x_2 + \epsilon_{i2}$ be a

signal for Stock 2 and $s_i = (s_{i1}, s_{i2})'$. Active investors see the two synthetic signals ($s_{i,IN}$ and $s_{i,LS}$) generated by Ts_i. Observe that these two synthetic signals are uncorrelated. Index investors only receive a signal about the index asset; that is, index trader i only observes the signal $s_{i,IN} = \frac{s_{i1}+s_{i2}}{\sqrt{2}}$. This setup is equivalent to giving active traders signals about both of the original assets while only giving index traders an aggregate signal. Let $\epsilon_{ik} \sim N(0, \tau_\epsilon^{-1})$ be the distribution of noise and assume that noise realizations are independent across assets k and agents i. [8] Further assume signal noise is independent of all other random variables in the model.

Equilibrium prices are reached through market clearing. Once the synthetic asset prices are discovered, it is straightforward to invert Equation (1) to find the original stock prices .

3.4 Timing

1. The principal and manager agree on a contract and publicly announce it. The manager exerts effort.

2. Investors make a rational inference about e_k given the contract. Denote this belief e_k^*.

3. Investors trade based upon their information sets, the managers' contracts, and their type (active or indexed). Equilibrium prices are generated.

4. The manager of each firm k receives wage w_k.

5. Gross payoffs x_k are realized.

Note that this timeline has the manager being paid before payoffs are realized. Thus, the manager's contract cannot depend on the actual realization of payoffs. Rather, it must

[8] Note that the composite signals have the same variance as the signals for the two base assets.

depend on stock prices—a noisy signal for payoffs. One can interpret the manager being paid before x_k is realized as the firm borrowing amount w_k at the risk-free rate once equilibrium prices are realized.

4 Model Solution

I solve for the equilibrium using the usual "guess-and-verify" method for REE models of financial markets. Specifically, I first conjecture an equilibrium price function for each risky asset. Then, given these prices, the principal and agent find the optimal moral hazard contract. Third, given the conjectured prices, managerial contracts, their information, and their type, each trader selects their optimal portfolio. Finally, given the asset demands, prices are reached via market clearing. I will then have an equilibrium if the resulting prices match the form of the initial conjecture.

4.1 Financial Market Equilibrium

I make the following conjectures for the prices:

$$\begin{aligned} P_1 &= A_1 + Bx_1 + Cx_2 + Dz_1 + Ez_2 \\ P_2 &= A_2 + Bx_2 + Cx_1 + Dz_2 + Ez_1 \end{aligned} \tag{2}$$

Traders form correct-in-equilibrium beliefs about the efforts chosen by the managers given contracts w_1 and w_2. Denote these beliefs as e_1^* and e_2^*. These conjectures imply that all traders have identical prior beliefs about the payoffs of the assets. I allow the constant terms in the asset prices (A_1 and A_2) to be different because they depend on the equilibrium effort

conjectures.[9]

We now must confirm that equilibrium prices will indeed be of the conjectured form. As discussed in Section 3, it will be convenient to transform the original assets into an index and a long-short asset. I will then use the law of one price to find the original asset prices. As a reminder, I define the synthetic prices as

$$\begin{bmatrix} P_{IN} \\ P_{LS} \end{bmatrix} = T \begin{bmatrix} P_1 \\ P_2 \end{bmatrix}, \text{with } T = \frac{1}{\sqrt{2}} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$$

I define all other transformed variables similarly: variables with subscript IN are for the index asset, and variables with subscript LS are for the long-short asset. I conjecture that the prices of the synthetic assets will be linear in their own payoffs and noise demands. This conjecture implies that the original prices are of the form specified in Equation (2).

$$\begin{aligned} P_{IN} &= A_{IN} + B_{IN} x_{IN} + C_{IN} z_{IN} \\ P_{LS} &= A_{LS} + B_{LS} x_{LS} + C_{LS} z_{LS} \end{aligned} \tag{3}$$

Because the two synthetic assets have zero covariance, traders do not need to include information about the long-short asset in their demand for the index asset and vice-versa. Standard results about CARA utility imply that Trader i's demand for the index asset will

[9] Of course, the managers will choose the same effort in equilibrium given the symmetrical nature of the problem. As a result, we will see that the constant terms will also be the same in equilibrium.

be:

$$D(i,IN) = \frac{E(x_{IN}|s_{i,IN},P_{IN}) - w_{IN} - P_{IN}}{Var(x_{IN}|s_{i,IN},P_{IN})}$$
$$= e^*_{IN} + s_{i,IN}\tau_\epsilon + \rho^2_{IN}\tau_z(x_{IN} + \rho^{-1}_{IN}z_{IN}) - (1 + \tau_\epsilon + \rho^2_{IN}\tau_z)(w_{IN} + P_{IN})$$

where $\rho_{IN} = \frac{B_{IN}}{C_{IN}}$ and e^*_{IN} is the traders' correct-in-equilibrium belief about the mean payoff of the index. Notice that the wage is a constant to traders because they are conditioning on the price and know all the contract parameters. Demand for the long-short asset is defined similarly. Market clearing for each asset then requires:

$$\int_0^1 D(i,IN)di + z_{IN} = \frac{2}{\sqrt{2}}$$
$$\int_0^\lambda D(i,LS)di + z_{LS} = 0$$

Index asset demand from rational traders integrates from zero to one because both active and index investors trade it. Long-short asset demand integrates to λ because only active traders trade it. The supply of each synthetic asset comes from:

$$T\begin{bmatrix}1\\1\end{bmatrix} = \begin{bmatrix}\frac{2}{\sqrt{2}}\\0\end{bmatrix}$$

Plugging the asset demands into the market clearing conditions and re-arranging allows me to verify that the synthetic prices are indeed of the form conjectured in Equation (3). I then pre-multiply the synthetic price vector by T^{-1} to confirm my conjecture from Equation (2).

Contracts impact prices in two ways: directly through effort's effect on the mean payoff and indirectly through the price coefficients. It will be convenient to follow Holmstrom

and Tirole (1993) and normalize the prices so that they only depend on the direct effect of contracting. Focusing on the direct effect highlights the key economic forces in my model and allows for sharper conclusions. I will discuss the results for the original prices later on, but as a preview, the signs on the optimal contract parameters are unchanged by this normalization.

From the prices (P_1, P_2) and contracting parameters $(l_1, l_2, m_1, m_2, n_1, n_2)$, we can create the following normalized prices:

$$\tilde{P_1} = (1 + m_1)P_1 + n_1 P_2 + l_1$$
$$\tilde{P_2} = (1 + m_2)P_2 + n_2 P_2 + l_2$$

These normalized prices can then be expressed as follows:

$$\tilde{P_1} = \tilde{A_1} + \tilde{B}x_1 + \tilde{C}x_2 + \tilde{D}z_1 + \tilde{E}z_2$$
$$\tilde{P_2} = \tilde{A_2} + \tilde{B}x_2 + \tilde{C}x_1 + \tilde{D}z_2 + \tilde{E}z_1 \text{ with}$$
$$\tilde{A_1} = \frac{e_1^* - 2 + e_2^*}{(\tau_z \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2} + \frac{e_1^* - e_2^*}{(\tau_z \lambda^2 \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2}$$
$$\tilde{A_2} = \frac{e_1^* - 2 + e_2^*}{(\tau_z \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2} - \frac{e_1^* - e_2^*}{(\tau_z \lambda^2 \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2}$$
$$\tilde{B} = \frac{\tau_z \tau_\epsilon{}^2 + \tau_\epsilon}{(\tau_z \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2} + \frac{\tau_z \lambda^2 \tau_\epsilon{}^2 + \tau_\epsilon}{(\tau_z \lambda^2 \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2}$$
$$\tilde{C} = \frac{\tau_z \tau_\epsilon{}^2 + \tau_\epsilon}{(\tau_z \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2} - \frac{\tau_z \lambda^2 \tau_\epsilon{}^2 + \tau_\epsilon}{(\tau_z \lambda^2 \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2}$$
$$\tilde{D} = \frac{\tau_\epsilon \tau_z + 1}{(\tau_z \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2} + \frac{\tau_\epsilon \tau_z \lambda^2 + 1}{\lambda\, (\tau_z \lambda^2 \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2}$$
$$\tilde{E} = \frac{\tau_\epsilon \tau_z + 1}{(\tau_z \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2} - \frac{\tau_\epsilon \tau_z \lambda^2 + 1}{\lambda\, (\tau_z \lambda^2 \tau_\epsilon{}^2 + \tau_\epsilon + 1)\, 2}$$

It can be shown that $\tilde{B}, \tilde{C}$, and $\tilde{D} \geq 0$ and $\tilde{E} \leq 0$. The signs of $\tilde{B}$ and $\tilde{D}$ are straightforward:

a firm's stock price increases following positive cash flow news or noise demand. The signs of $\tilde{C}$ and $\tilde{E}$ are consequences of indexing. Suppose Firm 1 has a large realization of x_1, so index investors receive a positive signal about the index asset. They know that $x_{IN} = \frac{x_1+x_2}{\sqrt{2}}$ is large, but do not know the relative contributions of each firm. As a result, they buy more of both firms through the index. Therefore, a large realization of x_1 leads to greater index demand, which increases Firm 2's stock price. Similarly, suppose Stock 1 has a lot of noise demand. Index investors see the index's price rise without any good cash flow news. Thus, they buy less of both stocks in the index, which drives down Firm 2's stock price.

Observe that the normalized prices are constructed from public information and equal the hypothetical asset prices from a model without the contracting problem (taking the mean payoff e_k^* as given). As a result, this normalization allows us to separate the financial market and contracting problem, so the principal can take the normalized prices as given when choosing a contract. Moreover, contracting on performance measures $\tilde{P}_1$ and $\tilde{P}_2$ is equivalent to contracting on P_1 and P_2 with the correct adjustments. Define the normalized contract for Firm 1 as $w_1 = \tilde{l_1} + \tilde{m_1}\tilde{P}_1 + \tilde{n_1}\tilde{P}_2$ with

$$\begin{aligned} \tilde{l_1} &= \frac{l_1 + l_1\, m_2 - l_2\, n_1}{m_1 + m_2 + m_1\, m_2 - n_1\, n_2 + 1} \\ \tilde{m_1} &= \frac{m_1 + m_1\, m_2 - n_1\, n_2}{m_1 + m_2 + m_1\, m_2 - n_1\, n_2 + 1} \\ \tilde{n_1} &= \frac{n_1}{m_1 + m_2 + m_1\, m_2 - n_1\, n_2 + 1} \end{aligned} \tag{4}$$

The compensation for Manager 2 is defined similarly (swap all the 1's and 2's).

4.2 Contracts

The principal's problem with the normalized performance measures is:

$$\max_{\tilde{l_k},\tilde{m_k},\tilde{n_k}} E(x_k - w_k) \tag{5}$$

$$\text{s.t. } E(w_k) - \frac{1}{2}e_k^2 - \frac{1}{2}Var(w_k) \geq 0 \tag{IR}$$

$$e_k \in \underset{\hat{e_k}}{\text{argmax}}\, E(w_k) - \frac{1}{2}\hat{e_k}^2 - \frac{1}{2}Var(w_k) \tag{IC}$$

Taking the manager's first-order condition in constraint IC and solving gives us the following characterization of optimal effort:

$$e_k^* = \tilde{m_k}\tilde{B} + \tilde{n_k}\tilde{C}$$

Optimal effort equals the weight the contract puts on the manager's stock price ($\tilde{m_k}$) times the sensitivity of his stock price to his effort ($\tilde{B}$) plus the weight the contract puts on the other firm's stock price ($\tilde{n_k}$) times the sensitivity of the other stock price to his effort ($\tilde{C}$). Notice the positive incentive effect of putting a positive weight on the other firm's stock price. We know that $\tilde{C} > 0$, so greater effort by Manager 1 boosts Firm 2's stock price through $\tilde{C}$. Thus, setting $\tilde{n_k} > 0$ generates more effort, all else equal. With this choice of effort, we can plug back into the optimization problem. Specifically, we can take e_k^* and insert it into the objective function and IR constraint. We then bind the IR and substitute it into the objective function. The principal's new problem is

$$\max_{\tilde{m_k},\tilde{n_k}} e_k^* - \frac{1}{2}e_k^{*2} - \frac{1}{2}\left((\tilde{m_k}^2 + \tilde{n_k}^2)Var(\tilde{P}) + 2\tilde{m_k}\tilde{n_k}Cov(\tilde{P_1}, \tilde{P_2})\right)$$

where $Var(\tilde{P}) = Var(\tilde{P}_1) = Var(\tilde{P}_2)$ and does not depend on $\tilde{l_k}, \tilde{m_k}$, or $\tilde{n_k}$. Solving this maximization problem then gives us:

$$\tilde{m_k}^* = \Gamma \left(\tilde{B} Var(\tilde{P}) - \tilde{C} Cov(\tilde{P}_1, \tilde{P}_2) \right) \geq 0 \tag{6}$$

$$\tilde{n_k}^* = \Gamma \left(\tilde{C} Var(\tilde{P}) - \tilde{B} Cov(\tilde{P}_1, \tilde{P}_2) \right) \tag{7}$$

$$\text{with } \Gamma \equiv \frac{1}{Var(\tilde{B}\tilde{P}_1 - \tilde{C}\tilde{P}_2) + Var(\tilde{P})^2 - Cov(\tilde{P}_1, \tilde{P}_2)^2} > 0$$

These contract parameters will be the same for both firms, which implies that $e_1^* = e_2^*$. Thus, the equilibrium asset prices will have identical constant terms (i.e., $\tilde{A}_1 = \tilde{A}_2 \equiv \tilde{A}$). Also, $\tilde{l_k}^*$ will be the value that binds the agent's participation constraint given $\tilde{m_k}^*$ and $\tilde{n_k}^*$.

Even before plugging in, we can tell that $\tilde{m_k}^*$ will be non-negative because $\tilde{B} \geq \tilde{C}$ and $Var(\tilde{P}) \geq Cov(\tilde{P}_1, \tilde{P}_2)$. This result is intuitive: the manager's own stock price is increasing in his effort, so putting a positive weight on $\tilde{m}$ is good for incentives. The sign of $\tilde{n}$, however, is unclear at this stage, so we will need to plug in the price coefficients. However, we can say that $\tilde{n}$ will be positive if and only if the following condition is met:

Lemma 3. *The optimal choice of $\tilde{n}$ will be positive if and only if $\frac{\tilde{C}}{\tilde{B}} > \frac{Cov(\tilde{P}_1, \tilde{P}_2)}{Var(\tilde{P})}$*

Lemma 3 is a direct application of the condition $\alpha > \frac{\rho}{2}$ (i.e., Lemma 2) from the toy model in Section 2; $\frac{\tilde{C}}{\tilde{B}}$ represents α and $\frac{Cov(\tilde{P}_1, \tilde{P}_2)}{Var(\tilde{P})}$ represents $\frac{\rho}{2}$. There are two reasons to tie the manager's wage to the other stock price: doing so provides additional evidence of the manager's effort (effort sensitivity effect), and doing so can eliminate noise from the manager's wage (hedging effect). The effort sensitivity effect is captured by $\frac{\tilde{C}}{\tilde{B}}$, and the hedging effect is represented by $\frac{Cov(\tilde{P}_1, \tilde{P}_2)}{Var(\tilde{P})}$. The effort sensitivity effect measures how efficient (in terms of price responsiveness) it is to incentivize effort via the other firm's stock price relative to the manager's stock price. The hedging effect measures how providing these

incentives affects the manager's risk. If $\tilde{C}$ is large relative to $\tilde{B}$, it will be efficient to incentivize effort by putting more weight on the other firm's stock price rather than just on the manager's stock price because it provides additional evidence of managerial effort. Additionally, suppose $Cov(\tilde{P}_1, \tilde{P}_2) > 0$. Then a larger covariance induces the principal to lower $\tilde{n}$ (and potentially make it negative) to hedge out common sources of noise in the manager's pay. The reverse will be true if the covariance is negative. If $\text{Var}(\tilde{P})$ is large, then the principal will rely less on the other stock for any level of covariance because tying the manager's compensation to another volatile stock will increase his risk. After plugging in all the relevant expressions, I get Proposition 1, which states that the optimal contract always puts a positive weight on the other firm's stock price when there are index investors.

Proposition 1. *When there are index investors (i.e., $\lambda \neq 1$), $\tilde{n}^* > 0$. When there are only active investors, $\tilde{n}^* = 0$.*

Proposition 1 claims that the effort sensitivity effect always dominates the hedging effect, so $n^* > 0$. The two effects are working in the same direction when $Cov(\tilde{P}_1, \tilde{P}_2) < 0$, so the claim is only in doubt when the covariance is positive.[10] In this case, the effort sensitivity effect dominates because noise traders dilute the benefits of hedging.

To see this result, note that the hedging effect depends on both the covariance and variance of the prices. I will address each of these items in turn. The covariance can be expressed as:

$$Cov(\tilde{P}_1, \tilde{P}_2) = 2\left(\tilde{B}\tilde{C} + \frac{\tilde{D}\tilde{E}}{\tau_z}\right) \tag{8}$$

Recall that $\tilde{B}, \tilde{C}, \tilde{D} \geq 0$ and $\tilde{E} \leq 0$. These signs us that the first term in the covariance

[10]Whether the covariance is positive or negative depends on the parameters in my model—both can be achieved.

$(2\tilde{BC})$ is positive and the second term $(2\frac{\tilde{DE}}{\tau_z})$ is negative. The first term is the cash flow component of the covariance, and it is increasing in the fraction of index investors. Intuitively, as index investing increases, Firm 1's payoff appears more prominently in Firm 2's stock price (and vice-versa), increasing the correlation between the stocks.

However, this positive correlation is mitigated by the second term: the noise trader component. This term is negative and decreasing in the fraction of index investors. Negativity follows immediately from $\tilde{D} \geq 0$ and $\tilde{E} \leq 0$, and it decreases in the fraction of index investors because of how market clearing interacts with trader risk aversion. To be more precise, one can interpret the rational traders submitting demand schedules (active or indexed) as suppliers of liquidity and the noise traders as demanders of liquidity. When rational traders are risk averse, they will require compensation (i.e., a more favorable price) to supply liquidity to noise traders—since doing so forces them to hold greater quantities of risky assets. It follows that keeping noise demand constant, a decrease in the number of liquidity suppliers should result in a higher price of liquidity (i.e., stock prices becoming more sensitive to noise trader demand), as each remaining supplier must bear relatively more risk. Consequently, as index investing increases, there will be fewer suppliers of *relative* liquidity; that is, fewer traders to accommodate the difference in noise demand between the two stocks. Index investors can supply absolute liquidity, but not relative liquidity. Thus, the increased compensation required by active traders to supply relative liquidity as indexing grows in popularity makes $\tilde{D}(\tilde{E})$ more positive (negative)—amplifying the negative noise trader component of the covariance.

Thus, the two terms in the covariance somewhat offset each other, preventing the covariance from ever getting too positive. This result can be seen in Figure 1 [11]. The covariance

[11] This example sets $\tau_\epsilon = 2$, and $\tau_z = 6$

equals zero when there are only active investors and then slowly increases with the fraction of index investors. However, the noise trader component ($\frac{\tilde{D}\tilde{E}}{\tau_z}$) keeps the covariance from ever getting "too big" and eventually becomes so dominant that it drives the covariance negative.

We can see an analogous trend for the variance. The variance is defined as

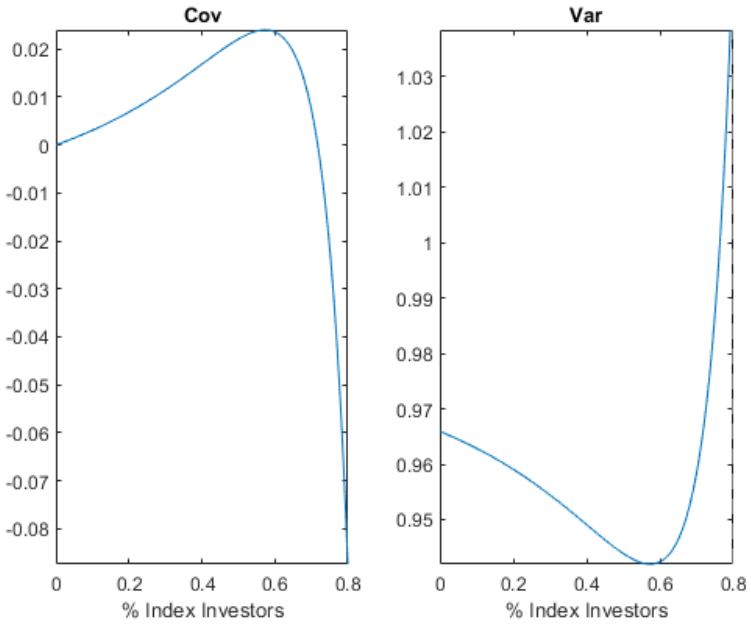
$$Var(\tilde{P}) = \tilde{B}^2 + \tilde{C}^2 + \frac{\tilde{D}^2 + \tilde{E}^2}{\tau_z}$$

Initially, the most important component of the variance is $\tilde{B}^2$, the squared sensitivity of the stock price to its cash flow (see Figure 2 for an illustration of the magnitudes). As a result, the variance initially decreases as the fraction of index investors increases because $\tilde{B}$ is decreasing in the fraction of index investors. However, for the same reasons mentioned in the discussion of the covariance, the increased sensitivity of prices to noise demand prevents the variance from ever getting too small.

Finally, the effort sensitivity effect gets stronger as indexing increases. This can be seen by looking at a graph of the price coefficients in Figure 2. As the fraction of index investors increases, $\tilde{B}$ decreases while $\tilde{C}$ increases, so the ratio $\frac{\tilde{C}}{\tilde{B}}$ is increasing in the fraction of index investors. Intuitively, with more indexers, prices should reflect the firm's cash flow less and the cash flow of the other firm more.

Putting all these pieces together, we see that the increased sensitivity of prices to noise trader demands as indexing increases prevents the benefits of hedging from ever getting large enough to dominate the effort sensitivity effect (Figure 3), leading to $\tilde{n}^* > 0$ whenever there are index investors. We can see these optimal normalized contracting coefficients as a function of the fraction of index investors in Figure 4. The principals put equal weight

Figure 1: Normalized Price Covariance and Variance

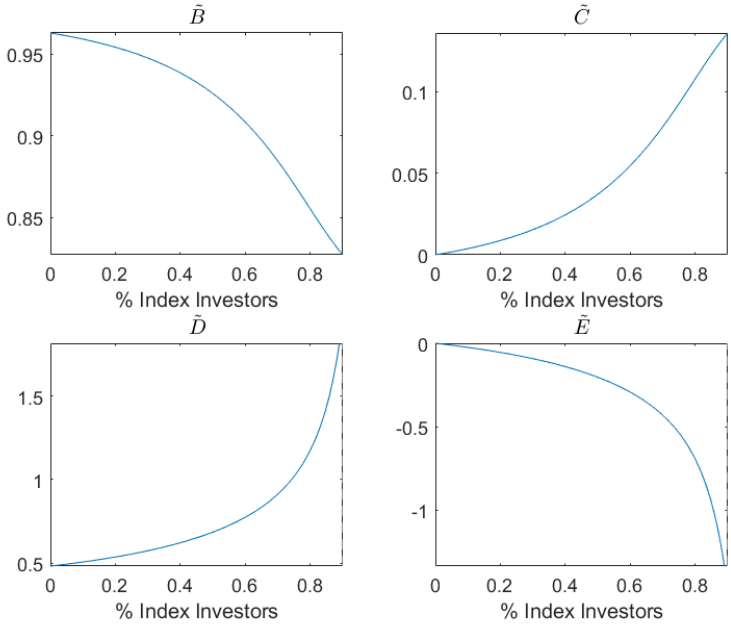


on both firms' stock prices when there are only index investors because the market cannot distinguish between the two firms in any way. The principals then put greater (less) weight on their (the other firm's) stock price as more active traders appear because it more (less) strongly reflects their manager's effort.

The above discussion implies that trader risk aversion is an important property for Proposition. My baseline case where the traders' common coefficient of absolute risk aversion equals one is enough to ensure that $\tilde{n}^* > 0$. However, when this coefficient of absolute risk aversion approaches zero (i.e., approaches risk neutrality), the active traders will not demand enough compensation in equilibrium to sufficiently dampen the correlation, making $\tilde{n}^*$ negative. Corollary 1 formalizes this argument.

Corollary 1. *There is some level of trader risk aversion $\gamma^* > 0$ such that for all $\gamma > \gamma^*$ we will have $\tilde{n^*} > 0$.*

Figure 2: Normalized Price Coefficients



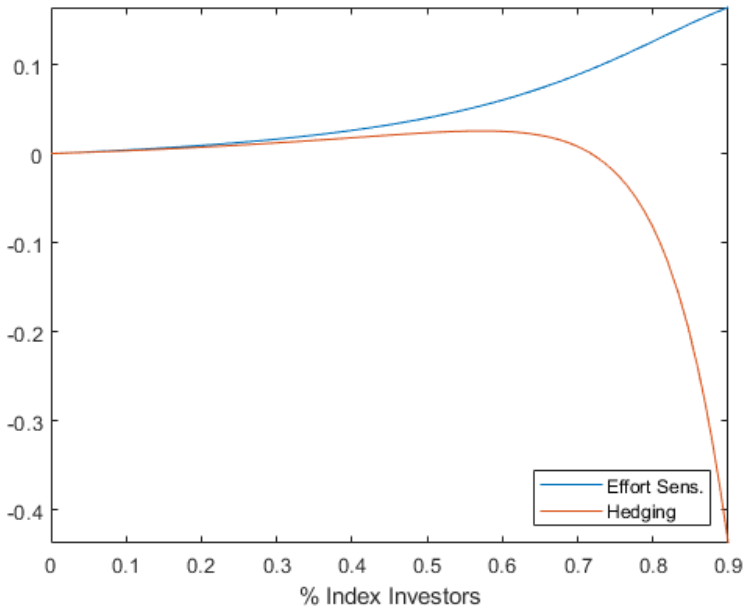
Interestingly, the manager's risk aversion has no impact on the signs of the contract parameters—it is only that of the traders that matters.

I can also derive the following results, whose empirical implications I will discuss in Section 7:

Proposition 2. *Comparitive statics for key outcomes:*

- $\tilde{n}^* \geq 0$ *and is increasing in the fraction of index investors.*
- $\tilde{m}^* \geq 0$. *Can be increasing or decreasing in the fraction of index investors.*
- *The wage covariance is positive and increasing in the fraction of index investors.*
- *Effort is positive and is decreasing in the fraction of index investors.*

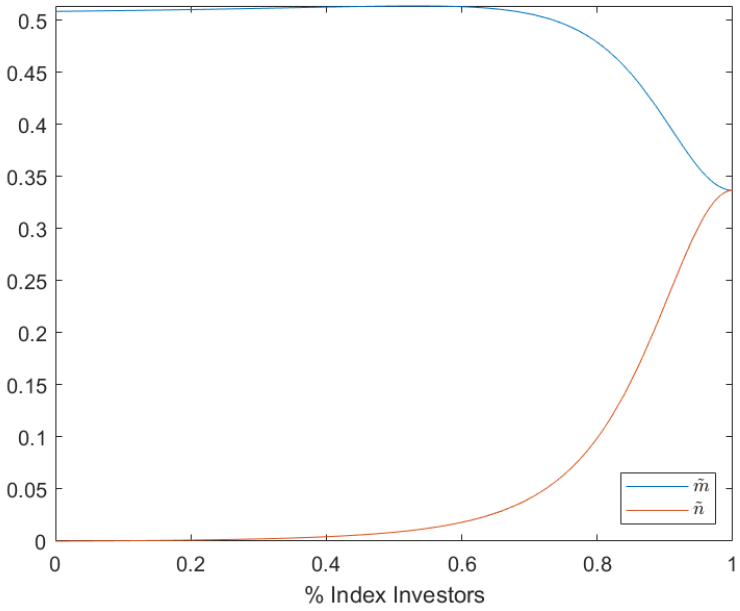
Figure 3: Effort Sensitivity and Hedging Effects



- *The principal's expected profits are positive and decreasing in the fraction of index investors.*

I have discussed the first point at length. The second point regarding the comparative statics of $\tilde{m}$ with respect to λ merits additional discussion. Under most parameters, $\tilde{m}$ decreases in the fraction of index investors because, with more index traders, the firm's stock price reflects managerial effort less intensely. However, price variance can also decrease with the fraction of index traders under certain parameters due to the magnitude of $\tilde{B}$—the most prominent coefficient in the pricing function (see Figures 1 and 2). Thus, when indexing reduces $\tilde{B}$, the variance declines, making stronger incentives—that is, a higher level of $\tilde{m}$—increasingly optimal as indexing grows. However, this effect only occurs when the traders' signal and noise demand is sufficiently precise, so under most parameters, $\tilde{m}$ decreases in the fraction of index investors.

Figure 4: Normalized Contracting Parameters



Increased wage covariance is a direct consequence of firms more closely tying their manager's wage to the stock performance of the other firms. The final two points follow from price efficiency decreasing with the fraction of index investors in my model. With more index investors, the manager's effort is reflected less strongly in his stock price, more strongly in the other firm's stock price, and less overall. Thus, some information is "lost" with more index investors, which hurts incentives and profits.

4.3 Original Performance Measures

I now want to map $\tilde{m}$ and $\tilde{n}$ back into the original contract parameters m and n. Inverting the mappings given by Equation (4) gives us the following characterization of m and n in

terms of $\tilde{m}, \tilde{n}$.

$$m_1^* = m_2^* \equiv m^* = \frac{\tilde{m}^2 - \tilde{m} - \tilde{n}^2}{2\tilde{m} - \tilde{m}^2 + \tilde{n}^2 - 1} \tag{9}$$

$$n_1^* = n_2^* \equiv n^* = \frac{-\tilde{n}}{2\tilde{m} - \tilde{m}^2 + \tilde{n}^2 - 1} \tag{10}$$

By undoing the normalization, we get the following proposition.

Proposition 3. *Optimal contract parameters based on the original prices have the same sign as those based on the normalized prices.*

The intuition for the original contract is largely the same as for the normalized contract.

We can also rewrite the original price coefficients as functions of the normalized price coefficients and the normalized contract parameters.

$$B = \tilde{B} - \tilde{m}\tilde{B} - \tilde{n}\tilde{C}$$

$$C = \tilde{C} - \tilde{m}\tilde{C} - \tilde{n}\tilde{B}$$

$$D = \tilde{D} - \tilde{m}\tilde{D} - \tilde{n}\tilde{E}$$

$$E = \tilde{E} - \tilde{m}\tilde{E} - \tilde{n}\tilde{D}$$

The price coefficients can be interpreted as the sum of the following three components. I'll use B as an example, but the rest of the coefficients follow the same pattern.

1. The normalized price coefficient ($\tilde{B}$)
2. The reduction in dividends caused by placing incentives on the firm's stock price ($-\tilde{m}\tilde{B}$)

3. The reduction in dividends caused by placing incentives on the other firm's stock price $(-\tilde{n}\tilde{C})$

How does a marginal increase in Firm 1's cash flow affect P_1? First, there is the elementary effect of higher cash flows leading to higher dividends. $\tilde{B}$ represents this effect and measures how sensitive the price is to dividends in a world without the contracting problem. Second, because higher cash flows mean higher prices, dividends are reduced because the manager receives a higher wage. The manager's compensation is related to his firm's cash flow through $\tilde{B}\tilde{m} + \tilde{C}\tilde{n}$. This term negatively affects dividends. Therefore, higher cash flows have both positive and negative effects on the stock price, but in the end, $B > 0$, so the positives outweigh the negatives. This result does not necessarily follow for C, however, because the positive cash flow effect of $\tilde{C}$ is relatively small and the negative cash flow effect of $\tilde{m}\tilde{C} + \tilde{n}\tilde{B}$ is large. Thus, C can be positive or negative depending on the parameters. Nevertheless, this outcome does not overturn my result about the effort sensitivity effect dominating the hedging effect in the most empirically relevant case where $Cov(P_1, P_2) > 0$ (see Barberis et. al (2005) and Da and Shive (2017)). Recall that the covariance between the two original prices is

$$Cov(P_1, P_2) = 2\left(BC + \frac{DE}{\tau_z}\right)$$

We still have $D > 0$ and $E < 0$, so a necessary condition for a positive covariance given the other parameters is $C > 0$. Thus, if we focus on parameters that generate a positive covariance, the effort sensitivity still dominates the hedging effect because n^* is guaranteed to be positive by Proposition 3.

5 Common Ownership

I have so far ignored how the growth of index investing may change the principal's objective function. Index investors typically purchase an index through an index fund or an ETF managed by a large asset manager such as Vanguard or BlackRock. The common ownership literature examines how corporate governance changes as these asset managers build increasingly large stakes in many firms due to the growth of indexing. One view is that these asset managers try to maximize the value of their entire portfolio, which may be inconsistent with maximizing the value of each constituent firm. For example, individual firm value maximization may lead to inefficiently aggressive competition between firms from the asset manager's perspective. One hypothesized way to prevent such things from happening is to rely less on relative performance evaluation for managerial incentives or even to put a positive contract weight on a competing firm's stock price (Gordon (1990) and Aggarwal and Samwick (1999)).

My paper, therefore, offers a separate rationale for placing a positive contract weight on competitors' stock prices: it helps incentivize managerial effort. In my model, introducing a common principal that maximizes

$$E(x_1 + x_2 - w_1 - w_2)$$

would not alter the optimal contracts because the $x's$ only depend on their own manager's effort. I will now provide an extension where each manager's effort impacts the other firm's payoff. Define Firm k's new mean payoff as

$$\overline{e_k} = e_k + \beta e_j, \text{ for } k, j \in \{1, 2\}, k \neq j \text{ and } \beta \in (-1, 1) \tag{11}$$

So now the mean of x_1 is $\overline{e_1}$, which is impacted by both Manager 1's effort (through e_1) and Manager 2's effort (through e_2). The parameter β reflects how sensitive Firm 1's output is to Manager 2's effort (and vice-versa). My base model is, therefore, a specialized case with $\beta = 0$. A positive β describes a situation where the two managers' efforts complement each other. This situation could represent a manufacturer and a retailer; both firms benefit if the manufacturer makes higher quality products and the retailer becomes more effective at sales. We can interpret a negative β as a situation where the two firms are rivals competing for the same market share.

This modeling change only affects the equilibrium asset prices $(\tilde{P}_1, \tilde{P}_2)$ through changed mean payoffs. Importantly, price coefficients $\tilde{B}, \tilde{C}, \tilde{D}$, and $\tilde{E}$ are unchanged because they only depend on exogenous parameters (τ_ϵ, τ_z, and λ). Consequently, the variances and covariances of the prices are also unchanged.[12]

Given the unchanged asset prices, we can jump directly to the contracting problem.

5.1 Single Principals

A single principal maximizing his own firm's expected dividends solves:

$$\max_{\tilde{l_k}, \tilde{m_k}, \tilde{n_k}} E(x_k - w_k) \tag{12}$$

$$\text{s.t. } E(w_k) - \frac{1}{2}e_k^2 - \frac{1}{2}Var(w_k) \geq 0 \tag{IR}$$

$$e_k \in \underset{\hat{e_k}}{\text{argmax}}\, E(w_k) - \frac{1}{2}\hat{e_k}^2 - \frac{1}{2}Var(w_k) \tag{IC}$$

[12] I focus on the normalized stock prices denoted with a tilde for tractability in this section.

where now:

$$E(x_k) = e_k + \beta e_j$$

$$E(w_k) = E(\tilde{l_k} + \tilde{m_k}\tilde{P_k} + \tilde{n_k}\tilde{P_j})$$

$$= \tilde{l_k} + \tilde{m_k}(\tilde{A} + \tilde{B}(e_k + \beta e_j) + \tilde{C}(e_j + \beta e_k)) + \tilde{n_k}(b_{0j} + \tilde{B}(e_j + \beta e_k) + \tilde{C}(e_k + \beta e_j))$$

Without loss of generality, I will focus on the optimal contract for Manager 1. Manager 2's contract will take an analogous form. Manager 1's optimal choice of effort is then

$$e_1^* = \tilde{m_1}(\tilde{B} + \beta\tilde{C}) + \tilde{n_1}(\tilde{C} + \beta\tilde{B}) \tag{13}$$

The manager's effort appears in two additional places relative to the base model: through the x_2 terms in both his and Firm 2's stock prices. Holding the contract fixed with $\tilde{m}, \tilde{n} > 0$, a positive β induces more effort from the manager because his effort is more strongly reflected in the stock market. Conversely, a negative β generates less effort because effort lowers the payoff and expected stock price of Firm 2. The signs of the optimal contracting parameters are described by a condition analogous to Lemma 3:

Lemma 4. *The optimal choice of $\tilde{m}$ will be greater than or equal to zero if and only if $\frac{\tilde{B}+\beta\tilde{C}}{\tilde{C}+\beta\tilde{B}} \geq \frac{Cov(\tilde{P_1},\tilde{P_2})}{Var(\tilde{P})}$. The optimal choice of $\tilde{n}$ will be greater than or equal to zero if and only if $\frac{\tilde{C}+\beta\tilde{B}}{\tilde{B}+\beta\tilde{C}} \geq \frac{Cov(\tilde{P_1},\tilde{P_2})}{Var(\tilde{P})}$.*

The hedging effect is the same as before, but now the effort sensitivity effect considers how effort affects the other firm's cash flows. I assume throughout that the exogenous parameters are such that $Cov(\tilde{P_1}, \tilde{P_2}) > 0$ because that is the most empirically relevant case.

Suppose $\beta > 0$; then both $\tilde{m}$ and $\tilde{n}$ remain positive. In fact, the effort sensitivity effect is

stronger than in the base case with $\beta = 0$. This result follows because a positive β increases Stock 2's sensitivity to Manager 1's effort more than Stock 1's; mathematically, $\frac{\tilde{C}+\beta\tilde{B}}{\tilde{B}+\beta\tilde{C}} > \frac{\tilde{C}}{\tilde{B}}$ because $\beta > 0$ and $\tilde{B} > \tilde{C} > 0$. Intuitively, because stock prices are more sensitive to their cash flow than the other firm's cash flow (i.e., $\tilde{B} \geq \tilde{C}$), the impact that effort has on Firm 2's cash flow through β is more strongly reflected in Firm 2's stock price than in Firm 1's.

The results are less clear cut when $\beta < 0$. I assume that $\beta \in (-\frac{\tilde{B}}{\tilde{C}}, 0)$ because if it were more negative, the manager's effort would be so destructive for the other firm that greater effort would actually reduce *his own* expected stock price, which seems unrealistic. If $\beta \in (-\frac{\tilde{B}}{\tilde{C}}, -\frac{\tilde{C}}{\tilde{B}})$, $\tilde{n}$ will trivially be negative because both the effort sensitivity and hedging effects call for a negative sign. The effort sensitivity effect wants a negative sign in this region because effort reduces the expected stock price of the other firm, and the hedging effect also wants a negative sign because the correlation between the two stock prices is positive. One can then show that if $\beta \in \left(-\frac{\tilde{C}}{\tilde{B}}, \frac{\tilde{C}var(\tilde{P})-\tilde{B}Cov(\tilde{P}_1,\tilde{P}_2)}{\tilde{C}Cov(\tilde{P}_1,\tilde{P}_2)-\tilde{B}var(\tilde{P})}\right)$, $\tilde{n}$ will be negative, and if $\beta \in \left(\frac{\tilde{C}var(\tilde{P})-\tilde{B}Cov(\tilde{P}_1,\tilde{P}_2)}{\tilde{C}Cov(\tilde{P}_1,\tilde{P}_2)-\tilde{B}var(\tilde{P})}, 0\right)$, $\tilde{n}$ will be positive. Basically, for a fixed hedging effect, a lower β makes a negative $\tilde{n}$ increasingly optimal because the manager's effort is reflected less positively in the other firm's stock price.

5.2 Common Owner

A common owner who maximizes joint dividends solves:

$$\max_{\tilde{l},\tilde{m},\tilde{n}} E(x_1 + x_2 - w_1 - w_2) \tag{14}$$

$$\text{s.t. } E(w_k) - \frac{1}{2}e_k^2 - \frac{1}{2}Var(w_k) \geq 0 \text{ for } k \in \{1,2\} \tag{IR}$$

$$e_k \in \underset{\hat{e_k}}{\text{argmax}}\, E(w_k) - \frac{1}{2}\hat{e_k}^2 - \frac{1}{2}Var(w_k) \text{ for } k \in \{1,2\} \tag{IC}$$

Each manager's optimal effort choice is still given by Equation (13). The only substantive difference between the common owner and single principal problems is that the common owner considers how each manager's effort impacts the other firm's payoff in the $E(x_1 + x_2)$ portion of his objective function. Thus, when deciding on Manager 1's contract, the common owner considers $(1+\beta)e_1^*$ instead of e_1^*. Let $\tilde{m_s}$ and $\tilde{n_s}$ be the optimal contracts for the single principal (as solved for in Section 5.1) and $\tilde{m_c}$ and $\tilde{n_c}$ be the optimal common owner contract. It turns out that there is a simple relation between the two:

Proposition 4. *The optimal common owner contract parameters are the optimal single owner contract parameters multiplied by* $1+\beta$*. That is,* $\tilde{m_c} = (1+\beta)\tilde{m_s}$ *and* $\tilde{n_c} = (1+\beta)\tilde{n_s}$*.*

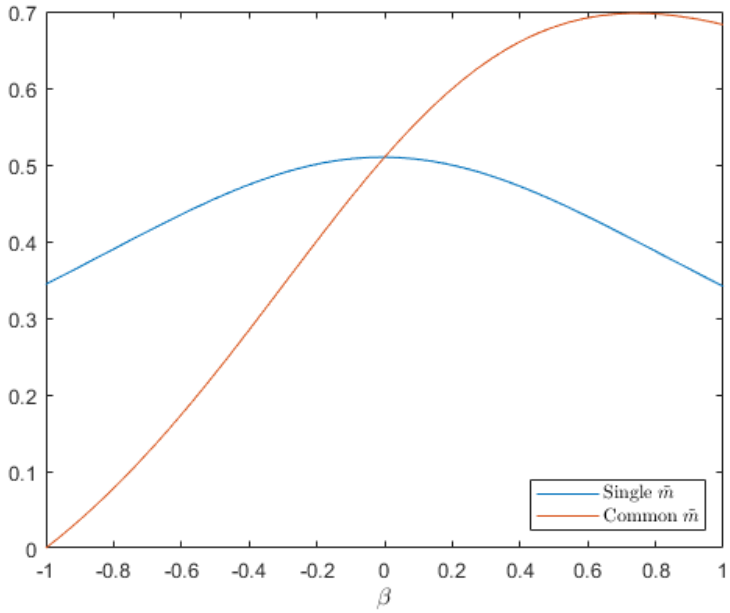
Thus, for $\beta > -1$, the common owner simply scales the single-owner contract up or down without changing the sign. A positive β means that each manager's effort generates a positive externality for the other firm that the single owner does not care about. The common owner wants to take advantage of this positive externality, which makes each contract more performance-sensitive in a positive direction. The opposite happens when $\beta \in (-1, 0)$. Each manager's effort generates a negative externality for the other firm, so the common owner makes the optimal contract less performance-sensitive, but with the same sign. In the extreme case where $\beta < -1$, the negative externality is so severe that it outweighs the positive effect the manager's effort has on his firm's performance, so the common owner flips the signs on the optimal contract parameters.

In sum, all common ownership does in the realistic case where $\beta \in (-1, 1)$ is change the magnitude of the single-owner contract without altering the sign. Common ownership is, therefore, not the driving force behind a positive sign on the other firm's stock price in the optimal contract; rather, the key is still the relative sizes of the effort sensitivity and the hedging effects. Thus, the results of my paper caution against interpreting the presence

of a positive association between managerial compensation and the stock performance of peers as evidence of anti-competitive activities. A model in which each firm is a strict profit maximizer that wants to incentivize greater managerial effort can also generate such a result.

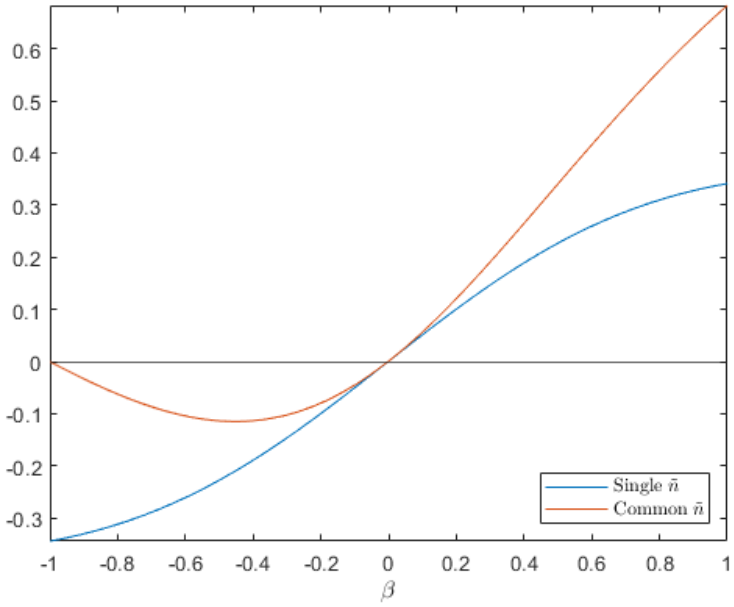
Plots of the optimal $\tilde{m}$ and $\tilde{n}$ for the single and common owner as a function of β are shown below. In these plots, the fraction of index investors is set at 33.5% to match the headline estimate from Chinco and Sammon (2024). In Figure 5, we see that the optimal $\tilde{m}$ is positive everywhere, but the common owner sets it higher when $\beta > 0$ and lower when $\beta < 0$. The optimal $\tilde{n}$ (see Figure 6) can be positive or negative depending on β, but the sign on the common owner's contract is always the same as the single owner's.

Figure 5: Single and Common Owner $\tilde{m}$



Finally, I address how common ownership addresses effort. Proposition 2 claims that effort decreases in the fraction of index investors because traders' information about the manager's actions is reflected less strongly in financial market prices. However, this result

Figure 6: Single and Common Owner $\tilde{n}$



may change if the growth in indexing also induces a common ownership motivation.

Corollary 2. *Equilibrium effort will be higher under common ownership whenever* $\beta > 0$.

The intuition for Corollary 2 is similar to Proposition 4; a common owner internalizes the manager's effort slipovers to a greater degree than separate owners and thus is more (less) willing to incentivize effort when β is positive (negative). Therefore, if $\beta > 0$, index investing can lead to greater equilibrium effort if it also induces common ownership.

6 Robustness

6.1 Number of Firms

It is tempting to think that the preeminence of the effort sensitivity effect in Proposition 1 is a consequence of there being two firms. With two firms, good aggregate cash flow signals can only come from two places, so indexed investors buy relatively large amounts of both firms. As a result, Firm $1's$ stock price will be quite sensitive to Firm $2's$ cash flows. It then stands to reason that index investors will further divide their asset demands as the number of firms increases, so Firm 1's stock price will be less sensitive to any other firm's cash flow. However, the effort sensitivity effect always dominates, even with an arbitrarily large number of firms.

Proposition 5. *Both $\tilde{m}^*$ and $\tilde{n}^*$ are greater than or equal to zero for all number of firms $N \geq 2$.*

The condition outlined in Lemma 3 is still decisive, even with N firms. Although the sensitivity of Firm 1's stock price to x_2 declines as the number of firms increases, so does the covariance-variance ratio and the sensitivity of Firm 1's stock price to its own cash flow. In the end, the effort sensitivity effect still dominates. However, even though $\tilde{n}^*$ is always positive, its magnitude is decreasing in N; the optimal contract puts less weight on each firm in the index, but that weight is always positive.

Even though the optimal contract puts less weight on the other firms' stock prices as N increases, it turns out that their combined weight is increasing in N. The principal will put the same weight, $\tilde{n}^*$, on all other index firms in the contract because they are ex-ante identical. Therefore, the principal puts a combined weight of $(N-1)\tilde{n^*}$ on all other firms. My claim is then formally expressed in the following lemma:

Lemma 5. *The combined weight that the optimal contract puts on all other index firms,* $(N-1)\tilde{n^*}$*, is increasing in N.*

The intuition for Lemma 5 comes from how index investors split their demands across index constituents. Suppose the manager of Firm 1 takes good action and increases his firm's payoff. Index investors expect higher index payoffs and buy more of all index firms. When there are N=2 firms in the index, this demand is split between the two firms. One can crudely think of this as index investors assigning 50% of "the credit" for this signal to Stock 1 and 50% to Stock 2. When there are N=100 firms in the index, the demand is split between one hundred firms, so index investors assign 1% of "the credit" to Stock 1 and 99% to the remaining stocks. As a result, they assign relatively more of "the credit" to other firms in the index as N increases. The optimal contract reflects this outcome by putting more combined weight on other firms' stock prices as N increases.

We can also see this result by looking at the stock prices when there are N firms.

$$\tilde{P_k} = \tilde{A} + \tilde{B}x_k + \tilde{C}(x_1 + ...x_{k-1} + x_{k+1} + ...x_N) + \tilde{D}z_k + \tilde{E}(z_1 + ...z_{k-1} + z_{k+1} + ...z_N)$$

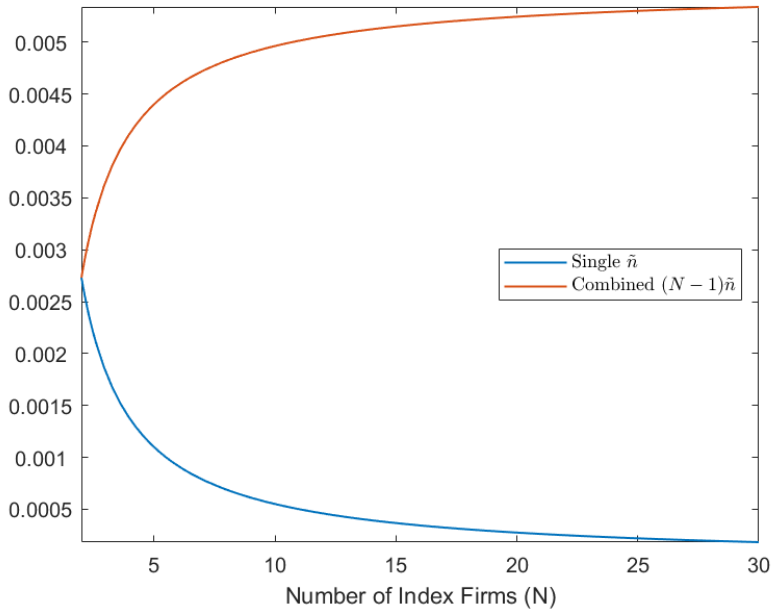
Therefore, the sensitivity of firm $k's$ stock price to its cash flow is $\tilde{B}$, while the combined sensitivity of all other firms' stock prices to firm k's cash flow is $(N-1)\tilde{C}$.

These terms equal:

$$\begin{aligned}\tilde{B} &= \frac{\tau_z\tau_\epsilon^2 + \tau_\epsilon}{\tau_z\tau_\epsilon^2 + \tau_\epsilon + 1} + \frac{1}{N}\left(\frac{\tau_z\tau_\epsilon^2 + \tau_\epsilon}{\tau_z\tau_\epsilon^2 + \tau_\epsilon + 1} - \frac{\lambda^2\tau_z\tau_\epsilon^2 + \tau_\epsilon}{\lambda^2\tau_z\tau_\epsilon^2 + \tau_\epsilon + 1}\right) \\ (N-1)\tilde{C} &= \frac{N-1}{N}\left(\frac{\tau_z\tau_\epsilon^2 + \tau_\epsilon}{\tau_z\tau_\epsilon^2 + \tau_\epsilon + 1} - \frac{\lambda^2\tau_z\tau_\epsilon^2 + \tau_\epsilon}{\lambda^2\tau_z\tau_\epsilon^2 + \tau_\epsilon + 1}\right) \end{aligned} \tag{15}$$

Since $\frac{\tau_z\tau_\epsilon^2+\tau_\epsilon}{\tau_z\tau_\epsilon^2+\tau_\epsilon+\tau_x} \geq \frac{\lambda^2\tau_z\tau_\epsilon^2+\tau_\epsilon}{\lambda^2\tau_z\tau_\epsilon^2+\tau_\epsilon+\tau_x}$, it is easy to see that $\tilde{B}$ is decreasing in N while $(N-1)\tilde{C}$ is increasing in N. That is, Firm 1's stock price becomes less sensitive to its cash flow, and the rest of the stock market becomes more sensitive to Firm 1's cash flow as N increases. These results can be seen graphically in Figure 7.[13]

Figure 7: Single $\tilde{n}$ and Combined $(N-1)\tilde{n}$



6.2 Index Investor Information Set

The theoretical literature has not yet reached a consensus about the best way to model the information sets of index investors. Some papers (e.g., Bond and Garcia (2022)) let index investors condition their index demand on both private information and equilibrium prices, while on the other extreme, Coles et al. (2022) model index investors as only us-

[13]The fraction of index investors is set to 33.5% to match the headline estimate from Chinco and Sammon (2024).

ing prior information. I follow the former approach in this paper and allow index investors to have private information. Specifically, index investors in my model only receive private information about the cash flows of the index, while active investors receive private information about both index and relative cash flows. Gathering private information on index cash flows can be thought of as focusing on broad economic developments rather than on individual firms. One can, therefore, view an index investor in my model as someone who researches the state of the economy and arrives at some private conclusion. Or alternatively, one can view the index investors in my model as macro or industry specialists who gather information about a given sector of the economy rather than on firm-specific details. With this interpretation, index investors are not necessarily passive investors—even though the two terms are generally used interchangeably in the literature.

However, I will now examine what happens to my results if index investors have no private information. Suppose we model index investors as having no private information but rationally incorporating any public information embedded in the prices. Each index investor then demands:

$$D(i, IN) = \frac{E(x_{IN}|P_{IN}) - w_{IN} - P_{IN}}{Var(x_{IN}|P_{IN})}$$

Shocks to Firm 1 still impact Firm 2's stock price through the demands of index investors. Suppose x_1's realization is higher than expected. Index investors see a higher index price, but since they do not see a commensurate increase in cash flow expectations, they buy less of the index; this action lowers Firm 2's stock price. Therefore, Firm 2's stock price still reflects Manager 1's effort (albeit in the opposite direction), so the optimal contract will depend on it. However, the effort sensitivity effect now suggests placing a negative weight

on the other firm's stock price. The hedging effect always implies a positive weight because the stock covariance is negative in this setting. In the end, the hedging effect dominates because both terms of the covariance (see Equation 8) are negative, making the covariance's magnitude more extreme and thus amplifying the benefits of hedging.

I can take this reasoning a step further. The minimum condition required for each firm's stock price to reflect the fundamentals[14] of the other is that index investors do not have perfectly inelastic demand for the index asset. As long as index investors have price-sensitive demand, each firm's stock price will somewhat reflect the fundamentals of the other through this demand. Private information, optimally incorporating all public information, or even downward sloping demand is not required—just that index demand is price sensitive.

The "no private information" conclusions also lead to some results that go against the empirical evidence. A model where index investors have no private information leads to a negative correlation between the two stock prices. In contrast, nearly all empirical work on index investing finds that indexing induces a positive correlation (e.g., Barberis et al. (2005) for S&P 500 index funds and Da and Shive (2017) for ETFs). A necessary condition for a positive correlation in my model is that index investors buy more of the index when its payoff is higher. This condition fails in the model with no private information because investors cannot tell index price increases caused by cash flows versus noise demand apart, so they buy less of the index following a price increase. Providing index investors with a private signal about index cash flows can be enough to increase their demand for the index following a rise in one of the firm's cash flows. My results also do not depend on index investors having the same aggregate signal quality as active investors. I only require that the indexers' signals are not *too* much worse.

[14]By fundamentals, I mean x and z.

6.3 Endogenous Indexing

So far, the fraction of indexers $(1 - \lambda)$ has been an exogenous parameter. However, one can endogenize this parameter by having investors decide ex-ante whether to be active or indexed. To do so, I impose some cost $c > 0$ to being active; otherwise, all investors would become active. Such an assumption is typical in equilibrium models of index investing (e.g., Bond and Garcia (2022) and Coles, Heath, and Ringgenberg (2022)). I interpret this cost as an information acquisition cost since active investors receive both aggregate and relative payoff signals instead of just aggregate.

Investors must be indifferent ex-ante between being active (and thus having greater portfolio flexibility) and being indexed (to avoid paying the cost c) for there to be an interior fraction of indexers in equilibrium. I formally analyze the equilibrium fraction of indexers in Appendix 2. I summarize the main conclusion of this analysis in the following proposition.

Proposition 6. *There are two types of equilibria: (1) with an interior fraction of index investors (i.e,* $\lambda \in (0, 1)$*) and (2) with no index investors (i.e,* $\lambda = 1$*). There does not exist an equilibrium with only index investors (i.e,* $\lambda = 0$*).*

In general, my proof follows closely that of Theorem 3 in the seminal work by Grossman and Stiglitz (1980), where they try to pin down the ratio of informed to uninformed traders. However, unlike in Grossman and Stiglitz (1980), there is no equilibrium where all the traders are of the less-informed type (i.e., index investors) in my model. This conclusion follows from the crucial fact that index investors are unable to supply relative liquidity to noise traders (see the discussion following Proposition 1). Because index investors cannot step in to supply liquidity when noise traders demand different quantities of Stocks 1 and 2, markets can only clear if there exists some positive mass of active traders who can. Thus, as the fraction of

index investors increases, prices become more sensitive to noise trader demand to compensate active investors for taking on greater relative payoff risk. Thus, for any finite cost of being active $c > 0$, there will always be some trader who will deviate from indexed to active as the fraction of index investors approaches one—since the expected trading gains from doing so become arbitrarily large.

7 Empirical Predictions

My model's primary empirical prediction is that greater index investing should result in executive pay being more positively linked with index performance (for firms in an index). To my knowledge, there is no direct empirical test of this prediction, but there are related studies examining how the growth in common ownership—which is driven by the indexing—affects executive pay; Anton et al. (2022) and Liang (2016) both show that increases in common ownership lead to executive pay that loads more positively on peer performance.[15] One could test my specific hypothesis that indexing drives greater pay for peer (or index) performance by looking at the response of CEO pay in firms that are added or deleted from indexes; that is, using the standard "index reconstitution" identification strategy (see Appel, Gormley, and Keim (2024) for a discussion of this common identification strategy).

Second, my model predicts that within-index executive pay should become more highly correlated as indexing grows. While not a direct test, recent work by Jochem et al. (2021) and Cabezon (2021) demonstrates that CEO pay has become more uniform. In particular, Jochem et al. (2021) claim that increased reciprocal benchmarking is the primary cause of this trend and that the growth of index investing drives reciprocal benchmarking. This

[15]Kwon (2016) finds the opposite result: common ownership is associated with more relative performance pay, so the empirical evidence is not unanimous.

result is consistent with my model. However, their rationale for why index investing increases benchmarking is that index investors are more likely to rely on proxy advisors— who typically analyze compensation relative to peers—for voting recommendations. My paper suggests an additional channel for this phenomenon: index investing causes stocks in the same index to reflect the effort of all managers, so linking a manager's compensation to the index's performance improves incentives. In other words, there are two ways through which index investing can make contracts more similar: (1) the governance channel identified by Jochem et al. (2021) and (2) the asset pricing channel implied by my model. Which channel is more important is an interesting unanswered empirical question.

Additionally, my model predicts that the effect of indexing on pay-performance sensitivity should be ambiguous. Specifically, this sensitivity should decrease whenever the traders' signals and noise demand are noisy enough to ensure that price volatility increases in the fraction of index investors. There exists evidence consistent with this condition, as Coles, Heath, and Ringgenberg (2018) and Ben-David et al. (2018) show that stock volatility increases with indexing. Given that the real-world parameters appear to be such that stock volatility increases with index investing, my model predicts that pay-performance sensitivity should decline with greater index investing. Once again, the most direct evidence for my prediction comes from the common ownership literature: Anton et al. (2022) find that increases in common ownership are associated with a decline in the performance sensitivity of managerial pay.

As the previous few paragraphs show, most of the existing evidence for my model's predictions comes from the common ownership literature rather than directly through indexing. Future theoretical work can examine the relative importance of these channels on executive compensation (or governance more generally) by integrating more realistic financial markets

into models of common ownership. Specifically, by having common ownership arise endogenously through the rise in index investing. Empirically, one can examine the differential impact of the asset pricing versus the common ownership effect of indexing by trying to isolate these two channels. One intriguing possibility for empirical work comes from the recent trend of asset managers instituting "pass-through voting," where end investors in a fund can independently cast votes instead of automatically delegating them to the fund. While few investors utilize these programs now,[16] if they become more popular going forward, we would see a reduction in effective common ownership while preserving the asset pricing effects of indexing. More specifically, my model predicts that common ownership has a second-order effect on executive compensation—the main driver is changing asset prices. Thus, holding indexing fixed, a decline in effective common ownership should not change the signs on the optimal contract parameters.

Conclusion

I develop a joint model of financial markets with index investors and contracting with moral hazard to examine how changes in the prevalence of indexing impact optimal managerial contracts. Index investors are constrained to purchase all risky assets in the same proportion, so information that affects their demand for the index is transmitted to all constituent stocks.

There are two (possibly conflicting) reasons to condition a manager's compensation on these other firms: (1) to increase the effort sensitivity of the manager's pay and (2) to hedge the manager's risks. The former reason is a consequence of the synchronized asset demands

[16]For example, only around 10% of the dollars in BlackRock's index equity funds exercise voting choice. https://www.blackrock.com/corporate/about-us/investment-stewardship/blackrock-voting-choice

of index investors distributing information about the manager's effort to these stocks. The latter reason comes from the relative performance evaluation literature: the principal should utilize the non-zero correlation between the stocks to reduce the manager's exposure to common risks. I find that the effort sensitivity channel dominates the hedging channel because indexing also allows noise traders to play a more prominent role in determining relative prices, which dampens the benefits of hedging.

Stock prices are a useful conditioning variable for managerial compensation because they are an easy-to-access and high-frequency performance measure. Thus, assuming prices are relatively efficient, they enable one to learn about actions privately taken by a manager. However, financial markets are constantly evolving, so firms must consider how these changes—such as the growth of index investing—impact the optimal incentive scheme for their manager.

References

Admati, A. R. (1985). A noisy rational expectations equilibrium for multi-asset securities markets. *Econometrica*, *53*(3), 629–657.

Admati, A. R., & Pfleiderer, P. (1987). Viable allocations of information in financial markets. *Journal of Economic Theory*, *43*(1), 76–115.

Aggarwal, R. K., & Samwick, A. A. (1999). Executive compensation, strategic competition, and relative performance evaluation: Theory and evidence. *The Journal of Finance*, *54*(6), 1999–2043.

Anton, M., Ederer, F., Gine, M., & Schmalz, M. (2022). Common ownership and relative performance evaluation. *Working Paper*.

Anton, M., Ederer, F., Gine, M., & Schmalz, M. (2023). Common ownership, competition, and top management incentives. *Journal of Political Economy*, *131*(5), 1294–1355.

Appel, I. R., Gormley, T. A., & Keim, D. B. (2024). Identification using russell 1000/2000 index assignments: A discussion of methodologies. *Critical Finance Review*, *13*(1-2), 151–224.

Azar, J., Schmalz, M. C., & Tecu, I. (2018). Anticompetitive effects of common ownership. *The Journal of Finance*, *73*(4), 1513–1565.

Barberis, N., Shleifer, A., & Wurgler, J. (2005). Comovement. *Journal of Financial Economics*, *75*(2), 283–317.

Baruch, S., & Zhang, X. (2022). The distortion in prices due to passive investing. *Management Science*, *68*(8), 6219–6234.

Bizjak, J., Kalpathy, S., Li, Z. F., & Young, B. (2022). The choice of peers for relative performance evaluation in executive compensation. *Review of Finance*, *26*(5), 1217–1239.

Bond, P., Edmans, A., & Goldstein, I. (2012). The real effects of financial markets. *Annual Review of Financial Economics*, *4*, 339–360.

Bond, P., & García, D. (2021). The equilibrium consequences of indexing. *The Review of Financial Studies*, *35*(7), 3175–3230.

Buss, A., & Sundaresan, S. (2023). More risk, more information: How passive ownership can improve informational efficiency. *The Review of Financial Studies*, *36*(12), 4713–4758.

Cabezon, F. (2025). Executive compensation: The trend toward one-size-fits-all. *Journal of Accounting and Economics*, *79*(1), 101708.

Chinco, A., & Sammon, M. (2024). The passive ownership share is double what you think it is. *Journal of Financial Economics*, *157*, 103860.

Coles, J. L., Heath, D., & Ringgenberg, M. C. (2022). On index investing. *Journal of Financial Economics*, *145*(3), 665–683.

Da, Z., & Shive, S. (2018). Exchange traded funds and asset return correlations. *European Financial Management*, *24*(1), 136–168.

Davies, S. (2024). ETF demand and stock returns. *Working Paper*.

De Angelis, D., & Grinstein, Y. (2020). Relative performance evaluation in ceo compensation: A talent-retention explanation. *The Journal of Financial and Quantitative Analysis*, *55*(7), 2099–2123.

DeMarzo, P. M., & Kaniel, R. (2023). Contracting in peer networks. *The Journal of Finance*, *78*(5), 2725–2778.

Diamond, D. W., & Verrecchia, R. E. (1982). Optimal managerial contracts and equilibrium security prices. *The Journal of Finance*, *37*(2), 275–287.

Diamond, D. W., & Verrecchia, R. E. (1981). Information aggregation in a noisy rational expectations economy. *Journal of Financial Economics*, *9*(3), 221–235.

Edmans, A., Gabaix, X., & Jenter, D. (2017). Chapter 7 - Executive Compensation: A Survey of Theory and Evidence. *The Handbook of the Economics of Corporate Governance*, *1*, 383–539.

Edmans, A., Gosling, T., & Jenter, D. (2023). CEO compensation: Evidence from the field. *Journal of Financial Economics*, *150*(3), 103718.

French, K. R. (2008). Presidential address: The cost of active investing. *The Journal of Finance*, *63*(4), 1537–1573.

Garvey, G., & Milbourn, T. (2003). Incentive compensation when executives can hedge the market: Evidence of relative performance evaluation in the cross section. *The Journal of Finance*, *58*(4), 1557–1582.

Giglio, S., Maggiori, M., Stroebel, J., & Utkus, S. (2021). Five facts about beliefs and portfolios. *American Economic Review*, *111*(5), 1481–1522.

Gong, G., Li, L. Y., & Shin, J. Y. (2011). Relative performance evaluation and related peer groups in executive compensation contracts. *The Accounting Review*, *86*(3), 1007–1043.

Gopalan, R., Milbourn, T., & Song, F. (2010). Strategic flexibility and the optimality of pay for sector performance. *The Review of Financial Studies*, *23*(5), 2060–2098.

Gordon, R. (1990). Do publicly traded corporations act in the public interest? *NBER Working Paper*.

Grossman, S. J., & Stiglitz, J. E. (1980). On the impossibility of informationally efficient markets. *The American Economic Review*, *70*(3), 393–408.

Hellwig, M. F. (1980). On the aggregation of information in competitive markets. *Journal of Economic Theory*, *22*(3), 477–498.

Himmelberg, C. P., & Hubbard, R. G. (2000). Incentive pay and the market for ceos: An analysis of pay-for-performance sensitivity. *Working Paper*.

Holmstrom, B. (1982). Moral hazard in teams. *The Bell Journal of Economics*, *13*(2), 324–340.

Holmström, B. (1979). Moral hazard and observability. *The Bell Journal of Economics*, *10*(1), 74–91.

Holmström, B., & Tirole, J. (1993). Market liquidity and performance monitoring. *Journal of Political Economy*, *101*(4), 678–709.

Jenter, D., & Kanaan, F. (2015). CEO turnover and relative performance evaluation. *The Journal of Finance*, *70*(5), 2155–2184.

Jin, L. (2002). CEO compensation, diversification, and incentives. *Journal of Financial Economics*, *66*(1), 29–63.

Jochem, T., Ormazabal, G., & Rajamani, A. (2024). Why have ceo pay levels become less diverse? *Working Paper*.

Kwan, H. J. (2016). Executive compensation under common ownership. *Working Paper*.

Lee, J. (2020). Passive investing and price efficiency. *Working Paper*.

Liang, L. (2016). Common ownership and executive compensation. *Working Paper*.

Liu, H., & Wang, Y. (2023). Mapping causes to consequences: The impact of indexing. *Working Paper*.

Murphy, K. J. (1999). Chapter 38: Executive Compensation. *Handbook of Labor Economics*, *3*, 2485–2563.

Oyer, P. (2004). Why do firms use incentives that have no incentive effects? *The Journal of Finance*, *59*(4), 1619–1650.

Sammon, M. (Forthcoming). Passive ownership and price informativeness. *Management Science*.

Appendix 1: Proofs from Main Text

Proof of Lemmas 1 and 2

Proof. Setting the first order condition for IC equal to 0 and solving for e_1 yields

$$e_1^* = m_1 + n_1\alpha$$

We can then bind the IR condition and plug it and e_1^* into the objective function to get (after some simplification):

$$\max_{m_1,n_1} = e_1^* - \frac{1}{2}e_1^{*2} - \frac{1}{2}Var(w_1)$$

where $Var(w_1) = m_1^2 Var(P_1) + n_1^2 Var(P_2) + 2m_1 n_1 Cov(P_1, P_2) = 2m_1^2 + 2n_1^2 + 2m_1 n_1 \rho$. We can then set the two first-order conditions with respect to m_1 and n_1 equal to zero to get a system of two equations for m_1 and n_1. Solving gives us:

$$m_1^* = \frac{2 - \alpha\rho}{\Gamma} > 0$$
$$n_1^* = \frac{2\alpha - \rho}{\Gamma}$$

where $\Gamma \equiv 2\alpha^2 - 2\alpha\rho - \rho^2 + 6 > 0$. Clearly, m_1^* is always positive given the restrictions on α and ρ. When $\alpha = 0$, we see that n_1^* will have the opposite sign of ρ, proving Lemma 1. Additionally, whenever $\alpha > \frac{\rho}{2}$, we are guaranteed to get $n_1^* > 0$, proving Lemma 2. □

Proof of Lemma 3

Proof. Follows immediately from Equation (7). □

Proof of Proposition 1

Proof. Plug the relevant price coefficients into Equation (7) and simplify. This gives us:

$$\tilde{n^*} = \frac{\tau_\epsilon \, \tau_z \, (1 - \lambda^2) \, (\tau_z \, \lambda^2 \, {\tau_\epsilon}^2 + \tau_z \, {\tau_\epsilon}^2 + \tau_\epsilon + 1)}{(\tau_\epsilon \, \tau_z \, \lambda^2 + 1) \, (\tau_\epsilon \, \tau_z + 1) \, (4 \, \lambda^2 \, {\tau_\epsilon}^4 \, {\tau_z}^2 + 3 \, \lambda^2 \, {\tau_\epsilon}^2 \, \tau_z + 3 \, {\tau_\epsilon}^2 \, \tau_z + 2)} \tag{16}$$

Since $\lambda \in [0, 1]$, it must be the case that $\tilde{n^*} > 0$ when $\lambda < 1$ and $\tilde{n^*} = 0$ when $\lambda = 1$.

Similarly, we can plug in and see that

$$\begin{aligned}
\tilde{m}^* =& \frac{K_1 \, \tau_\epsilon \, \tau_z}{K_2 \, (\tau_\epsilon \, \tau_z + 1)} \text{ where} \qquad (17)\\
K_1 =& 2 \, \lambda^4 \, {\tau_\epsilon}^5 \, {\tau_z}^3 + 2 \, \lambda^4 \, {\tau_\epsilon}^4 \, {\tau_z}^2 + 2 \, \lambda^4 \, {\tau_\epsilon}^3 \, {\tau_z}^2 + \lambda^4 \, {\tau_\epsilon}^2 \, \tau_z + 2 \, \lambda^2 \, {\tau_\epsilon}^4 \, {\tau_z}^2 \\
& + 2 \, \lambda^2 \, {\tau_\epsilon}^3 \, {\tau_z}^2 + 2 \, \lambda^2 \, {\tau_\epsilon}^3 \, \tau_z + 4 \, \lambda^2 \, {\tau_\epsilon}^2 \, \tau_z + 2 \, \lambda^2 \, \tau_\epsilon \, \tau_z + \lambda^2 \, \tau_\epsilon + \lambda^2 + {\tau_\epsilon}^2 \, \tau_z + \tau_\epsilon + 1 > 0 \\
K_2 =& 4 \, \lambda^4 \, {\tau_\epsilon}^5 \, {\tau_z}^3 + 3 \, \lambda^4 \, {\tau_\epsilon}^3 \, {\tau_z}^2 + 4 \, \lambda^2 \, {\tau_\epsilon}^4 \, {\tau_z}^2 \\
& + 3 \, \lambda^2 \, {\tau_\epsilon}^3 \, {\tau_z}^2 + 3 \, \lambda^2 \, {\tau_\epsilon}^2 \, \tau_z + 2 \, \lambda^2 \, \tau_\epsilon \, \tau_z + 3 \, {\tau_\epsilon}^2 \, \tau_z + 2 > 0
\end{aligned}$$

□

Proof of Corollary 1

Proof. Denote γ as each trader's coefficient of absolute risk aversion. Asset demands are adjusted by multiplying each trader's asset demand (D(i, IN) or D(i, LS)) by $1/\gamma$. Then, solving for prices in the usual manner, we can see that this change has no impact on $\tilde{B}$ and $\tilde{C}$ and that it alters $\tilde{D}$ and $\tilde{E}$ by replacing the 1 in the numerators with γ. That is, $\tilde{D} = \frac{\gamma + \tau_\epsilon \, \tau_z}{2 \, \tau_z \, {\tau_\epsilon}^2 + 2 \, \tau_\epsilon + 2} + \frac{\tau_\epsilon \, \tau_z \, \lambda^2 + \gamma}{2 \, \lambda \, (\tau_z \, \lambda^2 \, {\tau_\epsilon}^2 + \tau_\epsilon + 1)}$ and $\tilde{E} = \frac{\gamma + \tau_\epsilon \, \tau_z}{2 \, \tau_z \, {\tau_\epsilon}^2 + 2 \, \tau_\epsilon + 2} - \frac{\tau_\epsilon \, \tau_z \, \lambda^2 + \gamma}{2 \, \lambda \, (\tau_z \, \lambda^2 \, {\tau_\epsilon}^2 + \tau_\epsilon + 1)}$.

From there, the contracting problem remains unchanged, so the sign of $\tilde{n}^*$ still depends on the sign of $H(\gamma) \equiv \tilde{C}Var(\tilde{P}) - \tilde{B}Cov(\tilde{P}_1, \tilde{P}_2)$. Taking the derivative of this expression with respect to γ gives us

$$\frac{\tau_\epsilon \left(1-\lambda^2\right) \left(\lambda^4 {\tau_\epsilon}^4 {\tau_z}^3+\lambda^4 {\tau_\epsilon}^3 {\tau_z}^2+\lambda^2 {\tau_\epsilon}^4 {\tau_z}^3+3 \lambda^2 {\tau_\epsilon}^3 {\tau_z}^2+\lambda^2 {\tau_\epsilon}^2 {\tau_z}^2+2 \lambda^2 {\tau_\epsilon}^2 \tau_z+\lambda^2 \tau_\epsilon \tau_z+\tau_\epsilon^3 {\tau_z}^2+2 {\tau_\epsilon}^2 \tau_z+\tau_\epsilon \tau_z+\tau_\epsilon+1\right)}{\lambda^2 \tau_z \left(\tau_z \lambda^2 {\tau_\epsilon}^2+\tau_\epsilon+1\right)^2 \left(\tau_z {\tau_\epsilon}^2+\tau_\epsilon+1\right)^2} > 0$$

so $H(\gamma)$ is increasing in γ. Next, by plugging in $\gamma = 0$, we can see

$$H(0) = \frac{{\tau_\epsilon}^3 \tau_z \left(1-\lambda^2\right) \left(\tau_z \lambda^2 {\tau_\epsilon}^2 + \tau_z {\tau_\epsilon}^2 + 2\tau_\epsilon + 1\right)}{2\left(\tau_z \lambda^2 {\tau_\epsilon}^2 + \tau_\epsilon + 1\right)^2 \left(\tau_z {\tau_\epsilon}^2 + \tau_\epsilon + 1\right)^2} < 0$$

So $H(\gamma)$ is a continuous, increasing function with $H(0) < 0$ and $H(1) > 0$ (from the baseline model). Thus, by the intermediate value theorem, there must exist some $\gamma^* \in (0, 1)$ where $H(\gamma^*) = 0$ and $H(\gamma) > 0$ for all $\gamma > \gamma^*$. Consequently, by Lemma 3, $\tilde{n}^* > 0$ for all $\gamma > \gamma^*$. □

Proof of Proposition 2

Proof. See the proof of Proposition 1 for the signs of $\tilde{m}^*$ and $\tilde{n}^*$. Then take the partial derivatives of (16) and (17) with respect to λ. The partial derivative of $\tilde{n^*}$ with respect to λ is immediately shown to be negative after simplifying, so $\tilde{n^*}$ is increasing in the fraction of index investors. The sign of the $\tilde{m}^*$ derivative is ambiguous. For example, the parameterization $(\tau_\epsilon, \tau_z, \lambda) = (5, 1, .9)$ yields a negative partial derivative while $(\tau_\epsilon, \tau_z, \lambda) = (1, 1, .9)$ yields a positive partial derivative.

The wage covariance can be expressed as:

$$Cov(w_1, w_2) = (\tilde{m}^{*2} + \tilde{n}^{*2})Var(\tilde{P}) + 2 * \tilde{m}\tilde{n}Cov(\tilde{P}_1, \tilde{P}_2) = \frac{2{\tau_\epsilon}^2 \tau_z \left(\tau_z {\tau_\epsilon}^2 + 1\right)\left(1-\lambda^2\right)\left(\tau_z \lambda^2 {\tau_\epsilon}^2 + 1\right)}{\left(4\lambda^2 {\tau_\epsilon}^4 {\tau_z}^2 + 3\lambda^2 {\tau_\epsilon}^2 \tau_z + 3{\tau_\epsilon}^2 \tau_z + 2\right)^2}$$

This expression is clearly positive and its partial derivative with respect to λ is

$$\frac{\partial Cov(w_1, w_2)}{\partial \lambda} = -\frac{4\,\lambda\,{\tau_\epsilon}^2\,\tau_z\,(\tau_z\,{\tau_\epsilon}^2+1)^2\,(4\,\lambda^2\,{\tau_\epsilon}^4\,{\tau_z}^2+\lambda^2\,{\tau_\epsilon}^2\,\tau_z+5\,{\tau_\epsilon}^2\,\tau_z+2)}{(4\,\lambda^2\,{\tau_\epsilon}^4\,{\tau_z}^2+3\,\lambda^2\,{\tau_\epsilon}^2\,\tau_z+3\,{\tau_\epsilon}^2\,\tau_z+2)^3} < 0$$

Thus, the wage covariance is decreasing in the fraction of active investors, or equivalently, increasing in the fraction of index investors.

Equilibrium effort is defined in Section 4.2 as

$$e^* = \tilde{m}\tilde{B} + \tilde{n}\tilde{C} = \frac{{\tau_\epsilon}^2\,\tau_z\,(2\,\tau_z\,\lambda^2\,{\tau_\epsilon}^2+\lambda^2+1)}{4\,\lambda^2\,{\tau_\epsilon}^4\,{\tau_z}^2+3\,\lambda^2\,{\tau_\epsilon}^2\,\tau_z+3\,{\tau_\epsilon}^2\,\tau_z+2}$$

Taking the partial derivative of this expression with respect to λ and simplifying gives us:

$$\frac{\partial e^*}{\partial \lambda} = \frac{4\,\lambda\,{\tau_\epsilon}^2\,\tau_z\,(\tau_z\,{\tau_\epsilon}^2+1)^2}{(4\,\lambda^2\,{\tau_\epsilon}^4\,{\tau_z}^2+3\,\lambda^2\,{\tau_\epsilon}^2\,\tau_z+3\,{\tau_\epsilon}^2\,\tau_z+2)^2} > 0$$

From Section 4.2, the principal objective function (i.e., expected profits) equal

$$\begin{aligned} E(x_k - w_k) &= e^* - \frac{1}{2}e^{*2} - \frac{1}{2}\left((\tilde{m}^{*2}+\tilde{n}^{*2})Var(\tilde{P}) + 2\tilde{m}\tilde{n}Cov(\tilde{P}_1, \tilde{P}_2)\right) \\ &= \frac{{\tau_\epsilon}^2\,\tau_z\,(2\,\tau_z\,\lambda^2\,{\tau_\epsilon}^2+\lambda^2+1)}{2\,(4\,\lambda^2\,{\tau_\epsilon}^4\,{\tau_z}^2+3\,\lambda^2\,{\tau_\epsilon}^2\,\tau_z+3\,{\tau_\epsilon}^2\,\tau_z+2)} \end{aligned}$$

This expression is positive. We can once again take the partial derivative of this expression with respect to λ and see that it is positive. The partial dervative has the form:

$$\frac{\partial E(x_k - w_k)}{\partial \lambda} = \frac{2\,\lambda\,{\tau_\epsilon}^2\,\tau_z\,(\tau_z\,{\tau_\epsilon}^2+1)^2}{(4\,\lambda^2\,{\tau_\epsilon}^4\,{\tau_z}^2+3\,\lambda^2\,{\tau_\epsilon}^2\,\tau_z+3\,{\tau_\epsilon}^2\,\tau_z+2)^2}$$

Thus, the principal's expected profits are decreasing in the fraction of index investors. □

Proof of Proposition 3

Proof. Insert the expressions for $\tilde{m}^*$ and $\tilde{n}^*$ given in (16) and (17) to the mappings given equations (9) and (10) and simplify. We get

$$m^* = \frac{\tau_\epsilon \tau_z K_3}{K_4} > 0$$

$$n^* = \frac{\tau_\epsilon \, \tau_z \, (1-\lambda^2) \, (4\,\lambda^2 \, {\tau_\epsilon}^4 \, {\tau_z}^2 + 3\,\lambda^2 \, {\tau_\epsilon}^2 \, \tau_z + 3\,{\tau_\epsilon}^2 \, \tau_z + 2) \, (\tau_z \, \lambda^2 \, {\tau_\epsilon}^2 + \tau_z \, {\tau_\epsilon}^2 + \tau_\epsilon + 1)}{K_4} > 0 \text{ where}$$

$$K_3 = 4\,\lambda^6 \, {\tau_\epsilon}^9 \, {\tau_z}^5 + 4\,\lambda^6 \, {\tau_\epsilon}^8 \, {\tau_z}^4 + 6\,\lambda^6 \, {\tau_\epsilon}^7 \, {\tau_z}^4$$
$$+ 6\,\lambda^6 \, {\tau_\epsilon}^6 \, {\tau_z}^3 + 2\,\lambda^6 \, {\tau_\epsilon}^5 \, {\tau_z}^3 + 3\,\lambda^6 \, {\tau_\epsilon}^4 \, {\tau_z}^2 + 4\,\lambda^4 \, {\tau_\epsilon}^8 \, {\tau_z}^4 + 6\,\lambda^4 \, {\tau_\epsilon}^7 \, {\tau_z}^4 + 4\,\lambda^4 \, {\tau_\epsilon}^7 \, {\tau_z}^3 + 12\,\lambda^4 \, {\tau_\epsilon}^6 \, {\tau_z}^3$$
$$+ 8\,\lambda^4 \, {\tau_\epsilon}^5 \, {\tau_z}^3 + 6\,\lambda^4 \, {\tau_\epsilon}^5 \, {\tau_z}^2 + 11\,\lambda^4 \, {\tau_\epsilon}^4 \, {\tau_z}^2 + 2\,\lambda^4 \, {\tau_\epsilon}^3 \, {\tau_z}^2 + 3\,\lambda^4 \, {\tau_\epsilon}^3 \, \tau_z + 5\,\lambda^4 \, {\tau_\epsilon}^2 \, \tau_z + 6\,\lambda^2 \, {\tau_\epsilon}^6 \, {\tau_z}^3$$
$$+ 2\,\lambda^2 \, {\tau_\epsilon}^5 \, {\tau_z}^3 + 6\,\lambda^2 \, {\tau_\epsilon}^5 \, {\tau_z}^2 + 11\,\lambda^2 \, {\tau_\epsilon}^4 \, {\tau_z}^2 + 2\,\lambda^2 \, {\tau_\epsilon}^3 \, {\tau_z}^2 + 6\,\lambda^2 \, {\tau_\epsilon}^3 \, \tau_z + 6\,\lambda^2 \, {\tau_\epsilon}^2 \, \tau_z + 2\,\lambda^2 \, \tau_\epsilon + 2\,\lambda^2$$
$$+ 3\,{\tau_\epsilon}^4 \, {\tau_z}^2 + 3\,{\tau_\epsilon}^3 \, \tau_z + 5\,{\tau_\epsilon}^2 \, \tau_z + 2\,\tau_\epsilon + 2$$

$$K_4 = 4\,\lambda^6 \, {\tau_\epsilon}^{10} \, {\tau_z}^6 + 4\,\lambda^6 \, {\tau_\epsilon}^9 \, {\tau_z}^5 + 4\,\lambda^6 \, {\tau_\epsilon}^8 \, {\tau_z}^5 + 8\,\lambda^6 \, {\tau_\epsilon}^7 \, {\tau_z}^4 + \lambda^6 \, {\tau_\epsilon}^6 \, {\tau_z}^4 + 3\,\lambda^6 \, {\tau_\epsilon}^5 \, {\tau_z}^3 + 4\,\lambda^4 \, {\tau_\epsilon}^9 \, {\tau_z}^5$$
$$+ 4\,\lambda^4 \, {\tau_\epsilon}^8 \, {\tau_z}^5 + 4\,\lambda^4 \, {\tau_\epsilon}^8 \, {\tau_z}^4 + 8\,\lambda^4 \, {\tau_\epsilon}^7 \, {\tau_z}^4 + 2\,\lambda^4 \, {\tau_\epsilon}^6 \, {\tau_z}^4 + 8\,\lambda^4 \, {\tau_\epsilon}^6 \, {\tau_z}^3 + 9\,\lambda^4 \, {\tau_\epsilon}^5 \, {\tau_z}^3 + 3\,\lambda^4 \, {\tau_\epsilon}^4 \, {\tau_z}^2$$
$$+ 2\,\lambda^4 \, {\tau_\epsilon}^3 \, {\tau_z}^2 + 8\,\lambda^2 \, {\tau_\epsilon}^7 \, {\tau_z}^4 + \lambda^2 \, {\tau_\epsilon}^6 \, {\tau_z}^4 + 8\,\lambda^2 \, {\tau_\epsilon}^6 \, {\tau_z}^3 + 9\,\lambda^2 \, {\tau_\epsilon}^5 \, {\tau_z}^3 + 18\,\lambda^2 \, {\tau_\epsilon}^4 \, {\tau_z}^2 + 4\,\lambda^2 \, {\tau_\epsilon}^3 \, {\tau_z}^2$$
$$+ 8\,\lambda^2 \, {\tau_\epsilon}^2 \, \tau_z + 3\,{\tau_\epsilon}^5 \, {\tau_z}^3 + 3\,{\tau_\epsilon}^4 \, {\tau_z}^2 + 2\,{\tau_\epsilon}^3 \, {\tau_z}^2 + 8\,{\tau_\epsilon}^2 \, \tau_z + 4$$

□

Proof of Lemma 4:

Proof. The procedure to prove this is identical to that of Lemma 3. The only change is that the sensitivity of Firm 2's stock price to Manager 1's effort is now represented by $\tilde{C} + \beta\tilde{B}$ rather than $\tilde{C}$ and similarly for the sensitivity of Firm 1's stock price to Manager 1's effort

(i.e., $\tilde{B} + \beta\tilde{C}$ rather than $\tilde{B}$).

□

Proof of Proposition 4

Proof. The manager's optimal effort is given by Equation (13). Binding the IR constraint and plugging into the common owner's objective function gives us:

$$\max_{\tilde{l},\tilde{m},\tilde{n}} (1+\beta)e_1^* + (1+\beta)e_2^* - \frac{1}{2}e_1^{*^2} - \frac{1}{2}e_2^{*^2} - \frac{1}{2}Var(w_1) - \frac{1}{2}Var(w_2)$$

with $e_k^* = \tilde{m_k}(\tilde{B} + \beta\tilde{C}) + \tilde{n_k}(\tilde{C} + \beta\tilde{B})$. Take the first-order conditions with respect to $\tilde{m_1}, \tilde{m_2}, \tilde{n_1}$, and $\tilde{n_2}$ to get a pair of symmetric systems of equations: one for $\tilde{m_1}$ and $\tilde{n_1}$, and another for $\tilde{m_2}$ and $\tilde{n_2}$.

$$\tilde{m_k} = \frac{\overline{B} + \overline{B}\,\beta - \operatorname{cov}\tilde{n_k} - \overline{B}\,\overline{C}\,\tilde{n_k}}{\overline{B}^2 + \operatorname{var}}$$
$$\tilde{n_k} = \frac{\overline{C} + \overline{C}\,\beta - \operatorname{cov}\tilde{m_k} - \overline{B}\,\overline{C}\,\tilde{m_k}}{\overline{C}^2 + \operatorname{var}}$$
$$\text{with } \overline{B} = \tilde{B} + \beta\tilde{C} \text{ and } \overline{C} = \tilde{C} + \beta\tilde{B}$$

Solving then gives us answers analogous to (6) and (7) with $\overline{B}$ in place of $\tilde{B}$ and $\overline{C}$ in place of $\tilde{C}$ and the entire thing multiplied by $(1+\beta)$. The only change for the single owner case is that the $\beta\overline{B}$ and $\beta\overline{C}$ terms in the expressions for $\tilde{m_k}$ and $\tilde{n_k}$ respectively are eliminated. Thus, the common owner contract is just the single owner solution multiplied by $(1+\beta)$. □

Proof of Corollary 2

Proof. Recall from (13) that equilibrium effort expressed as $e^* = \tilde{m}(\tilde{B} + \beta\tilde{C}) + \tilde{n}(\tilde{C} + \beta\tilde{B})$ and from Proposition 4 that $\tilde{m_c} = (1+\beta)\tilde{m_s}$ and $\tilde{n_c} = (1+\beta)\tilde{n_s}$. Thus, the ratio of effort

under common and single ownership must therefore be $\frac{e_c}{e_s} = (1+\beta)$. As a result, equilibrium effort will be higher under common ownership whenever $\beta > 0$. □

Proof of Proposition 5

Proof. Following the same procedure as with $N = 2$ firms, we get the following price conjecture and resulting equilibrium coefficients:

$$\tilde{P_k} = b_0 + \tilde{B}x_k + \tilde{C}(x_1 + ...x_{k-1} + x_{k+1} + ...x_N) + \tilde{D}z_k + \tilde{E}(z_1 + ...z_{k-1} + z_{k+1} + ...z_N)$$

$$\tilde{B} = \frac{\tau_\epsilon\left(\tau_\epsilon\,\tau_z + 1\right)}{N\left(\tau_z\,{\tau_\epsilon}^2 + \tau_\epsilon + \tau_x\right)} + \frac{\tau_\epsilon\left(\tau_\epsilon\,\tau_z\,\lambda^2 + 1\right)(N-1)}{N\left(\tau_z\,\lambda^2\,{\tau_\epsilon}^2 + \tau_\epsilon + \tau_x\right)}$$

$$\tilde{C} = \frac{\tau_\epsilon\left(\tau_\epsilon\,\tau_z + 1\right)}{N\left(\tau_z\,{\tau_\epsilon}^2 + \tau_\epsilon + \tau_x\right)} - \frac{\tau_\epsilon\left(\tau_\epsilon\,\tau_z\,\lambda^2 + 1\right)}{N\left(\tau_z\,\lambda^2\,{\tau_\epsilon}^2 + \tau_\epsilon + \tau_x\right)}$$

$$\tilde{D} = \frac{\tau_\epsilon\,\tau_z + 1}{N\left(\tau_z\,{\tau_\epsilon}^2 + \tau_\epsilon + \tau_x\right)} + \frac{\left(\tau_\epsilon\,\tau_z\,\lambda^2 + 1\right)(N-1)}{N\,\lambda\left(\tau_z\,\lambda^2\,{\tau_\epsilon}^2 + \tau_\epsilon + \tau_x\right)}$$

$$\tilde{E} = \frac{\tau_\epsilon\,\tau_z + 1}{N\left(\tau_z\,{\tau_\epsilon}^2 + \tau_\epsilon + \tau_x\right)} - \frac{\tau_\epsilon\,\tau_z\,\lambda^2 + 1}{N\,\lambda\left(\tau_z\,\lambda^2\,{\tau_\epsilon}^2 + \tau_\epsilon + \tau_x\right)}$$

The manager's choice of effort will then be

$$e_k^* = \tilde{m}\tilde{B} + (N-1)\tilde{n}\tilde{C}$$

The above equation has the principal put the same weight on each of the other firms in the contract. Just like in the $N = 2$ case, this decision is optimal because all firms are ex-ante identical.

Then by binding the participation constraint and plugging into the objective, the principal's problem becomes

$$\max_{\tilde{m},\tilde{n}} e_k^* - \frac{1}{2}e_k^{*2} - \frac{1}{2}\left((\tilde{m}^2 + (N-1)\tilde{n}^2)var + 2((N-1)\tilde{m}\tilde{n} + \binom{N-1}{2}\tilde{n}^2)cov\right)$$

where

$$var = \tilde{B}^2 + (N-1)\tilde{C}^2 + \frac{\tilde{D}^2 + (N-1)\tilde{E}^2}{\tau_z}$$
$$cov = (N-2)\tilde{C}^2 + 2\tilde{B}\tilde{C} + \frac{(N-2)\tilde{E}^2 + 2\tilde{D}\tilde{E}}{\tau_z}$$

We can then take the first order conditions and solve the resulting system of equations for $\tilde{n}$ and $\tilde{m}$. For any integer $N \geq 2$, we can see that the optimal contract weight will be

$$\tilde{n}^* = \frac{\tau_\epsilon \tau_z (1-\lambda^2)(\tau_z \lambda^2 {\tau_\epsilon}^2 + \tau_z {\tau_\epsilon}^2 + \tau_\epsilon + 1)}{(\tau_\epsilon \tau_z \lambda^2 + 1)(\tau_\epsilon \tau_z + 1)(N + {\tau_\epsilon}^2 \tau_z + N {\tau_\epsilon}^2 \tau_z + 2N\lambda^2 {\tau_\epsilon}^4 {\tau_z}^2 + (2N-1)\lambda^2 {\tau_\epsilon}^2 \tau_z)} \geq 0 \tag{18}$$

$$\tilde{m}^* = \frac{\tau_\epsilon \tau_z \kappa}{(\tau_\epsilon \tau_z \lambda^2 + 1)(\tau_\epsilon \tau_z + 1)(N + {\tau_\epsilon}^2 \tau_z + N {\tau_\epsilon}^2 \tau_z + 2N\lambda^2 {\tau_\epsilon}^4 {\tau_z}^2 + (2N-1)\lambda^2 {\tau_\epsilon}^2 \tau_z)} \geq 0 \text{ with}$$

$$\kappa = (1-\lambda^2)\tau_\epsilon + (N-1)\lambda^2 + {\tau_\epsilon}^2 \tau_z + N\lambda^2 \tau_\epsilon + N\lambda^2 {\tau_\epsilon}^3 {\tau_z}^2 + N\lambda^2 {\tau_\epsilon}^4 {\tau_z}^2 + N\lambda^4 {\tau_\epsilon}^3 {\tau_z}^2$$
$$+ N\lambda^4 {\tau_\epsilon}^4 {\tau_z}^2 + N\lambda^4 {\tau_\epsilon}^5 {\tau_z}^3 + N\lambda^2 \tau_\epsilon \tau_z + 2N\lambda^2 {\tau_\epsilon}^2 \tau_z + N\lambda^2 {\tau_\epsilon}^3 \tau_z + (N-1)\lambda^4 {\tau_\epsilon}^2 \tau_z + 1$$

□

Proof of Lemma 5

Proof. Multiply Equation (18) by $N-1$ and take the partial derivative of the resulting expression with respect to N. This derivative can be expressed as:

$$\frac{\partial (N-1)\tilde{n}^*}{\partial N} = \frac{\tau_\epsilon \tau_z (2\tau_z {\tau_\epsilon}^2 + 1)(1-\lambda^2)(\lambda^4 {\tau_\epsilon}^4 {\tau_z}^2 + \lambda^2 {\tau_\epsilon}^4 {\tau_z}^2 + \lambda^2 {\tau_\epsilon}^3 \tau_z + 2\lambda^2 {\tau_\epsilon}^2 \tau_z + {\tau_\epsilon}^2 \tau_z + \tau_\epsilon + 1)}{(\tau_\epsilon \tau_z \lambda^2 + 1)(\tau_\epsilon \tau_z + 1)(N + {\tau_\epsilon}^2 \tau_z + N {\tau_\epsilon}^2 \tau_z + 2N\lambda^2 {\tau_\epsilon}^4 {\tau_z}^2 + (2N-1)\lambda^2 {\tau_\epsilon}^2 \tau_z)^2}$$

This expression is non-negative. □

Appendix 2: Endogenous Fraction of Index Investors

To endogenize the fraction of index investors, I will include a cost of being active $c > 0$ to my model. This cost can be thought of as the extra trading, information gathering, or information processing costs of dealing with multiple assets rather than just the index. Each investor must be indifferent between being an indexer and active ex-ante in order to have a positive fraction of both index and active traders ($\lambda \in (0, 1)$). Define the ex-ante (T=2 in the timeline) expected utilities of being an active and index investor as $E(U_a)$ and $E(U_{in})$ respectively. To avoid complications with correlated prices, I will stick to using the synthetic assets in this analysis. My proof is similar to Theorem 3 in Grossman and Stiglitz (1980) and can be viewed as a special case of Proposition 3.1 in Admati and Pfleiderer (1987). To avoid clutter, I will use variables without subscripts to indicate the set containing that variable's value for the two synthetic assets. For example, $P = \{P_{IN}, P_{LS}\}$.

Proposition A1 *The expected utilities of active (U_a) and index (U_{in}) traders can be expressed as:*

$$E(U_{in}) = -\sqrt{\frac{Var(x_{IN} - P_{IN}|s_i, P)}{Var(x_{IN} - P_{IN})}} \exp\left(-W_0 - \frac{E(x_{IN} - P_{IN})^2}{2Var(x_{IN} - P_{IN})}\right) \tag{19}$$

$$E(U_a) = E(U_{in})\sqrt{\frac{Var(x_{LS} - P_{LS}|s_i, P)}{Var(x_{LS} - P_{LS})}} \exp\left(c - \frac{E(x_{LS} - P_{LS})^2}{2Var(x_{LS} - P_{LS})}\right) \tag{20}$$

Proof. First, let's write down the expected utility of an active agent at the trading stage.

$$E(U_a|s, P) = -\exp\left(-w_0 + c - \frac{(E(x_{IN}|s_i, P) - P_{IN})^2}{2Var(x_{IN}|s_i, P)} - \frac{(E(x_{LS}|s_i, P) - P_{LS})^2}{2Var(x_{LS}|s_i, P)}\right)$$

We will now integrate over s_i and use the fact that (x, ϵ, z) are all independent to get:

$$E(U_a|P) = -\exp(-w_0+c)E\left(\exp\left(\frac{-(E(x_{IN}|s_i,P)-P_{IN})^2}{2Var(x_{IN}|s_i,P)}\right)|P\right)E\left(\exp\left(\frac{-(E(x_{LS}|s_i,P)-P_{LS})^2}{2Var(x_{LS}|s_i,P)}\right)|P\right) \tag{21}$$

Now define

$$Y_k \equiv \frac{E(x_k - P_k|s_i,P)}{\sqrt{Var(E(x_k - P_k|s_i,P))}}$$

Note that Y_k is a normal random variable with variance 1. Also define:

$$\xi \equiv \frac{Var(E(x_k - P_k)|s_i,P))}{2E(Var(x_k - P_k|s_i,P))}$$

Then observe that

$$E\left(\exp\left(\frac{-(E(x_k)|s_i,P)-P_k)^2}{2Var(x_k|s_i,P)}\right)|P\right) = E(\exp(-\xi Y_k^2)|P) \tag{22}$$

Because Y_k is normal with variance 1, Y_k^2 is a non-central chi square random variable. Equation (22) then defines the moment generating function, which equals (e.g., see Grossman and Stiglitz (1980) Equation (A21))

$$E(\exp(-\xi Y_k^2)|P) = \frac{1}{\sqrt{1+2\xi}}\exp\left(\frac{-E(Y_k|P)^2\xi}{1+2\xi}\right) \tag{23}$$

Following this process for both $k = IN, LS$ and plugging into Equation (21) gives us:

$$E(U_a|P) = -\sqrt{\frac{Var(x_{IN}-P_{IN}|s_i,P)}{Var(x_{IN}-P_{IN}|P)}}\sqrt{\frac{Var(x_{LS}-P_{LS}|s_i,P)}{Var(x_{LS}-P_{LS}|P)}}\exp(G) \text{ with}$$
$$G = -(W_0 - c) - \frac{E(x_{IN}-P_{IN}|P)^2}{2Var(x_{IN}-P_{IN}|P)} - \frac{E(x_{LS}-P_{LS}|P)^2}{2Var(x_{LS}-P_{LS}|P)} \tag{24}$$

Now we want to integrate out prices, so repeat this process and the result is Equation (20) for the ex-ante expected utility of the active agent. The derivation is identical for the indexed agent except that all terms involving the long-short synthetic asset disappear. The proposition then immediately follows. □

Corollary A1 *The ratio of expected utilities is*

$$\Lambda(\lambda) \equiv \frac{E(U_a)}{E(U_{in})} = \sqrt{\frac{Var(x_{LS} - P_{LS}|s,P)}{Var(x_{LS} - P_{LS})}} \exp\left(c - \frac{E(x_{LS} - P_{LS})^2}{2Var(x_{LS} - P_{LS})}\right) \tag{25}$$

Proof. Follows immediately from dividing Equation (20) by Equation (19). □

It will now be helpful to note the following lemma.

Lemma A1 $\Lambda(\lambda)$ *is an increasing function of* λ

Proof. Note that $E(x_{LS} - P_{LS}) = 0$ because it is an equal-weighted long-short portfolio of two ex-ante identical assets. Thus, both its expected payoff and expected price are zero; it does not carry any risk-premium. So the only term in $\Lambda(\lambda)$ involving λ is

$$\sqrt{\frac{Var(x_{LS} - P_{LS}|s,P)}{Var(x_{LS} - P_{LS})}} = \left(\frac{\lambda^2 \tau_z \left(\tau_z \lambda^2 {\tau_\epsilon}^2 + \tau_\epsilon + 1\right)}{\lambda^4 {\tau_\epsilon}^2 {\tau_z}^2 + 2\lambda^2 \tau_\epsilon \tau_z + \lambda^2 \tau_z + 1}\right)^{\frac{1}{2}} \tag{26}$$

It is straightforward to confirm that the RHS of Equation 26 is increasing in λ by taking the partial derivative with respect to λ. □

Lemma A1 states that active traders become relatively worse off as the fraction of active traders increases. This result should be intuitive: relative prices become more efficient as the number of active traders increases, so gathering information becomes less profitable. Also, recall that utilities are negative in this model, so $\Lambda(\lambda) < 1 (> 1)$ means active traders are

better (worse) off. Then, similar to Grossman and Stiglitz (1980), I can define different types of financial market equilibria as described in Proposition 6 of the main text.

Proof of Proposition 6

Proof. The first two parts of the proposition follow from Lemma A1 and the fact that higher levels of $\Lambda()$ indicate that active traders are worse off. More specifically, if $\lambda \in (0, 1)$ and $\Lambda(\lambda) = 1$, then we have an interior equilibrium. If $\lambda = 1$ and $\Lambda(1) \leq 1$, then we have a no-indexing equilibrium. To achieve either, one simply has to appropriately vary the exogenous cost of actively trading c; higher values of c make the interior equilibrium more likely. To show that there is no equilibrium where all traders are indexers, observe that if $\lambda = 0$, then $Var(x_{LS} - P_{LS})^{-1} = 0$. As a result, $\Lambda(0) = 0$ so some indexers will find it profitable to deviate and collect information. Correcting relative prices becomes increasingly profitable as λ approaches zero, making it optimal for someone to always be active. □

Thus, the type of equilibrium is completely determined by $\Lambda(1)$. If $\Lambda(1) \leq 1$, we have an equilibrium with only active traders. If $\Lambda(1) > 1$, then we have an interior equilibrium with a positive fraction of both active and index investors. The equilibrium percentage of index investors can then be manipulated by changing the cost of active investing c. Therefore, we can essentially talk about λ as if it is exogenous because changing the exogenous c amounts to changing the equilibrium λ that results.

Acknowledgement of Support

I have no sources of support or any conflicts of interest to disclose.