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Is There Too Much Benchmarking in Asset Management?†

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We propose a tractable model of asset management in which benchmarking arises endogenously, and analyze its welfare consequences. Fund managers' portfolios are not contractible and they incur private costs in running them. Incentive contracts for fund managers create a pecuniary externality through their effect on asset prices. Benchmarking inflates asset prices and creates crowded trades. The crowding reduces the effectiveness of benchmarking in incentive contracts for others, which fund investors fail to account for. A social planner, recognizing the crowding, opts for contracts with less benchmarking and less incentive provision. The planner also delivers lower asset management costs. (*JEL* D82, D86, G11, G12, G23, G41)

Investors worldwide have delegated the investment of over $100 trillion to asset management firms. These firms then turn the decision over how to invest the money to portfolio managers, who have a principal-agent relationship with investors. Portfolio managers are invariably paid based on how their fund performs relative to a benchmark.[1] The presence of benchmarks in compensation contracts is important because benchmarks are a significant driver of global capital flows and have an effect on the real economy. For example, Calomiris et al. (2022) document that emerging market firms are able to cut their cost of funds by an astounding 1 percentage point by issuing bonds eligible for inclusion in important international benchmark indices. We provide a tractable model of asset management in which

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[1] For example, Ma, Tang, and Gómez (2019) report that around 80 percent of US mutual funds explicitly base compensation on performance relative to a benchmark (usually a prospectus benchmark such as the S&P 500, Russell 2000, etc.).

benchmarking arises endogenously. More importantly, we use our model to assess the welfare implications of benchmarking and explore its unintended consequences.

To study these issues, we embed an optimal-contracting problem in a general equilibrium setting. We show that when the fund managers incur a private cost in managing portfolios, optimally designed contracts for the managers involve benchmarking. Because of this private cost, managers underinvest in the risky asset (stock market). Conditioning the managers' compensation on the performance of a benchmark portfolio partially protects them from risk and thus boosts their incentives to invest. In general equilibrium, the use of such incentive contracts creates a pecuniary externality through their effect on the risky asset's price. Benchmarking inflates the price of the risky asset and reduces its expected return. This in turn reduces the marginal benefit of using incentive contracts for others. We show that a constrained social planner, who internalizes this externality, would opt for less incentive provision and less benchmarking.

Here is how our model works. Some agents in the economy—direct investors—manage their own money and others—fund investors—delegate their investment choice to fund (or portfolio) managers. All agents are risk averse. Critically, the managers' portfolios are unobservable to fund investors and the cost of managing a portfolio is private. The managers are paid based on incentive contracts designed by the fund investors.[2] We focus on linear contracts, which include a fixed salary, a fee for absolute performance, and potentially a fee for performance relative to a benchmark.

We assume that the managers can potentially generate superior returns (or "alpha") relative to those of the direct investors through various sophisticated strategies. These include lending securities, conserving on transactions costs (e.g., from crossing trades in-house or by obtaining favorable quotes from brokers) or providing liquidity (i.e., serving as a counterparty to liquidity demanders and earning a premium on such trades). While these activities augment returns, they are associated with a private cost for a portfolio manager. We assume the costs are increasing in the size of the fund's risky portfolio. The simplest way to justify these assumptions is to appeal to the time costs involved in the activities and to interpret the rising costs as reflecting the additional time required for managing a larger fund/portfolio.

Fund investors design the manager's compensation contracts to incentivize the manager to take the risk associated with the sophisticated strategies. The presence of the private cost calls for a contract that rewards the manager based on fund performance and gives her a larger share of the return than if risk sharing were the only purpose of the contract. Because the stock market return is stochastic, rewarding performance exposes the manager to additional risk. This risk, if unmitigated, means that the manager will underinvest. Adding a benchmark to the contract partially protects the manager from this risk and therefore will be used by fund investors to improve the manager's incentives.

Our paper's main contribution is analyzing welfare consequences of benchmarking. When all fund investors use incentive contracts, they increase the total demand

[2] We abstract from the asset management firm and assume that the firm acts in the interest of the fund investors, so that effectively the fund investors directly control the compensation arrangements for the portfolio managers. This is consistent with the fund trustees having a fiduciary obligation to their investors.

for the risky asset. The increased demand boosts the price of the risky asset and lowers its expected return. In other words, benchmarking creates crowded trades.

Importantly, individual fund investors in our model take the stock price as given and do not internalize the effects of contracts they design on the equilibrium stock price. Crowded trades resulting from the contract-induced incentives are a pecuniary externality. Because of the agency frictions, markets are incomplete, so this pecuniary externality leads to an inefficiency. Specifically, the use of benchmarking contracts by a group of investors reduces the effectiveness of contracts designed by other investors through crowded trades. This happens because rewarding performance implies that the stock price enters the fund managers' incentive constraints. Each manager still has to incur the full private cost of managing assets but the benefits of doing so are reduced because of the crowded trades.

In light of this, it is natural to ask how would the incentive contract chosen by a social planner, who is subject to the same restrictions as individual investors but recognizes the effect of contracts on the stock price, differ from the privately optimal one? We show that individual investors underestimate the cost of incentive provision relative to the social planner, who internalizes the negative externality of incentive contracts. As a result, the planner opts for less incentive provision. Specifically, we show that both the performance sensitivity ("skin in the game") as well as the level of benchmarking are lower in the socially optimal contract than in the privately optimal one. This ameliorates the price pressure that portfolio managers exert and reduces the crowdedness of trades.

Our model informs the debate over whether the costs of asset management are excessive and whether returns delivered by the fund managers justify these costs. We use the model to compare the managers' costs and expected returns under privately and socially optimal contracts. We find that, from the socially optimal point of view, fund investors overincentivize risk taking so that managers invest too much at too high a cost.[3] In the equilibrium with privately optimal contracts, the stock price is higher and consequently the expected per-share return is lower than under the socially optimal contract. Key to these implications is that, in contrast to fund investors, the planner internalizes the pecuniary externality arising from crowded trades.

The remainder of the paper is organized as follows. In the next section, we review the related literature. Section II presents the model. Section III analyzes the model and presents the main results. Section IV concludes and outlines directions for future research. Omitted proofs, derivations, and other extensions are in the appendices.

I. Related Literature

Our work builds on the vast literature on optimal contracts with moral hazard. In a seminal contribution, Holmström (1979) argues that including a signal that is correlated with the output of the manager—in our case, the benchmark's performance—in a contract is beneficial to the principal. Importantly, in our paper the benefit of including the signal is endogenous through the general equilibrium effect

[3] While the cost is borne by the manager, it ultimately gets passed on to the fund investor, who needs to compensate the manager enough to ensure her participation.

on the stock price. To our knowledge, ours is the first paper that endogenizes the effectiveness of including the extra signal in the contract. Holmström and Milgrom (1991) introduce a tractable contracting setting with moral hazard, with which our model shares many similarities, and show that increasing the agent's share in the project's output helps provide incentives. In the context of delegated asset management though, giving the agent a larger share of portfolio return encourages her to scale down the risk of the (unobservable) portfolio by reducing risky asset holdings. Stoughton (1993) and Admati and Pfleiderer (1997) show that the manager is able to completely "undo" her steeper incentives to collect information on asset payoffs by such scaling. We design a contract that overcomes this challenge and show that it involves benchmarking. Another notable difference from the aforementioned literature is that we embed optimal (linear) contracts in a general equilibrium setting and study interactions between contracts and equilibrium prices, and the implications of these interactions on welfare.

Our work is also related to the literature in asset pricing and corporate finance theory that explores the general equilibrium implications of benchmarking. Brennan (1993) shows that benchmarking leads to lower expected returns on stocks included in the benchmark. In dynamic models, Cuoco and Kaniel (2011) and Basak and Pavlova (2013) show that benchmarking pushes up prices and lowers Sharpe ratios of stocks inside the benchmark. Basak and Pavlova also show that benchmarking leads to excess volatility and excess comovement of returns on these stocks. Kashyap et al. (2021) focus on implications of benchmarking portfolio managers for firms' corporate decisions and demonstrate that firms in the benchmark have a higher valuation for investment projects or merger targets. These papers take the benchmarking contract of managers to be exogenous.

There are very few papers that study the asset pricing implications of relative performance evaluation in asset management with optimal contracts. Kapur and Timmermann (2005) analyze the effects of relative performance evaluation on the equity premium. In their paper, managers have exogenously superior information about assets compared to investors, and investors use contracts purely for risk-sharing purposes. In Buffa, Vayanos, and Woolley (2014)[4] and Cvitanic and Xing (2018), benchmarking helps reduce diversion of cash flows by fund managers. Our rationale for benchmarking is to reward activities that generate superior returns. Sockin and Xiaolan (2023) study costly information acquisition by managers,[5] and, like us, highlight the pecuniary externality that emerges because of the effect of

[4] In the published version, Buffa, Vayanos, and Woolley (2022), constraints limiting deviations from benchmarks guard against the possibility that unskilled managers choose overly risky portfolios.

[5] See also Ozdenoren and Yuan (2017) who conduct a related analysis in the context of an industry equilibrium, in a classical moral-hazard setting with many principal-agent pairs. They show that benchmarking is privately optimal but it creates overinvestment and excessive risk taking at the industry level. Albuquerque, Cabral, and Guedes (2019) present a related model of industry equilibrium, enriched further with strategic interactions among firms in the industry, and show that benchmarking against peer performance induces agents to take correlated actions. Huang, Qiu, and Yang (2020) analyze a model of delegated asset management with asymmetric information and endogenous contracts (but without relative performance) to study the effect of institutional investors on price informativeness. Unlike us, they limit their analysis to privately optimal contracts and do not study welfare implications. Donaldson and Piacentino (2018) propose a model in which a rationale for benchmarking in managers' contracts is to attract fund inflows. Dybvig, Farnsworth, and Carpenter (2010) show that benchmarking emerges as optimal compensation in an environment where portfolio managers exert effort to improve the quality of a private signal about future prices.

contracts on equilibrium prices. In contrast to us, they show that a constrained social planner opts for more incentive provision and more benchmarking.

Our paper also relates to the literature on pecuniary externalities in competitive equilibrium settings with incomplete markets.[6] Lorenzoni (2008) studies a model of credit booms in which a pecuniary externality arises from the combination of limited commitment and asset prices being determined in spot markets. Decentralized equilibria feature overborrowing relative to the constrained optimum. Both our setting and mechanism are very different, but we share a similar prediction that asset prices in the decentralized equilibrium fall between those in the constrained and unconstrained optima. He and Kondor (2016) study a model in which individual firms' liquidity management decisions generate investment waves. These investment waves are constrained inefficient when future investment opportunities are noncontractible, and the social and private value of liquidity differs. In their model, overinvestment occurs during booms and underinvestment during recessions.

Gromb and Vayanos (2002) analyze a model in which competitive financially constrained arbitrageurs supply liquidity to the market, and fail to internalize the fact that their trading, in aggregate, affects prices. A social planner can achieve a Pareto improvement by either reducing or increasing the arbitrageurs' liquidity supply. Davila and Korinek (2018) highlight a distinction between "distributive externalities" that arise from incomplete insurance markets and "collateral externalities" that arise from price-dependent financial constraints. The externality in our paper falls into the second category, broadly defined, although in our case the inefficiency arises from the incentive problem rather than financial constraints. Di Tella (2019) studies optimal long-term contracts in a general equilibrium model where financial intermediaries manage capital on behalf of households and can divert capital to sell for private gains. He shows that, due to a pecuniary externality, competitive equilibrium is not constrained efficient and the socially optimal allocation can be implemented with a tax on asset holdings.[7]

Biais, Heider, and Hoerova (2021) analyze a model in which protection buyers trade derivatives with protection sellers and there is moral hazard on the side of protection sellers. In their model, although prices enter incentive constraints, a pecuniary externality does not lead to constrained inefficiency, as it does in our model, because investors can trade insurance against the risk of fire sales. We would have a similar result if we allowed for fully state-contingent contracts in our environment—see our discussion at the end of Section IIC. In Acemoglu and Simsek (2012), firms trade off providing insurance to workers and incentivizing them to exert effort. The authors show that, under certain conditions, equilibrium prices can tighten incentive constraints. They mainly focus on inefficient sharing of idiosyncratic risk. Instead, our focus is on the inefficient use of an additional signal—return of the benchmark portfolio—in the incentive contract.

There is some empirical evidence that benchmarking creates crowded trades. Lines (2016) observes that in times of high market volatility, portfolio tracking error rises.

[6] This literature goes back to Hart (1975); Greenwald and Stiglitz (1986); and Geanakoplos and Polemarchakis (1996).

[7] In a separate paper, Di Tella (2017) shows that there is another source of inefficiency if only short-term contracts are allowed.

This leads portfolio managers to rebalance their portfolios towards benchmark stocks. He finds that this trading behavior leads to lower returns for the rebalanced portfolios.

II. Model

To illustrate our mechanism and main results in the simplest way, we set up a model with one risky asset. However, all the main results extend to the case with multiple risky assets—see Remark 5 at the end of Section III.

A. *Investment Opportunities and Agents*

Except for portfolio managers and their clients, our environment is standard. There are two periods, $t = 0, 1$. Investment opportunities consist of a single risky asset (a stock or the stock market) and one risk-free bond. The stock is a claim to a cash flow $\tilde{D}$, realized at $t = 1$, where $\tilde{D} \sim N(\mu, \sigma^2)$. The risk-free bond pays an interest rate that is normalized to zero. There are $\bar{x} > 0$ shares of the risky asset and the bond is in infinite net supply. The stock price is denoted by p.

There is a continuum of agents of three types: direct investors, fund investors, and fund managers. Direct investors manage their own portfolios. Fund investors can only buy the bond themselves and hire the managers to trade both the stock and bond on their behalf. Each manager works for one fund investor, and is restricted to invest her personal wealth in the bond. The fractions of direct investors and managers in the population are λ_D and λ_M, respectively, and the total population is normalized to one so that $\lambda_D + 2\lambda_M = 1$.

Each agent has a constant absolute risk aversion (CARA) utility function over final wealth (or compensation in the case of the manager) W, $U(W) = -e^{-\gamma W}$, where $\gamma > 0$ is the coefficient of absolute risk aversion. Direct investors and fund investors are endowed with x_{-1}^D and x_{-1}^F shares of the risky asset, respectively, where $\lambda_D x_{-1}^D + \lambda_M x_{-1}^F = \bar{x}$.[8]

We do not model an agent's choice to become a direct investor or a fund investor—the fractions of different investors in the population are exogenous. One could endogenize this choice, for example, by assuming heterogeneous costs of participating in the asset market. In Remark 4 at the end of Section III we describe the additional considerations that arise in this kind of extension, but we do not consider it here to maintain our focus on the central message of the paper.

B. *Value Added and Costs of Asset Management*

For fund investors, delegating investment to a portfolio manager has costs and benefits. The benefits are that managers can potentially outperform direct investors. This advantage arises from having set up return-augmenting activities such as securities lending, providing liquidity by market making, or minimizing trade costs.[9]

[8] Without loss of generality, we assume that the managers are not endowed with the risky asset.

[9] Kashyap et al. (2022) includes an analysis of an alternative model in which the managers have stock-picking ability that comes from an informational advantage. That model is much more complicated, but we show that the mechanism is the same as in the model in this paper and the key results from this paper carry over.

In terms of the costs, delegation comes with an agency problem: the manager's portfolio choice is not contractible, meaning that fund investors cannot write contracts that condition the manager's compensation directly on their portfolio choice. Noncontractibility can occur, for example, if the fund investors do not observe the manager's portfolio choice. This is a realistic assumption because even when managers are required to disclose their portfolios at particular points in time, their actual portfolios between the disclosure dates typically differ from their reported portfolios (Kacperczyk, Sialm, and Zheng 2008), and a fund investor cannot obtain detailed information on the manager's trades. Furthermore, the managers incur a private cost in managing a portfolio. For example, managers must monitor market conditions to successfully lend shares. In online Appendix E.1, we also investigate an extension where the private cost is related to effort that cannot be observed. We elaborate on the interpretation of these benefits and costs in online Appendix C.

We model the costs and benefits as follows. Throughout, we will work with per-share rather than per-dollar returns. The return for a direct investor's portfolio x is given by $x(\tilde{D} - p)$. The fund manager's return is

$$r_x = x(\Delta + \tilde{D} - p) + \varepsilon, \tag{1}$$

where $\Delta \geq 0$ is the (exogenous) expected abnormal return and $\varepsilon \sim N(0, \sigma_\varepsilon)$ is a noise term. We will refer to the excess return of $x\Delta + \varepsilon$ as "alpha." The manager incurs a private portfolio-management cost $x\psi$, where $\psi > 0$ is the exogenous cost per share.

There are several key ingredients that are crucial for our results. It is essential for our mechanism that the manager's portfolio is not contractible (or unobservable), and the manager incurs a private cost of managing it (meaning that this cost is borne by the manager and cannot be directly shared with the fund investor through the contract). This cost will lead to a misalignment of the fund investor's and management's preferences for the risky asset. If there were no costs (or if they could be passed on to the fund investor), there would be no incentive problem, and the results would be trivial.

The other key ingredient is the noise ε in the return-augmenting activities.[10] It exposes the managers to additional risk in their compensation.[11] While the fund investor can partly shield the manager from the dividend risk by benchmarking, this additional risk cannot be eliminated. As a result, contracts will fail to achieve first best.[12]

Unlike ψ and ε, the variable Δ is not essential for our results, and we include it only for realism. If the managers could not outperform the direct investors, there would be no justification to hire them. Nonetheless, if we ignore all the empirical evidence that suggests that asset manager can add value and set $\Delta = 0$, the

[10] One might wonder what happens if the noise is proportional to x (that is, the noise term is εx instead of ε). This is a special case of the extension that we analyze in online Appendix E.1. The algebra is more involved in this case, but the main mechanism is the same.

[11] With one risky asset, ε also ensures that the investors cannot infer the exact portfolio choice of the manager from the observed return (as in Holmström and Milgrom 1991). With multiple risky assets, it would not be possible to infer the portfolio even without the ε.

[12] We come back to the issue of why ε is needed in Section IIIC following Lemma 2.

incentive problem and risk-sharing problems would still be present, and all of our results would go through.

Finally, for simplicity, we assume that the fund's abnormal return Δ is exogenous, which means we are ignoring market participants who would be on the other side of the transaction. Presumably the other party would have an abnormal return of $-\Delta$ per share. In addition, one might argue that we are ignoring the effects of crowded trades on Δ. To formalize these considerations, one needs to be more precise about the activity that generates Δ. Since we attempt to capture several of them, in the body of the paper we abstract from fully modeling any particular market. In online Appendix E.2, we endogenize Δ and assume that it comes from securities lending. In this case, we show that when we account for the short sellers and endogenize Δ, all our major insights carry through.

C. *Contracts*

To provide incentives for the managers to invest in the risky asset and to generate alpha, the fund investors design compensation contracts. The managers receive compensation w from fund investors. We assume that this compensation has three parts: the first is a linear payout based on absolute performance of the manager's portfolio x, a second part that depends on the performance relative to a benchmark portfolio, and a third that is independent of performance.[13] The benchmark portfolio is one share of the risky asset. That is, the manager's compensation is given by

$$w = \hat{a}r_x + b(r_x - r_b) + c = ar_x - br_b + c, \tag{2}$$

where r_x is the performance of the manager's portfolio defined in (1) and $r_b = \tilde{D} - p$ is the performance of the benchmark portfolio.[14] The contract for a manager depends on three numbers $(\hat{a}, b, c)$—or, equivalently, (a, b, c). We refer to $\hat{a}$ as the sensitivity to absolute performance and b as the sensitivity to relative performance. Our main analysis and the intuitions that follow will be in terms of a rather than $\hat{a}$. We refer to the variable a as the manager's "skin in the game." The contract for a particular manager is optimally chosen by the fund investor who employs her. As we mentioned earlier, the manager is restricted to investing her personal wealth in the bond and so she cannot "undo" her contract via trading in her personal account.[15]

We think of a manager's contract as a compensation contract between a portfolio manager and her investment-advisor firm (e.g., BlackRock, who we assume is acting in the interests of the fund investors). The structure of the contract in (2) is consistent with empirical evidence. For example, Ma, Tang, and Gómez (2019)

[13] The third part captures features such as a fee linked to initial assets under management or a fixed salary or any fixed costs.

[14] Given that there is only one risky asset, we effectively normalize the benchmark portfolio to one share of the risky asset. In a general model with multiple risky assets, the benchmark portfolio is a vector.

[15] In practice, portfolio managers have a fiduciary duty to their investors. This precludes them from taking actions that harm the investors, or engaging in any activity that creates a conflict of interest between the manager and the fund investors. Compliance departments at asset management firms attempt to deal with these problems by requiring preapproval of many types of trades by the manager or banning them altogether, and restricting when trading can occur. A trade such as shorting a manager's benchmark would be blocked by these policies. See US SEC (2004) for details.

analyze mandatory disclosures by US mutual funds and find that around 80 percent of the funds explicitly base managers' compensation on performance relative to a benchmark (usually the prospectus benchmark, e.g., S&P 500, Russell 2000, etc.). Managers also have a fixed salary component, but the fraction of fund managers whose entire compensation consists of only fixed salary is very small.[16]

The important feature of the contract driving our results is that the contract for the manager depends on the (per share) return, and hence the price of the risky asset. If asset prices vary across states (or time), then the compensation contract would necessarily depend on prices. Loosely speaking, if the fund investors were choosing for themselves, they would opt to buy less of the stock when its price is high. In delegating to the managers, the investors still want this consideration to be there. So, this feature of our contract is very realistic.

The restriction to linear contracts warrants some discussion. First, linear contracts make our model tractable and allow us to find optimal contracts in closed form. The closed-form solutions show the reader exactly where the various effects are coming from, and allow us to build intuition. However, our mechanism extends beyond the linear contracts considered here. The central results arise because the contracts raise the managers' demand, so that they will also drive up the equilibrium stock price. Individual investors do not account for this price effect but a social planner would recognize it. Consequently, a planner realizes that the price effect works against the incentive provision (as long as the manager's demand function is downward sloping) and will alter the contracts accordingly. This mechanism does not depend on contract linearity, and, intuitively, should be also present with other forms of contracts.

There is a subtle caveat, however, about the generality of the mechanism. The mechanism requires contracts not being fully state contingent/flexible. With fully state-contingent optimal contracts, the fund investors can effectively eliminate the dependence of the manager's incentive constraint on the price of the risky asset, which would yield to a constrained efficient outcome.[17] Nonetheless, our general mechanism would extend to environments with piecewise-linear contracts (e.g., "bonus" contracts of the form $w = \max\{ar_x - br_b, 0\} + c$) or to cases in which contract parameters can differ across some but not all states.[18]

[16]The performance-based bonus exceeds the fixed salary for 68 percent of the funds in the Ma, Tang, and Gómez (2019) sample, constituting more than 200 percent of fixed salary for 35 percent of funds. In contrast, Ibert et al. (2017) find surprisingly weak sensitivity of manager pay to performance for Swedish mutual funds.

[17]As we discussed in the literature review, this result is akin to the finding in Biais, Heider, and Hoerova (2021), who show that pecuniary externality does not lead to constrained inefficiency in their model because investors can trade insurance against the risk of fire sales. The result is different from that in Di Tella (2017), who finds that even with fully optimal contracts the decentralized equilibrium is constrained inefficient. The reason is that in his model the private benefit of diverting investment returns explicitly depends on the price. If we assumed that the private cost in our model includes the price of the risky asset, i.e., equal to $xp\psi$ instead of $x\psi$, then we would have the difference between privately and socially optimal contracts even with fully optimal contracts. For a broader analysis of issues arising in models with prices in incentive contracts see Kashyap et al. (2023b).

[18]The analysis of a discrete-state example with piecewise-linear contracts, as well as the numerical analysis with bonus contracts (where we show numerically that our results hold) are available from the authors upon request.

III. Analysis and Results

We now turn to the analysis of our model. We first present maximization problems of direct investors, fund managers, and fund investors. We then analyze privately and socially optimal contracts, and present the main results.

A. *Direct Investors' and Managers' Problems*

At $t = 0$, each direct investor chooses the number of shares of stock, x, and risk-free bond holdings to maximize his expected utility $-Ee^{-\gamma W}$. Since his return on the portfolio is $x(\tilde{D} - p)$, the resulting time-1 wealth is $W = x_{-1}^{D} p + x(\tilde{D} - p)$. It is well known that with the CARA utility function and normally distributed returns, a direct investor's maximization problem is equivalent to the following mean-variance optimization: $\max_x x(\mu - p) - \gamma x^2 \sigma^2 / 2$.

Next, consider the problem of a portfolio manager. Each manager chooses the number of shares of stock x and the risk-free bond holdings to maximize $-E\exp\left[-\gamma(ar_x - br_b + c - \psi x)\right]$, where the quantity inside the square brackets is her compensation net of the private cost. This maximization problem is equivalent to the following mean-variance optimization:

$$\max_x ax(\Delta - \psi/a + \mu - p) - b(\mu - p) + c - \frac{\gamma}{2}\left[(ax - b)^2\sigma^2 + a^2\sigma_\varepsilon^2\right].$$

Note that the manager receives a fraction a of the per-share abnormal return on the assets, Δ, but pays the entire cost ψ per share. (We later show that $a < 1$.)

Both the direct investors and managers take the stock price as given. Lemma 1 reports the optimal portfolio choices of the direct investors and managers arising from their optimizations, and the market-clearing asset price (for a given contract) arising from the market-clearing condition $\lambda_M x^M + \lambda_D x^D = \bar{x}$.[19]

LEMMA 1 (Portfolio Choices and Market-Clearing Price): *For a given a contract* (a, b, c),

(*i*) *the direct investors' and managers' optimal portfolio choices are as follows*:

$$x^D = \frac{\mu - p}{\gamma\sigma^2}, \tag{3}$$

$$x^M = \frac{\Delta - \psi/a + \mu - p}{a\gamma\sigma^2} + \frac{b}{a} = \frac{x^D}{a} + \frac{\Delta - \psi/a}{a\gamma\sigma^2} + \frac{b}{a}; \tag{4}$$

(*ii*) *the market-clearing price of the risky asset is*

$$p = \mu - \gamma\sigma^2\Lambda\left(\bar{x} - \lambda_M\frac{b}{a}\right) + \Lambda\frac{\lambda_M}{a}\left(\Delta - \frac{\psi}{a}\right), \tag{5}$$

where $\Lambda \equiv (\lambda_M/a + \lambda_D)^{-1}$ *modifies the market's effective risk aversion.*

[19] We define the equilibrium at the end of Section IIIB after we introduce the fund investor's problem.

A direct investor's portfolio is the standard mean-variance portfolio, scaled by his risk aversion γ. A manager's portfolio choice differs from that of a direct investor in three respects. First the manager holds the same scaled mean-variance portfolio, but because she only receives a of any performance that she generates, she adjusts her holdings by $1/a$. Second, because managers have access to return-augmenting strategies, they perceive the mean-variance trade-off differently from the direct investors and tilt their mean-variance portfolios to try to produce alpha. Consistent with this result, Johnson and Weitzner (2019) report that fund managers' portfolios in their sample overweight assets with high securities-lending fees. Finally, because the manager's compensation is exposed to fluctuations in the benchmark, she holds a hedging portfolio that is (in this case perfectly) correlated with the benchmark, i.e., the benchmark itself.[20] The split between the mean-variance portfolio and the benchmark is governed by the strength of the relative-performance incentives, captured by b. The higher the b, the closer the manager's portfolio to the benchmark.

Because contracts change the managers' demand functions, the equilibrium stock price will depend on these contracts. Benchmarking pushes up the stock price, thus lowering the stock's expected return. Unlike the social planner, individual fund investors take the stock price as given and do not account for this pecuniary externality. We turn to the fund investors' problem next.

B. *Fund Investors' Problem*

Each fund investor chooses a contract (a,b,c) and portfolio $x = x^M$ to maximize his expected utility subject to the manager's participation and incentive constraints. The latter is the manager's first-order condition (FOC) (4), capturing the fact that the portfolio x is the manager's private choice.[21]

To write the fund investor's problem formally, it is convenient to express payoffs in terms of the following variables:

$$y = ax - b, \quad z = x - y.$$

These are the effective allocations of asset holdings to the manager and fund investor, respectively. Then the fund investor's and manager's utilities (in the mean-variance form) can be written as follows:

$$\begin{aligned} U^F\Big(a,\frac{b}{a},c,y,p\Big) &= x(1-a)\Delta + z(\mu - p) - \frac{\gamma}{2}\big[z^2\sigma^2 + (1-a)^2\sigma_\varepsilon^2\big] \\ &\quad - c + x_{-1}^F p, \\ U^M\Big(a,\frac{b}{a},c,y,p\Big) &= x(a\Delta - \psi) + y(\mu - p) - \frac{\gamma}{2}\big[y^2\sigma^2 + a^2\sigma_\varepsilon^2\big] + c, \end{aligned}$$

[20] This implication is very general, and we share it with other models that analyzed benchmarking, both in two-period and multiperiod economies and for other investor preferences specifications. This result first appeared in Brennan (1993) in a two-period model. Cuoco and Kaniel (2011) and Basak and Pavlova (2013), among others, obtain it in dynamic models with different preferences.

[21] We show in the proof of Lemma 1 that the manager's second-order condition is satisfied, and thus the first-order approach is valid.

where x and z are given by

$$x = \frac{y}{a} + \frac{b}{a},$$

$$(6) \qquad z = \left(\frac{1}{a} - 1\right)y + \frac{b}{a} = \left(\frac{1}{a} - 1\right)\frac{\Delta - \psi/a + \mu - p}{\gamma\sigma^2} + \frac{b}{a}.$$

Then the fund investor's problem can then be written as follows:[22]

$$\max_{a,b/a,c} U^F$$

s.t.

$$(7) \qquad U^M \geq u_0,$$

$$(8) \qquad y = \frac{\Delta - \psi/a + \mu - p}{\gamma\sigma^2}.$$

Constraint (7) is the manager's participation constraint, where u_0 is (the mean-variance equivalent of) the value of manager's outside option.[23] Equation (8) is the manager's (modified) incentive constraint.

An equilibrium with privately optimal contracts consists of the contract, risky asset holdings by direct investors and fund managers, and the stock price such that the agents solve their corresponding problems and the stock market clears. Appendix A contains the formal definition. We characterize this equilibrium in the next subsection.

C. *Privately Optimal Contracts*

As a point of reference, consider the first best where the manager's portfolio choice is observable and contractible. The first best involves efficient risk sharing between the (equally risk-averse) fund investor and manager, and the contract that implements it is $a = 1/2$ and $b = 0$.[24]

However, if under efficient risk sharing the manager chose the portfolio privately, she would underinvest in the risky asset. A higher a reduces the manager's effective cost ψ/a, which increases her demand for the risky asset. However, a higher a also exposes the manager to more risk, which makes her scale down x^M, as can be seen in the denominator(s) of (4). Thus the use of performance pay creates a tension between incentive provision and risk sharing. The use of benchmarking, alleviates this tension by mitigating the adverse effect of a. Benchmarking shields the manager

[22] The formulation of the fund investor's problem in terms of the exponential utilities (rather than in the mean-variance form) can be found in online Appendix B.

[23] We do not model explicitly what this outside option is, as it does not matter for our main results. It can be exogenous, or it can be endogenized. Notice also that because of the contract's constant component c, in the mean-variance formulation utility becomes transferable, and the fund investor effectively maximizes the total utility of the fund investor and the manager subject to the manager's incentive constraint. The manager's participation constraint is then trivially satisfied by adjusting the constant c.

[24] See Lemma 5 in Appendix A for the formal analysis.

from risk by reducing variance in her compensation for a given portfolio choice.[25] As a result, (for the same a) the manager invests more. In what follows, we will consider how the fund investor will optimally choose the levels of a and b.

Notice that the fund investor fully internalizes the manager's cost of managing the fund.[26] But since the manager bears the cost privately and only receives fraction a of the return, for her the effective cost is higher, which is why ψ/a appears in (8). The difference between the actual cost (ψ) and the cost perceived by the manager (ψ/a) will play an important role in the trade-off between risk sharing and incentive provision.

First, consider the fund investor's optimal choice of relative performance in the contract, b. Notice that b enters the fund investor's and manager's problems only though b/a. The FOC with respect to b/a is given by[27]

$$\frac{\partial\left(U^F + U^M\right)}{\partial\left(b/a\right)} = \Delta - \psi + \mu - p - \gamma\sigma^2 z = 0. \tag{9}$$

This condition captures the fact that an increase in b/a makes the manager invest more in the risky stock. Therefore, the optimal level of b will be the one that balances a marginal increase in the total expected surplus, $\Delta - \psi + \mu - p$, with the marginal increase in the variance, $\sigma^2 z$.

Substituting out z using (6), equation (9) can be rewritten as[28]

$$\gamma\sigma^2 b = \left(2a - 1\right)\left(\Delta - \psi + \mu - p\right) + \left(1 - a\right)\left(\frac{1}{a} - 1\right)\psi. \tag{10}$$

The two terms on the right-hand side of equation (10) capture two considerations that fund investors have in mind when designing the benchmark. Note two extreme cases: $a = 1/2$ when perfect risk sharing is achieved, and $a = 1$ when the private and social costs are aligned. As we will show later, in the optimal contract $a \in \left(1/2, 1\right)$, so both terms on the right-hand side of (10) are positive. The first term, $\left(2a - 1\right)\left(\Delta - \psi + \mu - p\right)$, arises because the fund investor recognizes that benchmarking increases the total expected surplus net of cost. Since $a > 1/2$, the manager is exposed to more risk than is efficient, so the fund investor uses benchmarking to make her invest more. The second term, $\left(1 - a\right)\left(1/a - 1\right)\psi$, reflects the incentive-provision role of b. By protecting the manager from risk, benchmarking provides her with incentives to invest more.

Notice that (10) depends on the equilibrium price p. When choosing b, the fund investor takes p as given. In equilibrium, however, p depends on the contract as shown in equation (5). Then, to find the equilibrium value of b (the fixed point), we need to substitute (5) in (10) and solve it for b. This leads us to equation (13) in Lemma 2 below, which presents b only in terms of model parameters and a, which we will now solve for.

[25] By reducing the manager's risk exposure, benchmarking makes it cheaper for the fund investor to implement any particular portfolio choice.

[26] Formally, this can be seen by taking the FOC with respect to c, which implies that the Lagrange multiplier on the participation constraint equals one.

[27] We show in Lemma 7 in Appendix A that the second-order conditions hold in both privately and socially optimal cases.

[28] See the proof of Lemma 2 in Appendix A for derivations.

The FOC with respect to a is given by

$$(11)\qquad 0 = \frac{\partial\left(U^F + U^M\right)}{\partial a} + \frac{\partial U^F}{\partial y}\frac{\partial y}{\partial a}$$

$$= -(2a - 1)\gamma\sigma_\varepsilon^2 - \underbrace{\left(\Delta - \psi + \mu - p - \gamma\sigma^2 z\right)}_{=\,0 \text{ by FOC with respect to } b/a,\ (9)}\frac{y}{a^2}$$

$$+ \frac{1-a}{a}\underbrace{\left(\Delta + \mu - p - \gamma\sigma^2 z\right)}_{=\,\psi \text{ by FOC with respect to } b/a,\ (9)}\frac{\partial y}{\partial a}$$

$$= -(2a - 1)\gamma\sigma_\varepsilon^2 + (1 - a)\frac{\psi^2}{\gamma\sigma^2 a^3},$$

where the last equality uses the FOC with respect to b/a, (9), and $\partial y/\partial a = \psi/\left(\gamma\sigma^2 a^2\right)$. First, notice the appearance of $\partial y/\partial a$. It captures how a marginal increase in a affects the manager's incentive to invest in the risky asset. This is the way that the contract creates incentives. Second, several terms drop out because b/a is chosen optimally, leaving only a term that is proportional to σ_ε^2. The cancellation comes because the optimal level of benchmarking already optimally shares the dividend risk, so all that remains to be shared is the extra risk from return-augmenting activities.

Notice that unlike in (10), the incentive-provision term and the risk-sharing term have different signs. This means that there is a trade-off between incentive provision and risk sharing. A higher a is beneficial as it provides incentives for alpha production, but is also costly because it exposes the manager to too much risk.

The following lemma summarizes the closed-form expressions for the equilibrium contract, as well as the expressions for the equilibrium price and stock holdings:

LEMMA 2: *In the equilibrium with privately optimal contracts*,

(*i*) *a^* and b^* solve*

$$(12)\quad 0 = (1 - a^*)\frac{\psi^2}{\gamma\sigma^2 a^{*3}} - (2a^* - 1)\gamma\sigma_\varepsilon^2,$$

$$(13)\ b^* = (2a^* - 1)\left[\bar{x} + \frac{\lambda_D}{\gamma\sigma^2}(\Delta - \psi)\right] + (1 - a^*)\left[\frac{1}{a^*} - \left(\frac{\lambda_M}{a^*} + \lambda_D\right)\right]\frac{\psi}{\gamma\sigma^2};$$

(*ii*) *the risky asset's price is*

$$(14)\qquad p^* = \mu - \gamma\sigma^2\bar{x} + \lambda_M\left(2\Delta - \psi - \frac{\psi}{a^*}\right);$$

and each fund's risky asset holdings are

$$(15)\qquad x^{M*} = 2\bar{x} + \frac{\lambda_D}{\gamma\sigma^2}\left(2\Delta - \psi - \frac{\psi}{a^*}\right).$$

Notice that there is a recursive structure to these conditions. The expression in (12) does not depend on b^* and is a function of only a^* and the model parameters.[29] Given a^*, (13), (14), and (15) deliver the expressions for b^*, p^*, and x^{M*}, respectively.

Let us briefly comment on the expression for the equilibrium price given by (14). Absent fund managers, the equilibrium price would be $p = \mu - \gamma\sigma^2\bar{x}$. The last term in (14) means that the price reflects the managers' extra demand associated with their return-augmenting activities. Notice that the term in parentheses is a sum of $\Delta - \psi$ and $\Delta - \psi/a$, which are the (marginal) extra expected returns net of costs as perceived by the fund investors and by the managers, respectively. Similarly, the equilibrium asset holdings of managers in (15) are higher when the opportunities for alpha production are better. Notice that managers hold exactly $2\bar{x}$ when $\lambda_D = 0$. We will discuss this special case further in Section IIID.

Next, we turn to the characterizations of a^* and b^*, (12) and (13). We prove below that the equilibrium level a^* is strictly between $1/2$ (perfect risk sharing) and 1 (private and social costs coincide). Also note that as σ_ε^2 goes to zero, a^* approaches 1, and the allocation approaches the first-best one (see Lemma 5 in Appendix A.) Indeed, it is crucial for our results that the fund investor does not "sell the project" to the manager, i.e., $a^* < 1$. As an alternative to the assumption of $\sigma_\varepsilon^2 > 0$, there are other modeling choices that would ensure that $a^* < 1$, for example, a lower-bound on c, the constant part of the contract.

As long as $\bar{x} + \lambda_D(\Delta - \psi)/(\gamma\sigma^2) > 0$, all the terms on the right-hand side of (13) are positive. This condition is satisfied either if $\Delta - \psi > 0$ (the expected abnormal return exceeds the cost of managing the portfolio), or if the net supply of the stock $\bar{x}$ is large enough. This brings us to our first main result.

PROPOSITION 1 (Benchmarking Is Optimal): *Consider the equilibrium with privately optimal contracts.*

(*i*) *The equilibrium value of the "skin in the game" satisfies* $a^* \in (1/2, 1)$.

(*ii*) *Suppose that* $\bar{x} + \lambda_D(\Delta - \psi)/(\gamma\sigma^2) > 0$. *Then benchmarking is optimal, that is*, $b^* > 0$.

Part (ii) of Proposition 1 is essentially a version of Holmström's (1979) famous sufficient-statistic result—the use of an additional signal (in this case, the benchmark return) helps the contract designer provide incentives to the manager in a more effective way. While Holmström's result suggests that b^* is different from zero in general, provided $\bar{x} + \lambda_D(\Delta - \psi)/(\gamma\sigma^2) > 0$ we can say b^* is strictly positive, which is the relevant case given this application.

This proposition helps us understand why benchmarking in the asset management industry is so pervasive. Benchmarking is useful to fund investors because it incentivizes the manager to engage more in risky return-augmenting activities by partially protecting her from risk. In the language of the asset management

[29] Equation (12) has two roots, one positive and one negative. The negative root can be ruled out by the manager's second-order condition; see the proofs of Lemma 1 and Proposition 1 (i).

industry, benchmarked managers are being protected from "beta" (i.e., the fluctuations in the return of the benchmark/market portfolio) while being rewarded for "alpha."

We wrap up this subsection by stating some comparative-statics results:

LEMMA 3 (Comparative Statics): *Consider the equilibrium with privately optimal contracts.*

(*i*) *If the cost of managing the fund portfolio, ψ, is higher, then a^* is higher and p^* and x^{M*} are lower.*

(*ii*) *If the expected excess return, Δ, is higher, then b^*, p^*, and x^{M*} are higher.*

(*iii*) *If the extra risk associated with producing excess returns, σ_ε^2, is higher, then a^*, p^*, and x^{M*} are lower.*[30]

These results are intuitive. The higher the ψ, the more costly it is to incentivize the manager. The fund investor will react to an increase in the cost by giving the manager a larger share of the return. With a higher cost (and despite a higher a, since ψ/a^* is still increasing in ψ), the manager will invest less in the risky asset, leading to a lower stock price. On the other hand, the higher the extra risk associated with producing excess returns, σ_ε^2, the more important is the risk sharing. The fund investor will choose a lower a (closer to $1/2$), giving the manager lower incentives to invest in the risky asset, again leading to lower x^{M*} and p^*. Finally, when Δ increases, the abnormal return is higher. As a result, the fund investors use more benchmarking to shield the managers from risk, so that the managers invest more in the risky asset.

D. *Socially Optimal Contracts*

Fund investors design contracts to influence the manager's demand for the risky asset. Through the collective demand of the managers, contracts influence the equilibrium stock price, as given by (5). The price then affects the marginal cost/marginal benefit trade-off of contracts for all fund investors. Since fund investors take the stock price as given, they do not internalize how their choices of contracts (once aggregated) change the effectiveness of other fund investors' contracts. In other words, fund investors impose an externality on each other through their use of contracts. In this subsection, we ask what contract a planner, who is subject to the same restrictions as fund investors, would choose to internalize this externality.

We define the problem of a constrained social planner as follows. The planner maximizes the weighted average of fund investors' and direct investors' utilities subject to the participation and incentive constraints of the managers, as well as the constraint that direct investors choose their portfolios themselves.[31]

[30] Notice that the effects of ψ and σ_ε^2 on b^* are ambiguous.

[31] Equivalently, instead of imposing the manager's participation constraint, her utility can be included in the planner's objective function with a Pareto weight ω_M. For the transfer c to be finite, we must have $\omega_M = \omega_F$. This

As before, this problem can be equivalently rewritten in terms of mean-variance preferences.[32] Define $U^D = x^D_{-1} p + x^D(\mu - p) - \gamma x^{D2}\sigma^2/2$. Then the social planner's problem is

$$\max_{a,\, b/a,\, c} \ \omega_F U^F + \omega_D U^D,$$

subject to (3), (5), (7), and (8).

The social planner's FOC with respect to b/a is

$$(16) \qquad 0 = \underbrace{\left[\omega_F\left(x^F_{-1} - x^M\right) + \omega_D\left(x^D_{-1} - x^D\right)\right]\frac{\partial p}{\partial(b/a)}}_{\text{distributive pecuniary externality}}$$

$$+ \omega_F\left[\underbrace{\frac{\partial\left(U^F + U^M\right)}{\partial(b/a)}}_{\text{private FOC}} + \underbrace{\frac{\partial U^F}{\partial y}\frac{\partial y}{\partial p}\frac{\partial p}{\partial(b/a)}}_{\text{contracting pecuniary externality}}\right].$$

The terms in the first line of (16) capture what Davila and Korinek (2018) call "distributive effects" or "distributive pecuniary externality." Depending on the initial endowments and the Pareto weights, the social planner has incentives to use benchmarking to move the price so as to benefit one or the other party based on this distributive motive. We discuss the distributive effects in Remark 1 at the end of the next section. Our focus is on the "contracting pecuniary externality" that acts through the price entering the manager's incentive constraint. To isolate the planner's motive to correct the contracting externality from the distributive motive, we want to neutralize the latter. To do this, we set the Pareto weights equal to the population weights, $\omega_F = \lambda_M$ and $\omega_D = \lambda_D$.[33] Then by market clearing, $\omega_F\left(x^F_{-1} - x^M\right) + \omega_D\left(x^D_{-1} - x^D\right) = 0$, so the term in the first line of (16) is zero. (See Davila and Korinek 2018 for further discussion.)

Rewriting the term in the second line of (16) yields

$$(17) \qquad 0 = \underbrace{\left(\Delta - \psi + \mu - p - \gamma\sigma^2 z\right)\underbrace{\frac{\partial y}{\partial(b/a)}}_{=1}}_{\text{private FOC}}$$

$$+ \underbrace{\frac{1-a}{a}\left(\Delta + \mu - p - \gamma\sigma^2 z\right)\frac{\partial y}{\partial p}\frac{\partial p}{\partial(b/a)}}_{\text{contracting pecuniary externality}}.$$

is analogous to noticing that the Lagrange multiplier on the participation constraint, which effectively acts as the Pareto weight on the manager, equals ω_F.

[32] We provide the original formulation in terms of exponential utilities in online Appendix B.

[33] Choosing Pareto weights to cancel out the distributive effects is equivalent to allowing the social planner to use transfers for any Pareto weights. The planner would then use transfers to equate the marginal utilities (weighted by Pareto weights) of different agents.

Compare (17) with the FOC with respect to b/a in the private case, (9). The first term in (17) is exactly (9). The second term in (17) captures the contracting pecuniary externality that the planner is trying to correct and that the private agents ignore.

Consider the term $(\partial y/\partial p)[\partial p/\partial(b/a)]$. The term $\partial y/\partial p = -1/(\gamma\sigma^2)$ captures the fact that the manager's demand function is downward sloping. The term $\partial p/\partial(b/a) = \gamma\sigma^2\Lambda\lambda_M$ reflects the fact that the higher the value b/a collectively used by all fund investors, the more crowded the trades, and the higher the stock price. The product of the two, $(\partial y/\partial p)[\partial p/\partial(b/a)] = -\Lambda\lambda_M = -\lambda_M/(\lambda_M/a + \lambda_D)$ captures the fact that the general equilibrium effect of contracts on the risky asset's price reduces the effectiveness of b/a in incentivizing the manager to hold more of the risky asset. Hence (17) becomes

$$(\Delta + \mu - p - \gamma\sigma^2 z)\left[1 - \frac{(1-a)\lambda_M/a}{\lambda_M/a + \lambda_D}\right] - \psi = 0 \tag{18}$$

or

$$\Delta - \underbrace{\frac{\lambda_M/a + \lambda_D}{\lambda_M + \lambda_D}\psi}_{\text{cost from the planner's perspective}} + \mu - p - \gamma\sigma^2 z = 0. \tag{19}$$

Similar to the fund investors, the planner trades off the benefits and costs of inducing the agent to invest in the risky asset. Fund investors think of the benefit as the usual mean-variance consideration given by $(\Delta + \mu - p - \gamma\sigma^2 z)$, and the cost as ψ. For the planner, the benefit is smaller than for the fund investors, because she realizes that benchmarking inflates the risky asset's price and thus reduces its expected return. Put differently, due to this crowded-trades effect, the cost is higher for the same units of benefit: the cost is $(\lambda_M/a + \lambda_D)/(\lambda_M + \lambda_D)\psi$ in (19) versus ψ in (9). (This difference in the perceived costs will show up in our further comparisons between the socially and privately optimal contracts.) So, from the planner's point of view, incentive provision is less beneficial/more expensive, which, as we will see, will make her do less of it.

Substituting for z, we obtain the planner's counterpart to equation (10):

$$\gamma\sigma^2 b = (2a-1)\left[\Delta - \frac{\lambda_M/a + \lambda_D}{\lambda_M + \lambda_D}\psi + \mu - p\right] + (1-a)\left[\frac{1}{a} - \frac{\lambda_M/a + \lambda_D}{\lambda_M + \lambda_D}\right]\psi. \tag{20}$$

Compared to (10), the cost ψ is again replaced with $(\lambda_M/a + \lambda_D)/(\lambda_M + \lambda_D)\psi$. Finally, substituting in the equilibrium price, (5), yields the fixed-point value of b that depends only on the model parameters, as presented in equation (24) in Lemma 4 below.

Next, consider the planner's FOC with respect to a:

$$(21)\quad 0 = \frac{\partial\left(U^F + U^M\right)}{\partial a} + \frac{\partial U^F}{\partial y}\left[\frac{\partial y}{\partial a} + \underbrace{\frac{\partial y}{\partial p}\frac{\partial p}{\partial a}}_{\text{contracting externality}}\right]$$

$$= -(2a-1)\gamma\sigma_\varepsilon^2 - (\Delta - \psi + \mu - p - \gamma\Sigma z)\frac{y}{a^2}$$

$$+ \frac{1-a}{a}(\Delta + \mu - p - \gamma\Sigma z)\left[\frac{\partial y}{\partial a} + \frac{\partial y}{\partial p}\frac{\partial p}{\partial a}\right]$$

$$= -(2a-1)\gamma\sigma_\varepsilon^2 + \frac{1-a}{a}\frac{\lambda_M/a + \lambda_D}{\lambda_M + \lambda_D}\psi\left[\frac{\partial y}{\partial a} + \frac{\partial y}{\partial p}\frac{\partial p}{\partial a}\right.$$

$$\left. + \frac{y}{a^2}\frac{\partial y}{\partial p}\frac{\partial p}{\partial(b\theta/a)}\right],$$

where the last equality follows from (17). After some algebra (see the proof of Lemma 4 in Appendix A) this condition can be written as follows:

$$(22)\quad -(2a-1)\gamma\sigma_\varepsilon^2 + (1-a)\frac{\psi^2}{\gamma\sigma^2 a^3}\frac{\lambda_D}{\lambda_M + \lambda_D} = 0.$$

Compare this equation to its analog in the case with privately optimal contracts, (11). Notice that the benefit of incentive provision captured by the first term in (22) is smaller than the corresponding term in (11). As a result, the planner will choose a lower a than fund investors will. We will formalize this result later in Proposition 2.

The following lemma presents the resulting expressions for the equilibrium contract, price, and risky-asset holdings in closed form.[34]

LEMMA 4: *In the equilibrium with socially optimal contracts*,

(*i*) a^{**} *and* b^{**} *solve*[35]

$$(23)\quad 0 = \left(1 - a^{**}\right)\frac{\psi^2}{\gamma\sigma^2 a^{**3}}\frac{\lambda_D}{\lambda_M + \lambda_D} - \left(2a^{**} - 1\right)\gamma\sigma_\varepsilon^2,$$

$$(24)\quad b^{**} = \left(2a^{**} - 1\right)\left[\bar{x} + \frac{\lambda_D}{\gamma\sigma^2}(\Delta - \psi)\right]$$

$$+ \left(1 - a^{**}\right)\left[\frac{1}{a^{**}} - \frac{\lambda_M/a^{**} + \lambda_D}{\lambda_M + \lambda_D}\right]\frac{\psi}{\gamma\sigma^2};$$

(*ii*) *the risky asset's price is*

$$(25)\quad p^{**} = \mu - \gamma\sigma^2\bar{x} + \lambda_M\left(2\Delta - \frac{\lambda_M/a^{**} + \lambda_D}{\lambda_M + \lambda_D}\psi - \frac{\psi}{a^{**}}\right);$$

[34] See Appendix A for the formal definition of the equilibrium with socially optimal contracts.

[35] From (23), $1/2 \leq a^{**} < 1$, where the first inequality is strict so long as $\lambda_D > 0$.

and each fund's risky asset holdings are

$$x^{M**} = 2\bar{x} + \frac{\lambda_D}{\gamma\sigma^2}\left(2\Delta - \frac{\lambda_M/a^{**} + \lambda_D}{\lambda_M + \lambda_D}\psi - \frac{\psi}{a^{**}}\right). \tag{26}$$

Equations (23)–(26) are the analogs of (12)–(15) and have the same recursive structure. As expected, the two sets of equations coincide when $\lambda_M = 0$, and hence there is no externality. But so long as there are managers, the socially and privately optimal contracts are different. Proposition 2 below reveals how exactly they compare to each other.

We are now ready to present the central result of the paper.

PROPOSITION 2 (Socially versus Privately Optimal Contracts): *Compared to the privately optimal contract, the socially optimal contract involves*

(*i*) *less "skin in the game," that is*, $a^{**} < a^*$;

(*ii*) *less benchmarking, that is*, $b^{**} < b^*$, *if* $\bar{x} + \lambda_D(\Delta - \psi)/(\gamma\sigma^2) > 0$.[36]

As we have seen in our analysis, the use of contracts inflates the risky asset's price and thus *reduces the marginal benefit of incentive provision* for everyone else. The social planner internalizes this effect, and opts for less incentive provision than fund investors.

As a special case that helps make the point very clearly, suppose there are no direct investors, $\lambda_D = 0$. In this case, each fund will hold exactly $2\bar{x}$ shares and the total alpha in the economy is fixed, equal to $2\bar{x}\Delta$. The planner understands that incentive provision is unnecessary in this case, so there is no trade-off between incentive provision and risk sharing. Indeed, by substituting $\lambda_D = 0$ into (23) and (24), it immediately follows that the socially optimal contract is $a = 1/2$ and $b = 0$, which coincides with the first-best one (see Lemma 5 in Appendix A). In contrast, the fund investors do not appreciate the fact that, in equilibrium, their contracts will not help them generate higher returns, and use contracts with $a > 1/2$ and $b > 0$, as can be seen from (12) and (13).

To further emphasize that benchmarking is crucial for the comparison between privately and socially optimal contracts, consider a case where benchmarking is exogenously set to zero, $b = 0$. In this case, all incentive provision and risk sharing has to be done through a. As we discussed earlier, an increase in a has two opposing effects on the managers' demands and hence the risky asset's price. It can be shown that with $b = 0$ the comparison between a^* and a^{**} is ambiguous. Intuitively, both the marginal benefit of a (incentive provision) as well as its marginal cost (exposing the manager to more risk) are lower for the social planner who internalizes the effect of a on the price. Depending on which reduction is bigger, the planner might choose a higher or a lower a than the fund investors do. Thus, only because

[36] We also show in the proof of Proposition 2 that $b^{**}/a^{**} < b^*/a^*$.

of benchmarking ($b \neq 0$) can we be sure of the direction of the externality and are able to say that privately optimal contracts deliver excessive incentive provision.

We now show that excessive incentive provision and excessive benchmarking in private contracts give rise to crowded trades and excessive costs.

PROPOSITION 3 (Crowded Trades and Excessive Costs of Asset Management): *Compared to the equilibrium with privately optimal contracts, in the equilibrium with socially optimal contracts*

(*i*) *the risky asset's price is lower*, $p^{**} < p^{*}$;

(*ii*) *the fund's risky asset holdings are lower*, $x^{M**} < x^{M*}$, *and the managers' costs are lower*, $\psi x^{M**} < \psi x^{M*}$.

As Proposition 3 shows, excessive use of incentive contracts by fund investors inflates the risky asset's price and reduces its expected return per share. In addition, the managers overinvest in the stock market and the costs of asset management are excessively high. Our model thus contributes to the debate on whether costs of asset management are excessive and whether returns delivered by the managers justify these costs.

We close the analysis with a few final remarks about the model.

REMARK 1 (Distributive Effects): *Through our choice of weights in the social welfare function, we have shut down the contracts' distributive effects and isolated the pecuniary externality that the planner desires to correct. For certain applications, such as those related to wealth inequality, however, it could be interesting to analyze the transfers from one set of agents to another that benchmarking generates. Allowing for redistribution changes outcomes depending on whether an agent is a (net) buyer or a (net) seller of the risky asset. Because benchmarking boosts the risky asset price, this benefits (net) sellers of the risky asset at the expense of (net) buyers. If the social planner favors investors who have high endowments of the asset and are planning to sell (e.g., the older generations), she has incentives to use more benchmarking in order to inflate its price to assist them, and vice versa if she favors net buyers (who are typically the younger generations).*

REMARK 2 (Prices Relative to the First Best): *According to Proposition 3*, $p^{**} < p^{*}$. *We usually think of a constrained planner as being better at providing incentives than decentralized agents, and thus being closer to what an unconstrained planner can achieve. Surprisingly, the price of the risky asset in the first-best case exceeds equilibrium prices under both privately and socially optimal contracts, that is*, $p^{**} < p^{*} < p^{FB}$.[37] *So, the equilibrium price in the constrained optimum is not*

[37] The expression for the first-best asset price is given in Lemma 5 in Appendix A. Comparing it to p^{*} given in Lemma 2 immediately yields the result.

closer to the unconstrained-optimum price than the decentralized-equilibrium one, but is instead further away.[38]

While this might be surprising at first glance, this result is in fact quite intuitive. Under the first best, the portfolio is observable and it is optimal to choose high-alpha portfolios. This, of course, will push up the stock price and reduce its expected return. But, crowded trades are not a problem per se, because a pecuniary externality does not lead to an inefficiency in this case. In contrast, when the contract needs to provide incentives because the portfolio cannot be observed, a pecuniary externality does lead to an inefficiency, and crowded trades pose a problem as they reduce the effectiveness of incentive provision. While the comparison to the first best is irrelevant for practical purposes (because the first best is unattainable), it is helpful to highlight how exactly the mechanism that we explore works.

REMARK 3 (Achieving Social Optimum with Taxes): *Given that privately optimal contracts result in an externality, it is natural to ask whether some sort of taxes could implement the constrained social optimum. We provide a detailed analysis of this question in online Appendix D. We find the following. First, the manager's compensation needs to be (proportionally) taxed to make it more costly for the fund investor to provide incentives to the manager. This type of tax mimics the higher cost of incentive provision for the planner, who internalizes the externality. Second, the fund return net of the manager's compensation—which is the same as the fund investor's earnings in our model—should be (proportionally) subsidized. While this might be counterintuitive, the subsidy motivates the fund investor to lower* a *by increasing the benefit of keeping a larger* $1 - a$*. An alternative to the subsidy is imposing a cap* $\bar{a}$ *on the fund manager's "skin in the game." Of course, the specific levels for the tax and subsidy rates (or, alternatively, the tax rate and the cap on* a*) depend on the model parameters (see online Appendix D for the formulas).*

REMARK 4 (Endogenizing the Choice of Becoming a Fund versus Direct Investor): *To zero in on the main mechanism we consider in the paper, we exogenously fixed the fractions of different agents in the population. One could endogenize the choice of becoming a fund investor or a direct investor, for example, by assuming a heterogeneous cost of participating in the asset market. This type of extension would introduce another channel through which crowded trades matter. The choices of individual investors of whether to be a fund investor or a direct investor, in the aggregate, would determine the size of the asset management sector. This in turn would affect the strength of the externality that we identify in the paper (i.e., how much contracts affect the risky asset's price and thus effectiveness of contracts designed by others). When making their decisions, the individual agents ignore this effect while the planner would account for this "extensive margin" of the externality when designing contracts.*

[38] This result parallels that in Lorenzoni (2008), where the decentralized equilibrium falls between the constrained and unconstrained optima in terms of amount of borrowing and asset prices. However, in Lorenzoni's model the inequality signs in the price comparison are reverse—decentralized-equilibrium asset prices are lower than in the constrained optimum (higher in our model) and higher than in the first best (lower in our model).

REMARK 5 (Multiple Risky Assets): *A natural extension of our model is to allow for multiple risky assets. In that case, the fund investors and the planner choose benchmark portfolio weights as part of the contract. Our main results fully extend to the multiasset case. Moreover, the benchmark portfolio weights in privately and socially optimal contracts also differ* (*see Kashyap et al. 2022*).

IV. Conclusions

We consider the problem of optimal incentive provision for portfolio managers in a general equilibrium asset-pricing model. The optimal contacts involve benchmarking. We show that by ignoring the effects of contracts on the equilibrium stock price, fund investors impose an externality on each other—the effectiveness of their incentive contracts is lower than they perceive them to be. Benchmarking boosts the stock price and lowers the expected return, making the marginal benefit of alpha production lower for everyone. The social planner, who internalizes the effects of contracts on the equilibrium price, opts for less incentive provision, less benchmarking, and lower asset management costs.

In future work, it would be interesting to incorporate passive asset managers into the model. This extension is, however, not straightforward. The existing evidence on the compensation contracts in the asset management industry covers only active funds. Very little is known about contracts of managers in passive funds. Before engaging in modeling of passive managers, it would be important to collect such evidence. A natural starting point would be to analyze the Statements of Additional Information filed by the US mutual funds with the Securities and Exchange Commission, which contain information on managers' compensation structure. If contracts of passive managers turn out to be incentive contracts, it would be interesting to understand the incentive problem they solve. It is not obvious what kind of incentive problem would result in optimal contracts that make the managers closely follow the benchmark. We leave this problem for future work.

Finally, environmental, social, and governance investing is one of the fastest growing segments in asset management. Another interesting extension would be to use this framework to study the optimal design of environmental, social, and governance benchmarks. We explore this problem in Kashyap et al. (2023a).

Appendix A. Proofs

DEFINITION 1: *An equilibrium with privately optimal contracts is a contract* (a^*, b^*, c^*), *the direct investor's portfolio* x^D, *the manager's portfolio* $x^M(a,b)$, *and a price* p^* *such that*

(*i*) *given* p^*, x^D *solves the direct investor's problem* $\max_x x(\mu - p^*) - \gamma x^2\sigma^2/2$;

(*ii*) *given* p^*, *for any* (a,b), $x^M(a,b)$ *solves the fund manager's problem*

$$\max_x x(a\Delta - \psi) + (ax - b)(\mu - p^*) - \gamma\left[(ax - b)^2\sigma^2 + a^2\sigma_\varepsilon^2\right]/2;$$

(iii) *given* p^* *and* $x^M(a,b)$, (a^*,b^*,c^*) *solves the fund investor's problem*

$$\max_{a,b,c} x(1-a)\Delta + \big[(1-a)x+b\big](\mu-p^*) - \frac{\gamma}{2}\Big\{\big[(1-a)x+b\big]^2\sigma^2 + (1-a)^2\sigma_\varepsilon^2\Big\} - c$$

s.t.

$$x(a\Delta-\psi) + (ax-b)(\mu-p^*) - \frac{\gamma}{2}\big[(ax-b)^2\sigma^2 + a^2\sigma_\varepsilon^2\big] + c \geq u_0,$$

$$x = x^M(a,b);$$

(iv) *the stock market clears:* $\lambda_D x^D + \lambda_M x^M(a^*,b^*) = \bar{x}$.

Throughout the paper, we use the following notation: $x^{M^*} \equiv x^M(a^*,b^*)$.

DEFINITION 2: *An equilibrium with socially optimal contracts is a contract* (a^{**},b^{**},c^{**}), *the direct investor's demand function* $x^D(p)$, *the manager's demand function* $x^M(p,a,b)$, *and a price function* $p = \hat{p}(a,b)$ *such that*

(i) *for any* p, $x^D(p)$ *solves the direct investor's problem* $\max_x x(\mu-p) - \gamma x^2\sigma^2/2$;

(ii) *for any* p *and* (a,b), $x^M(p,a,b)$ *solves the fund manager's problem*

$$\max_x x(a\Delta-\psi) + (ax-b)(\mu-p) - \gamma\big[(ax-b)^2\sigma^2 + a^2\sigma_\varepsilon^2\big]/2;$$

(iii) *given* $\hat{p}(a,b)$, $x^D(p)$, *and* $x^M(p,a,b)$, (a^{**},b^{**},c^{**}) *solves the social planner's problem*

$$\max_{a,b,c} \lambda_M\Big\{x_{-1}^F p + x(1-a)\Delta + \big[(1-a)x+b\big](\mu-p) - \frac{\gamma}{2}\big[(1-a)x+b\big]^2\sigma^2 - \frac{\gamma}{2}(1-a)^2\sigma_\varepsilon^2 - c\Big\} + \lambda_D\Big\{x_{-1}^D p + x^D(p)(\mu-p) - \frac{\gamma}{2}\big[x^D(p)\big]^2\sigma^2\Big\}$$

s.t.

$$x(a\Delta-\psi) + (ax-b)(\mu-p) - \frac{\gamma}{2}\big[(ax-b)^2\sigma^2 + a^2\sigma_\varepsilon^2\big] + c \geq u_0,$$

$$x = x^M(p,a,b), \quad p = \hat{p}(a,b);$$

(iv) *the stock market clears:* $\lambda_D x^D\big(\hat{p}(a^{**},b^{**})\big) + \lambda_M x^M\big(\hat{p}(a^{**},b^{**}),a^{**},b^{**}\big) = \bar{x}$.

Throughout the paper, we use the following notation: $p^{**} \equiv \hat{p}(a^{**},b^{**})$, $x^{M**} \equiv x^M(p^{**},a^{**},b^{**})$.

PROOF OF LEMMA 1:

(i) Equation (3) immediately follows from taking the FOC of the direct investor's problem with respect to x. Similarly, (4) follows from taking the FOC of the manager's problem with respect to x. $a(\Delta - \psi/a + \mu - p) - \gamma\sigma^2(ax - b) = 0$. The second-order condition, $-\gamma a\sigma^2 < 0$, is (globally) satisfied so long as $a > 0$.

(ii) Substituting (3) and (4) in the market-clearing condition $\lambda_M x^M + \lambda_D x^D = \bar{x}$, we find the expression for the equilibrium asset price (5). ∎

LEMMA 5 (First Best): *If x is observable or if $\psi = 0$, then the optimal contract is $(a,b) = (1/2,0)$, and the stock price is $p^{FB} = \mu - \gamma\sigma^2\bar{x} + 2\lambda_M(\Delta - \psi)$.*

PROOF:

When x is observable, the fund investor's problem is $\max_{a,b,x} x(\Delta - \psi + \mu - p) - \gamma\left\{(ax - b)^2\sigma^2 + \left[(1-a)x + b\right]^2\sigma^2 + \left[a^2 + (1-a)^2\right]\sigma_\varepsilon^2\right\}/2$. The FOC with respect to x is $x^M = (\Delta - \psi + \mu - p)/\left\{\gamma\sigma^2\left[a^2 + (1-a)^2\right]\right\} + (2a-1)b/\left[a^2 + (1-a)^2\right]$. The FOC with respect to b is $\gamma\sigma^2(y - z) = 0$, where $y = ax - b$ and $z = (1-a)x + b$. The FOC with respect to a is $-\gamma\sigma^2(y - z)x + \gamma(1 - 2a)\sigma_\varepsilon^2 = 0$, which, using the FOC with respect to b, implies $a = 1/2$. Then setting $b = 0$ satisfies the FOC with respect to b.

The portfolio choice evaluated at the optimal contract is $x^M = 2(\Delta - \psi + \mu - p)/(\gamma\sigma^2)$. Using market clearing, $p^{FB} = \mu - \gamma\sigma^2\bar{x} + 2\lambda_M(\Delta - \psi)$. Comparing with (14), $p^{FB} > p^*$. Finally, substituting $p = p^{FB}$ in x^M, the first-best portfolio of the manager is $x_{FB}^M = 2\left[\bar{x} + \lambda_D(\Delta - \psi)/(\gamma\sigma^2)\right]$.

Lastly, notice that if $\sigma_\varepsilon^2 = 0$, then the FOC with respect to b implies that the FOC with respect to a holds automatically. Thus, a and b are not separately pinned down. In particular, both $(a,b) = (1/2,0)$ and $(a,b) = \left(1, \bar{x} + \lambda_D(\Delta - \psi)/(\gamma\sigma^2)\right)$ are optimal. ∎

PROOF OF LEMMA 2:

(i) Using (6) and (8) and rearranging terms, (9) can be rewritten as $\gamma\sigma^2 b/a = (2 - 1/)(\Delta - \psi + \mu - p) + (1 - 1/a)(1 - 1/a)\psi$. Using (5), this implies

$$\frac{\gamma\sigma^2 b}{a} = \left(2 - \frac{1}{a}\right)\left[\Delta - \psi + \gamma\sigma^2\Lambda\left(\bar{x} - \lambda_M\frac{b}{a}\right) - \frac{\lambda_M\Lambda}{a}\left(\Delta - \frac{\psi}{a}\right)\right]$$
$$+ \left(1 - \frac{1}{a}\right)\left(\psi - \frac{\psi}{a}\right).$$

Rearranging terms, we have

$$\gamma\sigma^2\underbrace{\Big[1+\Big(2-\frac{1}{a}\Big)\lambda_M\Lambda\Big]}_{=\Lambda}\frac{b}{a}$$

$$= \gamma\sigma^2\Lambda\Big(2-\frac{1}{a}\Big)\bar{x} + \Big(2-\frac{1}{a}\Big)\lambda_D\Lambda(\Delta-\psi)$$

$$+\Big[1-\frac{1}{a}-\Big(2-\frac{1}{a}\Big)\frac{\lambda_M\Lambda}{a}\Big]\Big(\psi-\frac{\psi}{a}\Big),$$

$$\gamma\sigma^2\Lambda\frac{b}{a} = \Lambda\Big(2-\frac{1}{a}\Big)\big[\gamma\sigma^2\bar{x}+\lambda_D(\Delta-\psi)\big] + \Big[\frac{\lambda_M}{a}+\lambda_D-\frac{1}{a}\Big]\Lambda\Big(\psi-\frac{\psi}{a}\Big),$$

implying (13). Equation (12) was derived in the main text.

(ii) Substituting (10) in the market clearing and rearranging terms yields (14). Substituting (10) in (4) and rearranging terms, implies $\gamma\sigma^2 x^{M*} = (\Delta-\psi+\mu-p^*)+(\Delta-\psi/a^*+\mu-p^*)$. Substituting (14) yields (15). ∎

PROOF OF PROPOSITION 1:

(i) Equation (12) has a negative and a positive root. We rule out the negative root because with $a < 0$ the manager's second-order condition is violated (and hence the first-order approach of writing the fund investor's problem is not valid)—see the proof of Lemma 1 in online Appendix B. The right-hand side of (12) is strictly decreasing in a. It is strictly positive at $a = 1/2$ and strictly negative at $a = 1$. Thus $a^* \in (1/2, 1)$.

(ii) Suppose that $\bar{x}+\lambda_D(\Delta-\psi)/(\gamma\sigma^2) > 0$. Then $b^* > 0$ follows from (13) and part (i) of this proposition. ∎

PROOF OF LEMMA 3:

Rewrite (12) as $(2a^*-1)a^{*3}\gamma^2\sigma^2/(1-a^*) = \psi^2/\sigma_\varepsilon^2$. The left-hand side is increasing in a^*, while the right-hand side is increasing in ψ and decreasing in σ_ε^2. Thus a^* is increasing in ψ and decreasing in σ_ε^2. Moreover, rewriting the equation above as $(2a^*-1)a^*\gamma^2\sigma^2\sigma_\varepsilon^2/(1-a^*) = (\psi/a^*)^2$ we can see that the left-hand side is still increasing in a^*. Since a^* is increasing in ψ, ψ/a^* is increasing in ψ. The dependence of p^* and x^{M*} on ψ and σ_ε^2 then follows from (14) and (15). Moreover, a^* does not depend on Δ. Then the dependence of b^*, p^*, and x^{M*} on Δ follows from (13), (14), and (15). ∎

PROOF OF LEMMA 4:

(i) Substituting the expression for z into (18) and rearranging terms, we have

$$0 = \Delta - \psi + \mu - p - \gamma\sigma^2\left[\frac{\Delta - \psi/a + \mu - p}{\gamma\sigma^2}\left(\frac{1}{a} - 1\right) + \frac{b}{a}\right] - \psi\frac{(1/a - 1)\Lambda\lambda_M}{1 - (1/a - 1)\Lambda\lambda_M}.$$

Rearranging terms,

$$\gamma\sigma^2\frac{b}{a} = \Delta - \psi + \mu - p + \left(1 - \frac{1}{a}\right)\left(\Delta - \frac{\psi}{a} + \mu - p\right) - \psi\frac{(1 - a)/a\Lambda\lambda_M}{1 - (1/a - 1)\Lambda\lambda_M},$$

$$\gamma\sigma^2 b = (2a - 1)(\Delta - \psi + \mu - p) + (1 - a)\left[\frac{1 - a}{a} - \frac{\Lambda\lambda_M}{1 - (1/a - 1)\Lambda\lambda_M}\right]\psi,$$

$$\gamma\sigma^2 b = (2a - 1)(\Delta - \psi + \mu - p) + (1 - a)\left(\frac{1}{a} - \frac{1}{\lambda_M + \lambda_D}\right)\psi.$$

Substituting the expression for the price and rearranging terms, we have

$$b = (2a - 1)\left[\bar{x} + \frac{1}{\gamma\sigma^2}\lambda_D(\Delta - \psi)\right] + (1 - a)\left[\frac{1}{a} - \frac{\lambda_M/a + \lambda_D}{\lambda_M + \lambda_D}\right]\frac{\psi}{\gamma\sigma^2}.$$

Turning to the FOC with respect to a, use (17) to rewrite (21) as follows:

$$0 = \frac{1 - a}{a}\frac{\lambda_M/a + \lambda_D}{\lambda_M + \lambda_D}\psi\left[\frac{\partial y}{\partial a} + \frac{\partial y}{\partial p}\frac{\partial p}{\partial a} + \frac{y}{a^2}\frac{\partial y}{\partial p}\frac{\partial p}{\partial(b/a)}\right] - (2a - 1)\gamma\sigma_\varepsilon^2. \tag{A.1}$$

To express the term in square brackets, differentiate the market clearing $\lambda_M(y/a + b/a) + \lambda_D x^D = 0$ with respect to b/a and a and use $\partial x^D/\partial p = \partial y/\partial p$ to get

$$\left(\frac{\lambda_M}{a} + \lambda_D\right)\frac{\partial y}{\partial p}\frac{\partial p}{\partial(b/a)} + \lambda_M = 0,$$

$$\left(\frac{\lambda_M}{a} + \lambda_D\right)\frac{\partial y}{\partial p}\frac{\partial p}{\partial a} - \lambda_M\frac{y}{a^2} + \frac{\lambda_M}{a}\frac{\partial y}{\partial a} = 0,$$

$$\left(\frac{\lambda_M}{a} + \lambda_D\right)\left[\frac{\partial y}{\partial p}\frac{\partial p}{\partial a} + \frac{y}{a^2}\frac{\partial y}{\partial p}\frac{\partial p}{\partial(b/a)}\right] + \frac{\lambda_M}{a}\frac{\partial y}{\partial a} = 0.$$

Then (A.1) becomes

$$0 = \frac{1-a}{a}\frac{\lambda_M/a + \lambda_D}{\lambda_M + \lambda_D}\psi\left[\frac{\partial y}{\partial a} - \frac{\partial y}{\partial a}\frac{\lambda_M/a}{\lambda_M/a + \lambda_D}\right] - (2a-1)\gamma\sigma_\varepsilon^2.$$

Finally, using $\partial y/\partial a = \psi/(\gamma\sigma^2 a^2)$, we obtain (23).

(ii) Substituting (20) in the market-clearing condition and rearranging terms yields (25). Substituting (20) in (4) and using (25) yields (26). ∎

LEMMA 6: *The following inequality holds:*

$$\frac{1-a^*}{a^*}\left[\frac{1}{a^*} - \left(\frac{\lambda_M}{a^*} + \lambda_D\right)\right] > \frac{1-a^{**}}{a^{**}}\left[\frac{1}{a^{**}} - \frac{\lambda_M/a^{**} + \lambda_D}{\lambda_M + \lambda_D}\right].$$

PROOF:

See online Appendix B.

PROOF OF PROPOSITION 2:

(i) Comparison $a^{**} < a^*$ follows from comparing (12) and (23) and selecting the positive roots of the two equations, see the proof of Proposition 1 (i).

(ii) Denote $a_1 = a^*, a_2 = a^{**}, b_1 = b^*, b_2 = b^{**}$. From (13) and (24),

$$\frac{b_1}{a_1} = \left(2 - \frac{1}{a_1}\right)\left[\bar{x} + \frac{1}{\gamma\sigma^2}\lambda_D(\Delta - \psi)\right]$$
$$+ \left(\frac{1}{a_1} - 1\right)\left[\frac{1}{a_1} - \left(\frac{\lambda_M}{a_1} + \lambda_D\right)\right]\frac{1}{\gamma\sigma^2}\psi,$$

$$\frac{b_2}{a_2} = \left(2 - \frac{1}{a_2}\right)\left[\bar{x} + \frac{1}{\gamma\sigma^2}\lambda_D(\Delta - \psi)\right]$$
$$+ \left(\frac{1}{a_2} - 1\right)\left[\frac{1}{a_2} - \frac{\lambda_M/a_2 + \lambda_D}{\lambda_M + \lambda_D}\right]\frac{1}{\gamma\sigma^2}\psi.$$

Under assumption $\bar{x} + \lambda_D(\Delta - \psi)/(\gamma\sigma^2) > 0$ and the fact that $a_1 > a_2$, Lemma 6 implies $b_1/a_1 > b_2/a_2$. Then using $a_1 > a_2\,(> 1/2), b_1 > b_2$ follows. ∎

LEMMA 7: *The fund investor's and planner's second-order conditions are satisfied in equilibria with privately and socially optimal contracts, respectively.*

PROOF:

See online Appendix B.

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