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Portfolio Disclosure, Portfolio Selection and Mutual Fund Performance Evaluation

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Portfolio Disclosure, Portfolio Selection, and Mutual Fund Performance Evaluation[1]

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ABSTRACT

The paper sets up a model of delegated portfolio management where mutual funds differ with respect to the amount of their portfolio disclosure. Mutual funds may report their holdings only infrequently or incompletely, as is the case for most mutual funds in all industrialized countries. With incomplete portfolio disclosure fund investors face an informational handicap compared to fund managers. The reported holdings reflect only a noisy signal about the genuine managerial positions. The level of portfolio disclosure determines the transparency of mutual funds and so influences the amount of fund risk borne by fund investors. With incomplete portfolio disclosure, fund investors face two sources of fund risk: risk on stock returns and risk regarding the fund's holdings. Since the portfolio strategies of fund managers reflect their private information, risk on fund holdings accounts for the investors' uncertainty about managerial talents. Portfolio disclosure reduces risk on fund holdings. It has three major implications: First, it affects the composition of efficient managed portfolios. More frequent disclosure permits fund managers to respond stronger to their private information. Second, by reducing fund risk it improves, ceteris paribus, mutual fund performance. Third, it requires that performance measures have to be designed with respect to the portfolio disclosure of funds in order to reflect fund risk and performance appropriately. We modify widely used performance measures of Sharpe (1966) and Jensen (1968) to incorporate the level of portfolio disclosure of mutual funds.

(JEL classification: G11, G23).

Delegated portfolio management of mutual funds is characterized by informational asymmetry between fund managers and fund investors. Fund managers know their talents much better than fund investors do. They know precisely the positions they hold and why they trade, whereas fund investors have to infer managerial talents based only on the track record of fund returns and the information funds report on their holdings.[1]

The size of the informational handicap faced by fund investors is determined by the disclosure frequency of the fund. If fund managers report their holding more frequently, portfolio disclosure reflects the genuine portfolio strategy of the manager more accurately. With funds reporting their positions only at infrequent disclosure dates, fund investors face two sources of fund risk: risk on stock returns and risk with respect to the fund's holdings. Since fund holdings reflect the portfolio strategy of the fund manager, risk on the fund holdings accounts for the fund investors' uncertainty about managerial talent. Its size depends on two factors: the frequency of portfolio disclosure of the fund and the intensity of the fund manager's trades. Both, more frequent disclosure and less intense trading increase transparency and so reduce fund risk. Our results have three major implications for delegated portfolio management. First, fund managers have to adapt their managed portfolios to the level of their portfolio disclosure.[2] Fund investors, once observing the fund holdings and once not, bear different amounts of risk when investing in one and the same fund. Since optimal portfolios balance expected return

[1]Section 30(e) of the U.S. Investment Company Act of 1940 specifies that mutual funds must send semiannual shareholder reports to their investors containing a summary of their end-of-period holdings. Beside mandatory disclosure, many funds voluntary report their holdings more frequently. Wermers (1999) reports that in 1995 almost 60% of the regulated funds disclosed their holdings each fiscal quarter. Further on, many funds provide additional information about their contemporaneous top holdings or sector weightings on their websites. For example, Fidelity posts the end-of-quarter top 10 holdings and the end-of-month sector weightings of each of its funds on its website. Effective May 2004, the U.S. Securities and Exchange Commission increased the mandated disclosure frequency from semiannual to quarterly portfolio disclosure, reflecting the belief that fund investors benefit from more frequent portfolio disclosure through increased fund transparency.

[2]Managed portfolios are portfolios whose weights are not yet fixed but depend (in a prespecified way) on some information still to be received by the portfolio manager.

and risk, portfolio disclosure impacts the optimal composition of managed portfolios. Additional disclosure permits the fund manager to respond stronger to her private information, implying a higher optimal trading intensity. Therefore, whether a managed portfolio is efficient or not depends on the portfolio disclosure of the fund.

Second, mutual funds may increase their performance not only by performing better research, but also by supplying their investors precise information on their holdings. Mutual fund performance is the expected fund return adjusted for fund risk. Additional portfolio disclosure alleviates the informational handicap faced by fund investors and so reduces fund risk. Informed fund managers with restrictive disclosure policies can improve their performance by increasing the extent of portfolio disclosure and adjusting their managed portfolios accordingly.[3]

Third, unlike existing literature on performance evaluation, which asserts that performance measures should be designed with respect to the type of managerial information —market timing or stock picking— [e.g Jensen (1972), Dybvig and Ross (1985), Admati and Ross (1985), Grinblatt and Titman (1989b)], our analysis suggests that performance measures should be understood as referring to the level of portfolio disclosure of mutual funds.

Our paper relates to two strands of literature. First, it is related to papers on the efficient use of conditioning information in managed portfolios. Hansen and Richard (1987) show that conditional efficiency of managed portfolios does not imply their efficiency with respect to only unconditional information. Ferson and Siegel (2001) derive unconditionally efficient managed portfolios in closed form. They show that these portfolios are non-linear functions of the conditionally expected stock returns. We extend

[3]These benefits of portfolio disclosure must be balanced against potential costs of reporting the holdings to the public. For example, Wermers (2001) and Frank, Poterba, Shackelford, and Shoven (2003) argue that frequent portfolio disclosure might facilitate free riding by competitors and encourage front running by market participants then positioned to anticipate the fund manager's needs to trade.

their analysis in two ways. First, we investigate the effects of disclosure of conditioning information, which is typical for the mutual fund industry, on the composition of efficient managed portfolios. Second, we analyze the implications of portfolio disclosure for performance evaluation and design performance measures which incorporate the level of portfolio disclosure of funds.

Second, our paper relates to literature on performance evaluation. Traditional performance measures [e.g. Sharpe (1966), Jensen (1968)] estimate mutual fund performance by the average past fund return adjusted for fund risk. Subsequently, Grinblatt and Titman (1989a), (1993), Daniel, Grinblatt, Titman, and Wermers (1997), and Wermers (2000) suggest performance measures focusing on the fund holdings rather than on the fund returns. Both types of measures ignore information if mutual funds report their holdings, but reporting takes place only at infrequent points in time. Traditional performance measures, in focusing exclusively on fund returns, neglect information contained in reported fund holdings. They overestimate fund risk and thus underestimate fund performance [e.g. Dybvig and Ross (1985), Grinblatt and Titman (1989b)]. On the other hand, those measures based exclusively on the funds' holdings neglect the information contained in funds' returns in-between disclosure dates. They share the implicit assumption that fund managers do not rebalance their portfolios in-between disclosure dates and therefore underestimate fund risk and overstate fund performance. Our paper elaborates on existing performance measures in order to incorporate the detail of portfolio disclosure of funds. Since our measures incorporate fund risk appropriately, they provide unbiased estimates of mutual fund performance.

The paper is organized in four sections: Section 1 sets up our model. Section 2 derives efficient managed portfolios for funds with full portfolio disclosure, without portfolio disclosure, and with arbitrary portfolio disclosure. Section 3 focuses on performance evaluation. It elaborates on performance measures of Sharpe (1966) and Jensen (1968) to allow for different portfolio disclosure among mutual funds. Section 4 concludes.

1 The Model

Consider an economy with N risky securities (the *stocks*) and one asset with a riskless rate of return (the *bond*). There is a mutual fund run by a fund manager who invests the money owned by a number of fund investors.

Fund Manager: The fund manager receives noisy signals, $\tilde{s}_i$, about the excess returns, $\tilde{R}_i$, of the stocks $i = 1, \ldots, N$. The vector of stock returns is denoted by $\tilde{R}$.[4] From the manager's perspective, the random stock returns consist of three parts:

$$\tilde{R} \;=\; \mu + \tilde{s} + \tilde{\gamma} \tag{1}$$

The vector of unconditional risk premia, μ, is public information, the vector of signals, $\tilde{s}$, is private information of the manager, and $\tilde{\gamma}$ is a vector of unobserved noise. The signals $\tilde{s}$ and noise $\tilde{\gamma}$ are independent, normally distributed, and have an unconditional mean of zero. The fund manager may have signals about all or only some stocks. The quality of the signals is determined by their covariance matrix, $\Sigma(\tilde{s})$. Furthermore, the fund manager does not face any arbitrage opportunities, i.e. the covariance matrix of the noise terms, $\Sigma(\tilde{\gamma})$, is not singular. Both $\Sigma(\tilde{s})$ and $\Sigma(\tilde{\gamma})$ are private information of the fund manager.

The fund manager conditions the delegated portfolio on her superior beliefs about the stock returns, $\mu + s$ and $\Sigma(\tilde{\gamma})$. In the absence of fund fees and transaction costs,

[4] Throughout the paper all returns are denoted in excess of the riskless rate of return, and the terms *return* and *excess return* are used synonymously.

the fund return, $\tilde{R}_P$, is determined by the random stock returns, $\tilde{R}$, and the portfolio shares, $w(\tilde{s})$, invested in these stocks:

$$\tilde{R}_P = w\left(\tilde{s}\right)'\tilde{R} \tag{2}$$

Since our focus is on discretionary disclosure, we assume that the trades of the fund manager have no impact on stock returns, i.e. $\tilde{R}$ does not depend on $w(\tilde{s})$.This assumption implies (i) that the fund manager can use her private information without mitigating it and (ii) that fund investors cannot infer the manager's private information from stock price reactions. So disclosure is at the discretion of the manager.[5]

The fund manager reports a noisy signal, $\tilde{x}$, about her portfolio strategy, $w(\tilde{s})$, to her investors:

$$\tilde{x} = w\left(\tilde{s}\right) + \tilde{\varepsilon} \tag{3}$$

The covariance matrix of the disturbances, $\Sigma\left(\tilde{\varepsilon}\right)$, determines the precision of portfolio disclosure. The modeling (3) does not impose restrictions on the form of the portfolio information disclosed. For example, $\tilde{x}$ may be completely uninformative about some of the managerial positions and fully revealing about others. Two extreme examples are discussed in detail below: In the event of $\sigma^2\left(\tilde{\varepsilon}_i\right) = 0$, $i = 1, \dots, N$, the reported signal unravels the complete portfolio strategy of the manager, whereas $\sigma^2\left(\tilde{\varepsilon}_i\right) = \infty$, $i = 1, \dots, N$, means that the reported signal is useless.

[5] Verrecchia (2001) distinguishes between two types of disclosure: *association based* and *discretionary* disclosure. Association based disclosure results from the equilibrium mechanism revealing some of the agents' private information, e.g. through prices, and is ruled out here. This assumption is justified if the market share of the fund is small. Discretionary disclosure is voluntary disclosure. It results from the agents' own decisions to report some of their private information to others.

Fund Investors: Fund investors receive no own information signal about stock returns. They only know the unconditional fund and stock return distributions and observe the portfolio disclosure, x, of the fund. Based on this information, the conditional stock return distribution from the fund investors' perspective has a mean of $\mathrm{E}\big[\tilde{R}|x\big] = \mu + \mathrm{E}\big[\tilde{s}|x\big]$ and a variance of $\Sigma\big(\tilde{R}|x\big) = \Sigma\big(\tilde{\gamma}\big) + \Sigma\big(\tilde{s}|x\big)$.[6]

Investors are risk averse. They invest in the fund offering them the largest expected return per unit of fund risk, conditional on their signal about the portfolio strategy, x. The utility of the fund investors can thus be represented by the objective function

$$\Phi \;=\; \mathrm{E}\big[w(\tilde{s})'\tilde{R}|x\big] - \frac{\lambda}{2}\mathrm{var}\big(w(\tilde{s})'\tilde{R}|x\big), \tag{4}$$

with parameter of risk aversion, $\lambda > 0$.[7] Although mean variance models are widely used to analyze portfolio selection and to study mutual fund performance, it should be mentioned that the maximization of (4) is not equivalent to a universal expected utility approach when delegated portfolio management is analyzed [e.g. Dybvig and Ross (1985)]. Even though all stock returns are normally distributed, the distribution of the return of managed portfolios is not normal due to the non-linear impact of the managerial signals, $\tilde{s}$, on the fund return, $w(\tilde{s})'\tilde{R} = w(\tilde{s})'\big(\mu + \tilde{s} + \tilde{\gamma}\big)$.

[6] We assume that $\Sigma(\tilde{R}|x)$ is constant across all disclosure states, i.e. the precision of disclosure does not depend on the realized signal. Further on, the focus of this paper is on the effects of discretionary portfolio disclosure on mutual fund portfolio selection and performance. Therefore, we do not pursue that rational investors might exploit the joint distribution of the fund and stock returns or higher order moments of the fund return distribution in order to infer about the managed portfolio [e.g. Mamaysky, Spiegel, and Zhang (2003)]. This assumption is a simplifying one. It enables us to analyze discretionary disclosure of funds while keeping the model tractable.

[7] We opt for a constant parameter of risk aversion, λ, for simplicity of exposition. All results hold for non-constant risk aversion, i.e. for λ as a function of the disclosed signal, x, as well.

2 Disclosure and Optimal Fund Portfolio

In their shareholder reports mutual funds account for their end-of-period portfolio holdings. The reported holdings serve the fund investors as a signal about the managed portfolio chosen by the fund manager. Since the managed portfolio reflects the private information of the manager, portfolio disclosure signals the fund investors about the quality of managerial information. Portfolio disclosure varies among funds in its detail. More detailed portfolio disclosure constitutes a more precise signal about the managerial information. This section investigates the effects of portfolio disclosure on the composition of efficient managed portfolios for funds. It turns out that a restrictive disclosure policy reduces the turnover of efficient managed portfolios and so rules out extreme positions associated with large signals.

We begin our analysis with two examples at different extremes: The first example of *full portfolio disclosure* deals with a fund reporting the exact composition of the managed portfolio to its shareholders. The second extreme, *no portfolio disclosure*, studies a fund that does not provide its shareholders with any information on its holdings. Although this case is prohibited by regulation in many countries, the analysis proves useful for illustrating the impact of incomplete portfolio disclosure on the composition of efficient managed portfolios. Finally, we solve our model for the general case of *arbitrary portfolio disclosure*.

2.1 Full Portfolio Disclosure

This section focuses on a fund reporting to its shareholders the exact composition of the managed portfolio ($\sigma^2(\tilde{\varepsilon}_i) = 0$, $i = 1, \ldots, N$). Therefore, fund investors are able to condition their expectations in (4) on the portfolio strategy chosen by the fund manager,

$w(\tilde{s})$. Since the fund manager controls the portfolio of the fund investors, the optimal delegated portfolio maximizes the utility of the fund investors. The problem of the fund manager, conditional on her private information, s, and her full disclosure policy, is to choose $w(s)$ to maximize:

$$\begin{aligned} \Phi_{\text{Full}} &= \mathrm{E}\big[w(s)'\tilde{R}|w\big] - \frac{\lambda}{2}\mathrm{var}\big(w(s)'\tilde{R}|w\big) \\ &= w(s)'\big(\mu + \mathrm{E}\big[\tilde{s}|w\big]\big) - \frac{\lambda}{2}w(s)'\big[\Sigma\big(\tilde{\gamma}\big) + \Sigma\big(\tilde{s}|w\big)\big]w(s) \end{aligned} \tag{5}$$

The following theorem provides the solution for the set of efficient managed portfolios for mutual funds with full portfolio disclosure.

Theorem 1 *Denote by $\mathcal{A}$ the set of continuously differentiable, admissible managed portfolios, $w\big(s\big)$. An admissible managed portfolio $w^{\star}_{\text{Full}}\big(s\big) \in \mathcal{A}$ is mean variance efficient with full portfolio disclosure if it satisfies*

$$w^{\star}_{\text{Full}}\big(\tilde{s}\big) = \frac{1}{\lambda}\Sigma\big(\tilde{\gamma}\big)^{-1}\big(\mu + \tilde{s}\big). \tag{6}$$

Proof: *See Appendix A.*

Since the fund manager responds to her private information so as to maximize the expected utility of the fund investors, rational fund investors expect the manager to do so. Therefore, full disclosure of the fund holdings is equivalent to a direct disclosure of the managerial signals. It eliminates the informational asymmetry between the fund manager and fund investors and reveals the quality of the managerial information. With manager and investors sharing the same information, the fund manager chooses the delegated portfolio as if she were to invest her own money.

2.2 No Portfolio Disclosure

We now turn to the other extreme of a fund withholding all information on its holdings from its shareholders. In this case, the disclosed signal $\tilde{x}$ is completely uninformative ($\sigma^2\big(\tilde{\varepsilon}_i\big) = \infty$, $i = 1, \ldots, N$), and the informational asymmetry between fund manager and fund investors persists. Then, the utility of the fund investors is exclusively determined by the parameters of the unconditional fund and stock return distributions. The portfolio problem of the fund manager, conditional on her private information, $\tilde{s}$, and her no disclosure policy, thus is to choose $w(\tilde{s})$ to maximize:[8]

$$\begin{aligned}
\Phi_{\text{No}} &= \mathrm{E}\big[w(\tilde{s})'\tilde{R}\big] - \frac{\lambda}{2}\mathrm{var}\big(w(\tilde{s})'\tilde{R}\big) \\
&= \mathrm{E}\Big[w(\tilde{s})'\big(\mu + \tilde{s}\big)\Big] \\
&\quad -\frac{\lambda}{2}\Big\{\mathrm{E}\Big[w(\tilde{s})'\big[\big(\mu + \tilde{s}\big)\big(\mu + \tilde{s}\big)' + \Sigma\big(\tilde{\gamma}\big)\big]w(\tilde{s})\Big] - \mathrm{E}\Big[w(\tilde{s})'\big(\mu + \tilde{s}\big)\Big]^2\Big\}
\end{aligned} \tag{7}$$

Since the managed portfolio, $w(\tilde{s})$, is conditional on the signals $\tilde{s}$ received only by the manager, it cannot be verified by the fund investors. Therefore, the fund holdings are random for the fund investors without portfolio disclosure.

Theorem 2 *Denote by $\mathcal{A}$ the set of continuously differentiable, admissible managed portfolios, $w\big(s\big)$. An admissible managed portfolio $w^{\star}_{\text{No}}\big(s\big) \in \mathcal{A}$ is mean variance efficient without portfolio disclosure if it satisfies*

$$w^{\star}_{\text{No}}(\tilde{s}) = w^{\star}_{\text{Full}}(\tilde{s})\,\frac{\psi(\tilde{s})}{\mathrm{E}\big[\psi(\tilde{s})\big]}, \tag{8}$$

$$\psi(\tilde{s}) = \Big\{1 + \big(\mu + \tilde{s}\big)'\Sigma\big(\tilde{\gamma}\big)^{-1}\big(\mu + \tilde{s}\big)\Big\}^{-1}. \tag{9}$$

[8] It is important to note that the problem (7) consists of determining the optimal *functional form* of the managed portfolio, w, as a function of the managerial signal, s, to be received.

Proof: *The proof is a special case of the proof of Theorem 3 in Appendix B.*

Without disclosure, the efficient managed portfolios, $w^{\star}_{\text{Full}}\big(\tilde{s}\big)$, are scaled by a factor, $\psi(\tilde{s})/\mathrm{E}\big[\psi(\tilde{s})\big]$, depending on the size of the realized signal. The adjustment factor can be greater or less than one, indicating that the fund manager, compared to full portfolio disclosure, sometimes responds more moderately and sometimes more aggressively to her private information. Figure 1 illustrates the optimal managed portfolios for the single stock case ($N = 1$) (a) assuming full portfolio disclosure and (b) assuming no portfolio disclosure.

Insert Figure 1 here.

Different disclosure strategies give rise to different managed portfolios. The two aforementioned managed portfolios lead to similar positions for small signals, but they differ considerably when the managerial signal gets large. With full portfolio disclosure, the optimal managed portfolio increases linearly in the size of the managerial signal. Without portfolio disclosure, the adjustment factor in (8) biases the optimal managed portfolio towards more conservative positions. It can even be the case that the manager reduces her stock holding as her signal becomes sufficiently large.

The fund manager has to choose more conservative positions because fund investors without disclosure face a larger fund risk. Without portfolio disclosure, fund investors are unable to identify portfolio shifts in response to private information. As a result, they face two sources of fund risk: The risk associated with the random stock returns and the risk concerning the fund holdings. Since the fund holdings mirror the portfolio strategy of the fund manager, the risk on the fund holdings reflects the fund investors' uncertainty about the quality of the managerial information. In responding to her signal, the fund manager affects both components of fund risk: On the one hand, the managed portfolio is fixed based on a smaller residual stock return risk. On the other hand, the managed portfolio involves random fund holdings and so gives rise to risk on the fund holdings. The adjustment factor in (8) accounts for the risk on the fund holdings.

The optimal managed portfolio (8) balances the private information of the fund manager, on which the portfolio is conditioned, and the public information of investors, for which the portfolio has to be optimal. It trades off the higher expected return of managed portfolios and the risk on the fund holdings. Compared to full portfolio disclosure, it requires the fund manager to respond more moderately to extreme signals (implying a large value of $(\mu+\tilde{s})'(\mu+\tilde{s})$) and permits here to respond more pronouncedly to moderate signals (implying a small value of $(\mu+\tilde{s})'(\mu+\tilde{s})$). Extreme signals are associated with large portfolio shifts and so have a strong impact on the risk concerning the fund holdings. In responding less to extreme signals the fund manager benefits from her superior information without inflating the risk on the fund holdings.

A fund manager disregarding the risk associated with the fund holdings and investing in the managed portfolio that would be efficient with full portfolio disclosure chooses too extreme positions. With such a manager, it can be advantageous for investors to follow a simple benchmark strategy instead of giving the money to the better informed fund manager. Ignoring the amount of portfolio disclosure when deciding on the composition of the managed portfolio thus can undermine good research.[9]

2.3 Arbitrary Portfolio Disclosure

In most countries, regulatory requirements bind funds to disclose some information on their holdings. On the other hand, full disclosure facilitates free-riding by other funds, and so limits the fund manager in benefiting from her private information. Therefore,

[9] See Appendix C for a proof of this argument.

most funds report their holdings with a certain time lag and only at infrequent points in time. In this case, portfolio disclosure represents a noisy signal, $\tilde{x}$, about the fund holdings, $w(\tilde{s})$. As in the previous sections, the problem of the fund manager, given her private information, s, and her disclosure policy, x, is to choose $w(s)$ to maximize:

$$\begin{aligned}\Phi &= \mathrm{E}\big[w(\tilde{s})'\tilde{R}|x\big] - \frac{\lambda}{2}\mathrm{var}\big(w(\tilde{s})'\tilde{R}|x\big) \\ &= \mathrm{E}\Big[w(\tilde{s})'\big(\mu+\tilde{s}\big)|x\Big] \qquad (10)\\ &\quad -\frac{\lambda(x)}{2}\Big\{\mathrm{E}\Big[w(\tilde{s})'\big[\big(\mu+\tilde{s}\big)\big(\mu+\tilde{s}\big)'+\Sigma\big(\gamma\big)\big]w(\tilde{s})|x\Big] - \mathrm{E}\Big[w(\tilde{s})'\big(\mu+\tilde{s}\big)|x\Big]^2\Big\}\end{aligned}$$

Theorem 3 provides the solution for the set of efficient managed portfolios depending on the portfolio disclosure standard, x, of the fund.

Theorem 3 *Denote by $\mathcal{A}$ the set of continuously differentiable, admissible managed portfolios, $w(s)$. An admissible managed portfolio $w^{\star}(s) \in \mathcal{A}$ is mean variance efficient with disclosure standard x if it satisfies*

$$w^{\star}(\tilde{s}) \;=\; w^{\star}_{\mathrm{Full}}(\tilde{s})\,\frac{\psi(\tilde{s})}{\mathrm{E}\big[\psi(\tilde{s})|x\big]}, \qquad (11)$$

where $\psi(\tilde{s})$ is defined according to (9).

Proof: *See Appendix B.*

Efficient managed portfolios depend on both the private information of the fund manager and the portfolio disclosure of the fund. As before, they can be decomposed into the portfolio, $w^{\star}_{\mathrm{Full}}(\tilde{s})$, that would be efficient if the fund reported its holdings and an adjustment factor. However, the adjustment factor here depends not only on the size of the managerial signals, but also on the disclosure standard of the fund, x. Therefore, fund managers have to account for the degree of portfolio disclosure in their portfolio selection. They have to choose the managed portfolio such that it is adapted to the disclosure standard of the fund.

Theorem 3 has two implications: First, portfolio selection of mutual funds can be separated into two steps: In a first step, the fund manager determines the managed portfolio, $w^\star_{\text{Full}}(\tilde{s})$, that would be efficient with full portfolio disclosure. This decision is independent of the disclosure standard of the fund. Then, the manager specifies the fraction of money to be invested in that portfolio subject to the level of portfolio disclosure. Second, Theorem 3 permits conclusions about the relations between the sets of efficient managed portfolio using the same signal $\tilde{s}$, but with different levels of portfolio disclosure x_A and x_B: a managed portfolio that is mean variance efficient with disclosure standard x_B is not mean variance efficient for any other disclosure standard x_A provided that x_B cannot be recovered by the knowledge of x_A.[10] This result is a generalization of Hansen and Richard (1987) who show that efficient portfolios implied by a conditional model are not unconditionally efficient.

Figure 2 illustrates the effects of the disclosure strategy on the composition of optimal managed portfolios. For the single stock case ($N = 1$) it shows the composition of the optimal managed portfolio depending on the precision of portfolio disclosure. The precision of portfolio disclosure is given by $R^2 = 1 - \sigma^2(\tilde{s}|x)/\sigma^2_s$.

Insert Figure 2 here.

In general, additional portfolio disclosure permits the fund manager to respond more strongly to her private information [Figure 2(a)]. However, the situation is different for

[10]Replacing x in (11) by x_A and x_B, respectively, we immediately get the relation between the two sets of efficient managed portfolios: $w^\star_{\text{B}}(\tilde{s}) = w^\star_{\text{A}}(\tilde{s})\,\big(\lambda_A(x_A)\,\mathrm{E}[\psi(\tilde{s})|x_B]\big)/\big(\lambda_B(x_B)\,\mathrm{E}[\psi(\tilde{s})|x_A]\big)$. If x_B is measurable with respect to x_A, then $w^\star_B(\tilde{s})$ is a linear combination of $w^\star_A(\tilde{s})$ and the bond, conditional on x_A, and therefore lies on the efficient frontier for any realization of x_A. Otherwise, $w^\star_B(\tilde{s})$ is not a linear combination of $w^\star_A(\tilde{s})$ and the bond, and is thus not efficient with disclosure standard x_A.

extreme ($s = 2\sigma_s$) and for moderate signals ($s = 0$): for extreme signals, the optimal fraction of money to be invested in the stock increases with the amount of portfolio disclosure of the fund [Figure 2(b)]. For moderate signals, managerial stock holding has its maximum with a restrictive disclosure policy and then decreases with disclosure becoming more precise [Figure 2(c)]. Extreme signals lead to conditional expectations of the fund manager deviating strongly from the unconditional expectations of the fund investors. They require a stronger rebalancing of the managed portfolio than small signals, and therefore account for most of the risk on the fund holdings.

3 Disclosure and Mutual Fund Performance

Investors have to decide on a fund investment without any knowledge of the private information of the fund manager. They need performance measures which help them to overcome their informational handicap and to direct their money to a fund manager with superior information. This section focuses on the role of portfolio disclosure for mutual fund performance evaluation. The extent of portfolio disclosure of funds has two effects on performance evaluation: first, more detailed portfolio disclosure reduces fund risk—as discussed in Section 2— and so affects fund performance. Second, with more detailed portfolio disclosure fund investors have additional information available for performance evaluation. Therefore, performance measure must incorporate the amount of portfolio disclosure of funds in order to reflect managerial talent appropriately.

Section 3.1 proposes two new performance measures which incorporate the extent of portfolio disclosure of funds. The first is based on the measure of Jensen (1968), and the second extends the ratio of Sharpe (1966). Both measures are unbiased in the notion of Dybvig and Ross (1985). Then, Section 3.2 discusses the effects of additional portfolio disclosure on the performance of mutual funds.

3.1 Disclosure Based Performance Evaluation

There are two sources of risk investing the money in mutual funds: the residual stock return risk of the fund manager and the risk concerning the fund holdings. With full portfolio disclosure, fund investors can verify managerial holdings, and their risk on the fund holdings is zero. Therefore, fund risk is reduced to the residual stock return risk of the fund manager. Without portfolio disclosure, fund investors bear the complete risk concerning the fund holdings. In this case, the fund risk corresponds to the unconditional fund return variance. With incomplete portfolio disclosure, the size of the fund investors' risk associated with the fund holdings (and hence fund risk) depends on the level of portfolio disclosure of the fund.

Disclosure Based Alpha

Traditional security market line analysis [Jensen (1968)] defines mutual fund performance by the deviation of the expected fund return from the security market line. The expected fund and benchmark return and the fund risk are determined using the unconditional fund and benchmark returns as reference points. However, if mutual funds report their holdings to their investors, they unveil a part of the private information of the fund manager. Rational fund investors should also consider the disclosed portfolio information in performance evaluation. In order to reflect fund performance appropriately, performance measures should therefore be based on the updated expected fund return and risk, which incorporate the reported fund holdings, rather than on their unconditional counterparts.

The following performance measure extends traditional security market line analysis to include portfolio disclosure among mutual funds:

$$DBJ_P(x) = \mathrm{E}\big[\tilde{R}_P\big] - \beta_P(x)\mu_E, \tag{12}$$

where μ_E is the expected return of an (unconditionally) efficient benchmark.[11] The systematic fund risk is a function of the extent of portfolio disclosure of the fund:

$$\beta_P(x) = \mathrm{E}\left[\frac{\mathrm{cov}\big(\tilde{R}_P, \tilde{R}_E|x\big)}{\mathrm{var}\big(\tilde{R}_E|x\big)}\right] \tag{13}$$

Our disclosure-based alpha resembles the unconditional alpha of Jensen (1968) except for the systematic fund risk, $\beta_P(x)$. With portfolio disclosure, the conditional systematic fund risk, $\mathrm{cov}\big(\tilde{R}_P, \tilde{R}_E|x\big)/\mathrm{var}\big(\tilde{R}_E|x\big)$, depends on the reported holdings, x, and varies across different disclosure states. Variations of the conditional fund beta reflect portfolio shifts in response to private information, which are recognized by the fund investors due to the portfolio disclosure of the fund. Therefore, the systematic fund risk faced by the fund investors corresponds to the expected conditional fund beta, i.e. the updated systematic fund risk averaged across all disclosure states, $\tilde{x}$.[12]

Proposition 1 *The disclosure-based alpha (12) is an unbiased measure of mutual fund performance:*

(i) It is zero for uninformed fund managers.

(ii) It is positive for informed fund managers who choose an efficient managed portfolio (8).

[11] In conjunction with homogeneous beliefs of uninformed investors our model allows for the capital asset pricing model to hold approximately [e.g. Hirshleifer (1975) and Mayers and Rice (1979)]. In this case, the benchmark is the (unconditionally efficient) market portfolio.

[12] Of course, portfolio disclosure also affects the expected fund and benchmark return. However, by the law of iterated expectations, the expected average fund and benchmark return given disclosure x equal their unconditionally expected counterparts. By contrast, iterated expectations do not apply to systematic fund risk.

(iii) It is ceteris paribus the larger, the more private information fund managers have.

Proof: *See Appendix D.*

Two examples of our new performance measure deserve further discussion: without portfolio disclosure, the disclosure-based alpha corresponds to the unconditional alpha of Jensen (1968):[13]

$$J_P \;=\; \mathrm{E}\big[\tilde{R}_P\big] - \frac{\operatorname{cov}\big(\tilde{R}_P, \tilde{R}_E\big)}{\sigma_E^2}\mu_E \tag{14}$$

With full portfolio disclosure the conditioning information of the fund investors corresponds to the private information of the fund manager, and the disclosure-based alpha simplifies to the performance measure suggested by Grinblatt and Titman (1989b) and (1993) for internal performance evaluation:[14]

$$GT_P \;=\; \mathrm{E}\big[\tilde{R}_P\big] - \mathrm{E}\big[w\big(\tilde{s}\big)\big]'\mu \tag{15}$$

Since the unconditional alpha of Jensen (1968) and the measure suggested by Grinblatt and Titman (1989b) and (1993) are both special cases of our new measure (12), they are both unbiased measures of mutual fund performance. However, they have to be applied to funds with different detail of portfolio disclosure. The Jensen measure is unbiased for performance evaluation of funds without portfolio disclosure, whereas the measure of Grinblatt and Titman is unbiased for funds completely disclosing their portfolio strategy. In most cases, mutual funds report their holdings only infrequently and maybe incompletely. Between disclosure dates the reported holdings become stale, and

[13] Without portfolio disclosure, the conditional beta of the fund corresponds to the unconditional beta of the fund return, and $\beta_P(x)$ is consequently equal to $\beta_P = \operatorname{cov}(\tilde{R}_P, \tilde{R}_E)\big/\sigma_E^2$ in this case.

[14] With full disclosure, the systematic fund risk (13) simplifies to $\beta_P(x) = \mathrm{E}[w(\tilde{s})]'\beta$. Using the efficiency of the benchmark with respect to public information, it follows that $\mu = \beta\mu_E$. Together, both arguments imply (15).

they are thus only a noisy signal about the fund's contemporaneous positions. In this case, only the disclosure-based alpha (12) allows for correct rankings of funds reflecting managerial performance.

Disclosure Based Sharpe Ratio

Sharpe (1966) defines mutual fund performance by the unconditional expected fund return per unit of unconditional fund risk, defined by the standard deviation of the fund return. Using similar arguments, we now modify the Sharpe ratio to allow for different portfolio disclosure of mutual funds:

$$DBS_P\left(x\right) \quad = \quad \frac{\mathrm{E}\left[\tilde{R}_P\right]}{\sqrt{\mathrm{E}\left[\mathrm{var}\left(\tilde{R}_P|x\right)\right]}} \tag{16}$$

The disclosure-based Sharpe ratio (16) resembles the unconditional Sharpe ratio except for the parameter of fund risk. With portfolio disclosure, the variance of the fund return is conditional on the disclosed holdings, x. Variations of the conditional fund return variance reflect portfolio shifts in response to private information, which are perceived by fund investors because of the portfolio disclosure of the fund. Therefore, the fund investors' risk is determined by the expected conditional fund return variance given the reported holdings.

Proposition 2 *The disclosure-based Sharpe ratio (16) is an unbiased measure of mutual fund performance:*

(i) It is less or equal to the Sharpe ratio of the benchmark for uninformed fund managers.

(ii) It exceeds the Sharpe ratio of the benchmark for informed fund managers who

choose an efficient managed portfolio (8).

(iii) It is ceteris paribus the larger, the more private information fund managers have.

Proof: *See Appendix E.*

Without portfolio disclosure, fund investors only know the unconditional fund returns, and the disclosure-based Sharpe ratio (16) simplifies to the unconditional performance measure of Sharpe (1966). Therefore, the traditional Sharpe ratio is unbiased for performance evaluation of funds without portfolio disclosure. However, the vast majority of mutual funds reports some information about their portfolio strategy. For those funds, only the disclosure-based Sharpe ratio permits correct rankings reflecting managerial performance.

Prior research recommends the use of different performance measures for assessing stock picking and market timing talents of fund managers. Furthermore, it is argued that market timing by fund managers can lead to biased estimates of their stock picking talents (e.g. Dybvig and Ross (1985), Grinblatt and Titman (1989b) and Grinblatt and Titman (1995)). Our results highlight the role of portfolio disclosure in designing performance measures. In order to reflect the information structure surrounding a fund appropriately, performance measures must incorporate the amount of portfolio disclosure by mutual funds. We developed measures that adjust for different amounts of portfolio disclosure among mutual funds and therefore allow for rankings of funds that differ with respect to the amount of their portfolio disclosure, regardless of whether fund managers are stock pickers, markets timers, or both.

3.2 Impact of Disclosure on Fund Performance

The U.S. Investment Company Act of 1940 specifies as a minimum disclosure requirement that mutual funds must report their holdings in their semiannual shareholder reports. Beside this obligation, there is a wide range of disclosure strategies fund managers can adopt. When offering a mutual fund, fund managers thus have to decide how many additional holdings information they intend to report to their investors. This decision requires the knowledge of the way portfolio disclosure affects the performance of mutual funds. We investigate the impact of portfolio disclosure on mutual fund performance by considering a fund manager equipped with some private information, $\tilde{s}$. We compare the performance of this manager under both measures with a loose disclosure standard x_A and a restrictive disclosure standard x_B. The results are summarized by the following corollary.

Corollary 1 *The performance of mutual funds with private information increases with the precision of their portfolio disclosure. This result holds for the disclosure-based alpha (12) as well as for the disclosure-based Sharpe ratio (16).*

Proof: *See Appendix F.*

Portfolio disclosure mitigates the informational asymmetry between fund investors and fund manager. Additional portfolio disclosure reduces the fund investors' risk on the portfolio strategy of the fund manager and so reduces their uncertainty about the quality of the managerial signal. Therefore, more detailed portfolio disclosure reduces the systematic fund risk, $\beta_P\big(x\big)$, as well as the aggregate fund risk, $\mathrm{E}\big[\mathrm{var}\big(\tilde{R}_P|x\big)\big]$. Since by the law of iterated expectations the expected fund and benchmark return are unaffected by portfolio disclosure, additional portfolio disclosure increases the performance of mutual funds. Two fund investors with different information about the fund holdings bear different amounts of risk investing in the same fund. They rightly assign different performances to the same fund.

4 Conclusion

The paper has analyzed the role of portfolio disclosure for mutual fund portfolio selection and performance evaluation. It has three major contributions: First, portfolio disclosure affects fund risk and so impacts the optimal composition of managed portfolios. Fund managers have to consider the level of their portfolio disclosure in their portfolio selection. They have to adapt their managed portfolio to the extent of their portfolio disclosure. More restrictive portfolio disclosure requires fund managers to scale down their managed portfolios in case of extreme signals and to scale them up when receiving moderate signals. By such a behavior, fund managers benefit from their private information without inflating the fund risk by trading too intensely.

Second, mutual funds can increase their performance by disclosing their investors more precise information on their holdings. The disclosure policy of mutual funds matters. Given the efficiency of financial markets it appears much easier for fund managers to increase their performance by revising their disclosure policy than by gathering more private information.

Third, performance measures must incorporate the amount of portfolio disclosure of mutual funds. This paper has elaborated on widely used performance measures of Sharpe (1966) and Jensen (1968) in order to incorporate the level of portfolio disclosure of mutual funds. Our measures include the aforementioned measures as special cases for funds doing without portfolio disclosure. Instead of interpreting performance measures with regard to the type of managerial information —market timing or stock picking—

our analysis suggests to understand performance measures as referring to the extent of portfolio disclosure of mutual funds.

Appendices

Appendix A

Solving the first order condition to (5), we find that $w^\star_{\text{Full}}\big(\tilde{s}\big)$ must satisfy:

$$w^\star_{\text{Full}}\big(\tilde{s}\big) \quad = \quad \frac{1}{\lambda}\Big(\Sigma\big(\tilde{\gamma}\big) + \Sigma\big(\tilde{s}|w\big)\Big)^{-1}\big(\mu + \mathrm{E}\big[\tilde{s}|w\big]\big) \tag{A1}$$

The conditional expectation, $\mathrm{E}\big[\tilde{s}|w\big]$, is equal to the regression forecast of $\tilde{R}$ in excess of μ, based on every measurable transformation of $\tilde{w}$. To determine $\mathrm{E}\big[\tilde{s}|w\big]$ in optimum we have to distinguish two different cases regarding managerial behavior: (i) the fund manager conditions the managed portfolio exclusively on $\tilde{s}$ and (ii) the manager conditions the managed portfolio on $\tilde{s}$ plus some additional information, $\tilde{\nu}$.

(i) Since $\tilde{w}$, in this case, is measurable on $\tilde{s}$ and continuously differentiable, the inverse $s(\tilde{w})$ exists and is likewise measurable on $\tilde{w}$. Therefore, investors can infer the managerial signal from the joint distribution of the stock returns, $\tilde{R}$, and the fund holdings, $\tilde{w}$:

$$\mathrm{E}\big[\tilde{s}|w\big] \quad = \quad \tilde{s} \tag{A2}$$

$$\Sigma\big(\tilde{s}|w\big) \quad = \quad \mathbf{0} \tag{A3}$$

Inserting (A2) and (A3) in (A1), we immediately get solution (6).

(ii) By the definition of $\tilde{s}$, $\tilde{\nu}$ is unrelated to the assets' returns, $\tilde{R}$. Therefore, $\tilde{\nu}$ is noise, and conditioning the managed portfolio on the signal $\tilde{s}$ and on $\tilde{\nu}$ is equivalent to conditioning the portfolio on some less precise signal in (i). It follows that conditioning the portfolio on any information additional to $\tilde{s}$ cannot be optimal.

Statement (i) along with (ii) proves Theorem 1. Q.E.D.

Appendix B

In integral notation, the problem of the fund manager (10) consists of determining the reaction function $w(s)$ that maximizes:

$$\begin{aligned}\Phi &= \int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} w(s)'\big(\mu+s\big)f(s|x)\,ds \qquad \text{(B1)}\\ &-\frac{\lambda}{2}\Bigg\{\int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} w(s)'\Big[\big(\mu+s\big)\big(\mu+s\big)'+\Sigma(\tilde{\gamma})\Big]w(s)f(s|x)\,ds\\ &-\Big[\int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} w(s)'\big(\mu+s\big)f(s|x)\,ds\Big]^2\Bigg\}\end{aligned}$$

Here, $f(s|x) = f\big(s_1,\ldots,s_N|x_1,\ldots,x_N\big)$ denotes the joint density of the signals $s_1,\ldots,s_N$ conditional on portfolio disclosure $x_1,\ldots,x_N$. Using multidimensional calculus of variations [e.g. Seierstad and Sydsaeter (1987), chapter 1, and for the multivariate extension Gelfand and Fomin (1963), chapter 7], the Euler-Lagrange equations of the problem (B1) are

$$\begin{aligned}0 &= \big(\mu+s\big)-\lambda\Bigg[\Big[\big(\mu+s\big)\big(\mu+s\big)'+\Sigma(\tilde{\gamma})\Big]w^\star(s) \qquad \text{(B2)}\\ &\quad -\big(\mu+s\big)\int_{-\infty}^{\infty}\cdots\int_{-\infty}^{\infty} w^\star(s)'\big(\mu+s\big)f(s|x)\,ds\Bigg],\end{aligned}$$

where $w^\star\big(\tilde{s}\big)$ denotes the optimal reaction function of the manager. Solving (B2) for $w^\star\big(\tilde{s}\big)$, we get:

$$\begin{aligned}w^\star\big(\tilde{s}\big) &= \frac{1}{\lambda}\Big[\big(\mu+\tilde{s}\big)\big(\mu+\tilde{s}\big)'+\Sigma(\tilde{\gamma})\Big]^{-1}\big(\mu+\tilde{s}\big)\Big[1+\lambda \mathrm{E}\big[\tilde{R}_P|x\big]\Big] \qquad \text{(B3)}\\ &= \frac{1}{\lambda}\Sigma(\tilde{\gamma})^{-1}\big(\mu+\tilde{s}\big)\frac{1+\lambda\mathrm{E}\big[\tilde{R}_P|x\big]}{1+\big(\mu+\tilde{s}\big)'\Sigma(\tilde{\gamma})^{-1}\big(\mu+\tilde{s}\big)},\end{aligned}$$

where we use that

$$\mathrm{E}\big[\tilde{R}_P|x\big] \quad = \quad \int_{-\infty}^{\infty}\dots\int_{-\infty}^{\infty} w^\star(s)'\big(\mu+s\big)f(s|x)\,ds \tag{B4}$$

defines the conditional expectation of $\tilde{R}_P$ given disclosure x and that [e.g. Schott (1997), p. 9f.]:

$$\Big[\big(\mu+\tilde{s}\big)\big(\mu+\tilde{s}\big)'+\Sigma(\tilde{\gamma})\Big]^{-1} \quad = \quad \Sigma(\tilde{\gamma})^{-1}-\frac{\Sigma(\tilde{\gamma})^{-1}\big(\mu+\tilde{s}\big)\big(\mu+\tilde{s}\big)'\Sigma(\tilde{\gamma})^{-1}}{1+\big(\mu+\tilde{s}\big)'\Sigma(\tilde{\gamma})^{-1}\big(\mu+\tilde{s}\big)} \tag{B5}$$

In order to get an explicit solution for $w^\star\big(\tilde{s}\big)$, we calculate the expected fund return in optimum. Inserting (B3) into (B4) yields:

$$\begin{aligned}\mathrm{E}\big[\tilde{R}_P|x\big] \quad &= \quad \frac{1}{\lambda}\,\frac{\mathrm{E}\Big[\big(\mu+\tilde{s}\big)'\Sigma(\tilde{\gamma})^{-1}\big(\mu+\tilde{s}\big)\psi(\tilde{s})\big|x\Big]}{\mathrm{E}\big[\psi(\tilde{s})|x\big]} \\ &= \quad \frac{1}{\lambda}\left\{\frac{1}{\mathrm{E}\big[\psi(\tilde{s})|x\big]}-1\right\},\end{aligned} \tag{B6}$$

where $\psi(\tilde{s})$ is defined according to (9). Replacing $\mathrm{E}\big[\tilde{R}_P|x\big]$ in (B3) by (B6), we get the explicit solution (11) for the optimal managed portfolio. Q.E.D.

Appendix C

For the proof it is sufficient to give an example in which the fund investors get a higher utility from a passive benchmark investment than from investing the money with a fund manager with private information choosing $w^\star_{\text{Full}}\big(\tilde{s}\big)$ without disclosure. Therefore, consider the example with $N=1$ stock. Since $w^\star_{\text{Full}}\big(\tilde{s}\big)$ is not efficient without disclosure, we first have to determine the optimal fraction, y, of money for the investors to invest in the fund. Inserting a multiple y of (6) into (7), the problem is to choose y so as to maximize:

$$\Phi\big(y\big) \quad = \quad y\mathrm{E}\left[\frac{\mu+\tilde{s}}{\lambda\sigma_\gamma^2}\big(\mu+\tilde{s}\big)\right] - \frac{\lambda}{2}\mathrm{var}\left(\frac{\mu+\tilde{s}}{\lambda\sigma_\gamma^2}\big(\mu+\tilde{s}+\tilde{\gamma}\big)\right) \tag{C1}$$

$$\quad = \quad y\left[\frac{\mu^2+\sigma_s^2}{\lambda\sigma_\gamma^2}\right] - \frac{\lambda}{2}y^2\left[\frac{\sigma_\gamma^2\big(\mu^2+\sigma_s^2\big)+2\sigma_s^2\big(2\mu^2+\sigma_s^2\big)}{\lambda^2\sigma_\gamma^4}\right] \tag{C2}$$

Solving (C1), the optimal share of funds to invest in the fund is:

$$y^\star \quad = \quad \frac{\sigma_\gamma^2\big(\mu^2+\sigma_s^2\big)}{\sigma_\gamma^2\big(\mu^2+\sigma_s^2\big)+2\sigma_s^2\big(2\mu^2+\sigma_s^2\big)} \tag{C3}$$

Inserting (C3) into (C1), the maximum utility for investors investing with the fund is:

$$\Phi\big(y^\star\big) \quad = \quad \frac{\big(\mu^2+\sigma_s^2\big)^2}{2\lambda\Big[\sigma_\gamma^2\big(\mu^2+\sigma_s^2\big)+2\sigma_s^2\big(2\mu^2+\sigma_s^2\big)\Big]} \tag{C4}$$

The maximum utility from a passive investment in the stock is $\mu^2/\big\{2\lambda\big(\sigma_s^2+\sigma_\gamma^2\big)\big\}$. Subtracting this expression from (C4), the difference in utility is:

$$\Delta(\Phi) = \frac{\sigma_s^2\Big[\big(\sigma^2-\mu^2\big)\big(\mu^2+\sigma_s^2\big)-2\mu^4\Big]}{2\lambda\sigma^2\Big[\sigma_\gamma^2\big(\mu^2+\sigma_s^2\big)+2\sigma_s^2\big(2\mu^2+\sigma_s^2\big)\Big]} \tag{C5}$$

This difference is negative provided that $\sigma^2 < \mu^2$. It is also negative for some parameter constellations where $\sigma^2 > \mu^2$, depending on the size of σ_s^2. Only if $\sigma^2 \geq 3\mu^2$, $\Delta(\Phi) > 0$ for every $\sigma_s^2 > 0$. Q.E.D.

Appendix D

Proof of Statement (i): If the manager is uninformed, $\tilde{w}$ and $\tilde{x}$ are independent from $\tilde{R}$, and using $\alpha = \frac{1}{\lambda}\Sigma^{-1}\mu$ (12) simplifies to:

$$
\begin{aligned}
DBJ_P\big(x\big) &= \mathrm{E}\big[\tilde{w}'\tilde{R}\big] - \mathrm{E}\left[\frac{\mathrm{E}\big[\tilde{w}'\tilde{R}\tilde{R}'\alpha|x\big] - \mathrm{E}\big[\tilde{w}'\tilde{R}|x\big]\mu'\alpha}{\alpha'\Sigma\alpha}\right]\alpha'\mu \\
&= \mathrm{E}\big[\tilde{w}\big]'\mu - \mathrm{E}\left[\frac{\mathrm{E}\big[\tilde{w}|x\big]'\big(\mu\mu' + \Sigma\big)\Sigma^{-1}\mu - \mathrm{E}\big[\tilde{w}|x\big]'\mu\mu'\Sigma^{-1}\mu}{\mu'\Sigma^{-1}\Sigma\Sigma^{-1}\mu}\right]\mu'\Sigma^{-1}\mu \\
&= \mathrm{E}\big[\tilde{w}\big]'\mu - \frac{\mu'\Sigma^{-1}\mu}{\mu'\Sigma^{-1}\mu}\mathrm{E}\big[\tilde{w}\big]'\mu \\
&= 0
\end{aligned}
\tag{D1}
$$

This proves statement (i).

Proof of Statement (ii): Inserting (13) in (12), $DBJ_P\big(x\big)$ is:

$$
\begin{aligned}
DBJ_P\big(x\big) = \; & \mathrm{E}\left[\mathrm{E}\big[\tilde{R}_P|x\big] - \frac{\mathrm{cov}\big(\tilde{R}_P, \tilde{R}_E|x\big)}{\mathrm{var}\big(\tilde{R}_E|x\big)}\mathrm{E}\big[\tilde{R}_E|x\big]\right] \\
& + \mathrm{cov}\left(\frac{\mathrm{cov}\big(\tilde{R}_P, \tilde{R}_E|x\big)}{\mathrm{var}\big(\tilde{R}_E|x\big)}, \mathrm{E}\big[\tilde{R}_E|x\big]\right)
\end{aligned}
\tag{D2}
$$

In the remainder of the proof we need $\mathrm{cov}\big(\tilde{R}_P, \tilde{R}_E|x\big)$ and $\mathrm{var}\big(\tilde{R}_P|x\big)$ in optimum. From (11) and (B6) we get:

$$
\begin{aligned}
\mathrm{cov}\big(\tilde{R}_P, \tilde{R}_E|x\big) &= \mathrm{E}\Big[w^{\star}(\tilde{s})'\tilde{R}\tilde{R}'\alpha\Big|x\Big] - \mathrm{E}\big[\tilde{R}_P|x\big]\mathrm{E}\big[\tilde{R}_E|x\big] \\
&= \frac{\mathrm{E}\big[\tilde{R}_P|x\big]\mathrm{E}\Big[\psi\big(\tilde{s}\big)\psi\big(\tilde{s}\big)^{-1}\big(\mu + \tilde{s}\big)'\alpha|x\Big]}{1 - \mathrm{E}\big[\psi(\tilde{s})|x\big]} - \mathrm{E}\big[\tilde{R}_P|x\big]\mathrm{E}\big[\tilde{R}_E|x\big] \\
&= \mathrm{E}\big[\tilde{R}_P|x\big]\mathrm{E}\big[\tilde{R}_E|x\big]\frac{\mathrm{E}\big[\psi(\tilde{s})|x\big]}{1 - \mathrm{E}\big[\psi(\tilde{s})|x\big]} \\
&= \frac{1}{\lambda}\mathrm{E}\big[\tilde{R}_E|x\big]
\end{aligned}
\tag{D3}
$$

$$
\begin{aligned}
\mathrm{var}\big(\tilde{R}_P|x\big) &= \mathrm{E}\Big[w^\star(\tilde{s})'\tilde{R}\tilde{R}'w^\star(\tilde{s})\big|x\Big] - \mathrm{E}\big[\tilde{R}_P|x\big]^2 \\
&= \frac{\mathrm{E}\big[\tilde{R}_P|x\big]^2\mathrm{E}\Big[\psi\big(\tilde{s}\big)^2\psi\big(\tilde{s}\big)^{-1}\big(\mu+\tilde{s}\big)'\Sigma\big(\tilde{\gamma}\big)^{-1}\big(\mu+\tilde{s}\big)\big|x\Big]}{\big(1-\mathrm{E}\big[\psi(\tilde{s})|x\big]\big)^2} - \mathrm{E}\big[\tilde{R}_P|x\big]^2 \\
&= \mathrm{E}\big[\tilde{R}_P|x\big]^2\frac{\mathrm{E}\big[\psi(\tilde{s})\big(\psi(\tilde{s})^{-1}-1\big)|x\big]}{\big(1-\mathrm{E}\big[\psi(\tilde{s})|x\big]\big)^2} - \mathrm{E}\big[\tilde{R}_P|x\big]^2 \qquad \text{(D4)} \\
&= \mathrm{E}\big[\tilde{R}_P|x\big]^2\,\frac{\mathrm{E}\big[\psi(\tilde{s})|x\big]}{1-\mathrm{E}\big[\psi(\tilde{s})|x\big]},
\end{aligned}
$$

Inserting (D3) in (D2) yields:

$$
\begin{aligned}
DBJ_P\big(x\big) &= \mathrm{E}\Bigg[\mathrm{E}\big[\tilde{R}_P|x\big] - \frac{\mathrm{cov}\big(\tilde{R}_P,\tilde{R}_E|x\big)}{\mathrm{var}\big(\tilde{R}_E|x\big)}\mathrm{E}\big[\tilde{R}_E|x\big]\Bigg] + \frac{1}{\lambda}\,\frac{\alpha'\big(\Sigma(\tilde{s})-\Sigma\big(\tilde{s}|x\big)\big)\alpha}{\alpha'\big(\Sigma\big(\tilde{\gamma}\big)+\Sigma\big(\tilde{s}|x\big)\big)\alpha} \\
&= \mathrm{E}\Bigg[\mathrm{E}\big[\tilde{R}_P|x\big]\Bigg\{1-\frac{\mathrm{E}\big[\psi(\tilde{s})|x\big]}{1-\mathrm{E}\big[\psi(\tilde{s})|x\big]}\,\frac{\mathrm{E}\big[\tilde{R}_E|x\big]^2}{\mathrm{var}\big(\tilde{R}_E|x\big)}\Bigg\}\Bigg] \qquad \text{(D5)} \\
&\quad +\frac{1}{\lambda}\,\frac{\alpha'\big(\Sigma(\tilde{s})-\Sigma\big(\tilde{s}|x\big)\big)\alpha}{\alpha'\big(\Sigma\big(\tilde{\gamma}\big)+\Sigma\big(\tilde{s}|x\big)\big)\alpha}
\end{aligned}
$$

Since $\Sigma\big(\tilde{\gamma}\big) > 0$ and $\Sigma\big(\tilde{s}\big) \geq \Sigma\big(\tilde{s}|x\big) \geq 0$, the second component of (D5) is ≥ 0. We verify that the first component of (D5) is ≥ 0 by consideration of a portfolio consisting of a long position of \$1 in the managed portfolio, a short position of \$ $\mathrm{E}\big[\tilde{R}_P|x\big]/\mathrm{E}\big[\tilde{R}_E|x\big]$ in the benchmark asset, and a long position of \$ $\mathrm{E}\big[\tilde{R}_P|x\big]/\mathrm{E}\big[\tilde{R}_E|x\big]$ in the bond. From (D3) and (D4), the variance of this portfolio, conditional on x, is:

$$
\begin{aligned}
&\mathrm{var}\Bigg(\tilde{R}_P - \frac{\mathrm{E}\big[\tilde{R}_P|x\big]}{\mathrm{E}\big[\tilde{R}_E|x\big]}\tilde{R}_E\big|x\Bigg) \\
&\quad = \mathrm{var}\big(\tilde{R}_P|x\big) + \frac{\mathrm{E}\big[\tilde{R}_P|x\big]^2}{\mathrm{E}\big[\tilde{R}_E|x\big]^2}\mathrm{var}\big(\tilde{R}_E|x\big) - 2\,\frac{\mathrm{E}\big[\tilde{R}_P|x\big]}{\mathrm{E}\big[\tilde{R}_E|x\big]}\mathrm{cov}\big(\tilde{R}_P,\tilde{R}_E|x\big) \qquad \text{(D6)} \\
&\quad = \mathrm{E}\big[\tilde{R}_P|x\big]^2\Bigg\{\frac{\mathrm{var}\big(\tilde{R}_E|x\big)}{\mathrm{E}\big[\tilde{R}_E|x\big]^2} - \frac{\mathrm{E}\big[\psi(\tilde{s})|x\big]}{1-\mathrm{E}\big[\psi(\tilde{s})|x\big]}\Bigg\} \;\geq\; 0
\end{aligned}
$$

Since $\psi(\tilde{s}) < 1$ by definition (9), $\mathrm{E}[\tilde{R}_P|x] > 0$ follows from (B6). Therefore, (D6) implies that

$$\frac{\mathrm{E}[\psi(\tilde{s})|x]}{1-\mathrm{E}[\psi(\tilde{s})|x]} \quad \leq \quad \frac{\mathrm{var}(\tilde{R}_E|x)}{\mathrm{E}[\tilde{R}_E|x]^2} \tag{D7}$$

must hold. In conjunction with $\mathrm{E}[\tilde{R}_P|x] > 0$, (D7) implies that the first component of (D5) is ≥ 0.

With incomplete disclosure, the portfolio in (D6) is risky conditional on x, and (D6) is strictly positive in this case. This implies that $DBJ_P(x) > 0$. With full disclosure, the portfolio in (D6) is risky conditional on x if the fund manager is not a pure market timer, which implies that $DBJ_P(x) > 0$.[15] However, if the manager is a pure market timer, $\Sigma(\tilde{s}) > 0$, and the second component in (D5) is positive in this case. Altogether, these arguments imply that $DBJ_P(x) > 0$. This proves statement (ii).

Proof of statement (iii): A managed portfolio A is based on more information than a managed portfolio B, if $\tilde{s}_A = \tilde{s}_B + \tilde{\xi}$, where $\Sigma(\tilde{\xi}) \geq 0$ is not the null matrix and $\mathrm{E}[\tilde{\xi}|s_B] = 0$. From (D5) the difference of the disclosure-based alphas of the two managed portfolios is:

$$\begin{aligned} DBJ_A - DBJ_B \quad = \quad & \mathrm{E}\Bigg[\mathrm{E}[\tilde{R}_A|x]\left\{1 - \frac{\mathrm{E}[\psi(\tilde{s}_A)|x]}{(1-\mathrm{E}[\psi(\tilde{s}_A)|x])}\,\frac{\mathrm{E}[\tilde{R}_E|x]^2}{\mathrm{var}(\tilde{R}_E|x)}\right\} \\ & -\mathrm{E}[\tilde{R}_B|x]\left\{1 - \frac{\mathrm{E}[\psi(\tilde{s}_B)|x]}{(1-\mathrm{E}[\psi(\tilde{s}_B)|x])}\,\frac{\mathrm{E}[\tilde{R}_E|x]^2}{\mathrm{var}(\tilde{R}_E|x)}\right\}\Bigg] \\ & +\frac{1}{\lambda}\left(\frac{\alpha'[\Sigma(\tilde{s}_A) - \Sigma(\tilde{s}_A|x)]\alpha}{\alpha'[\Sigma(\tilde{\gamma}_A) + \Sigma(\tilde{s}_A|x)]\alpha} - \frac{\alpha'[\Sigma(\tilde{s}_B) - \Sigma(\tilde{s}_B|x)]\alpha}{\alpha'[\Sigma(\tilde{\gamma}_B) + \Sigma(\tilde{s}_B|x)]\alpha}\right), \end{aligned} \tag{D8}$$

[15] For a pure market timer, the managed portfolio consists only of the benchmark asset and the bond. With full disclosure, the portfolio in (D6) is riskless in this case.

where $x = \big(x_A, x_B\big)$ is the joint conditional information from the disclosure of both funds. (B6) with the optimal managed portfolio now conditioned on the joint disclosure $x = \big\{x_A, x_B\big\}$ implies for the relation of the expected returns of the two managed portfolios in optimum:

$$\mathrm{E}\big[\tilde{R}_B|x\big] \;=\; \mathrm{E}\big[\tilde{R}_A|x\big]\,\frac{\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}{\big(1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]\big)}\frac{\big(1-\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]\big)}{\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]} \tag{D9}$$

Replacing $\mathrm{E}\big[\tilde{R}_B|x\big]$ in (D8) by (D9), we get:

$$\begin{aligned} DBJ_A - DBJ_B \;=\; & \mathrm{E}\left[\mathrm{E}\big[\tilde{R}_A|x\big]\left\{1-\frac{\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}{\big(1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]\big)}\frac{\big(1-\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]\big)}{\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]}\right\}\right] \\ & +\frac{1}{\lambda}\left(\frac{\alpha'\big[\Sigma\big(\tilde{s}_A\big)-\Sigma\big(\tilde{s}_A|x\big)\big]\alpha}{\alpha'\big[\Sigma\big(\tilde{\gamma}_A\big)+\Sigma\big(\tilde{s}_A|x\big)\big]\alpha}-\frac{\alpha'\big[\Sigma\big(\tilde{s}_B\big)-\Sigma\big(\tilde{s}_B|x\big)\big]\alpha}{\alpha'\big[\Sigma\big(\tilde{\gamma}_B\big)+\Sigma\big(\tilde{s}_B|x\big)\big]\alpha}\right) \end{aligned} \tag{D10}$$

Since $\Sigma\big(\tilde{\gamma}_i\big) > 0$, $\Sigma\big(\tilde{s}_i\big) \geq \Sigma\big(\tilde{s}_i|x\big) \geq 0$, and $\Sigma\big(\tilde{\gamma}_i\big)+\Sigma\big(\tilde{s}_i|x\big) = \Sigma - \big[\Sigma\big(\tilde{s}_i\big)-\Sigma\big(\tilde{s}_i|x\big)\big]$, $i \in \big\{A, B\big\}$, the second component of (D10) ≥ 0, provided that $\Sigma\big(\tilde{s}_B|x\big) \geq \Sigma\big(\tilde{s}_A|x\big)$.

We verify that the first component of (D10) is ≥ 0 by a portfolio consisting of a long position of \$1 in the managed portfolio A, a short position of \$ $\mathrm{E}\big[\tilde{R}_A|x\big]/\mathrm{E}\big[\tilde{R}_B|x\big]$ in the managed portfolio B, and a long position of \$ $\mathrm{E}\big[\tilde{R}_A|x\big]/\mathrm{E}\big[\tilde{R}_B|x\big]$ in the bond. From (D3) and (D4), the variance of this portfolio, conditional on the joint disclosure $\tilde{x}$, is:

$$\begin{aligned} & \mathrm{var}\Big(\tilde{R}_A - \frac{\mathrm{E}\big[\tilde{R}_A|x\big]}{\mathrm{E}\big[\tilde{R}_B|x\big]}\tilde{R}_B|x\Big) \\ &= \mathrm{var}\big(\tilde{R}_A|x\big) + \frac{\mathrm{E}\big[\tilde{R}_A|x\big]^2}{\mathrm{E}\big[\tilde{R}_B|\tau\big]^2}\mathrm{var}\big(\tilde{R}_B|x\big) - 2\frac{\mathrm{E}\big[\tilde{R}_A|x\big]}{\mathrm{E}\big[\tilde{R}_B|x\big]}\mathrm{cov}\big(\tilde{R}_A,\tilde{R}_B|x\big) \qquad \text{(D11)} \\ &= \mathrm{E}\big[\tilde{R}_A|x\big]^2\left\{\frac{\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]}{\big(1-\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]\big)} - \frac{\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}{\big(1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]\big)}\right\} \;\geq\; 0 \end{aligned}$$

For the second equality in (D11) we use:

$$
\begin{aligned}
&\operatorname{cov}\big(\tilde{R}_A, \tilde{R}_B|x\big) \\
&\quad = \mathrm{E}\Big[w^\star\big(\tilde{s}_A\big)'\tilde{R}\tilde{R}'w^\star\big(\tilde{s}_B\big)\big|x\Big] - \mathrm{E}\big[\tilde{R}_A|x\big]\mathrm{E}\big[\tilde{R}_B|x\big] \\
&\quad = \mathrm{E}\big[\tilde{R}_A|x\big]\left\{\frac{\mathrm{E}\Big[\psi(\tilde{s}_A)\big(\psi(\tilde{s}_A)^{-1}-1\big)\big(\mu+\tilde{s}_A\big)'w^\star(\tilde{s}_B)\big|x\Big]}{1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]} - \mathrm{E}\big[\tilde{R}_B|x\big]\right\} \qquad \text{(D12)} \\
&\quad = \mathrm{E}\big[\tilde{R}_A|x\big]\mathrm{E}\big[\tilde{R}_B|x\big]\frac{\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}{1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}
\end{aligned}
$$

Since $\psi\big(\tilde{s}_A\big) < 1$ by definition (9), $\mathrm{E}\big[\tilde{R}_A|x\big] > 0$ follows from (B6). Therefore, (D11) implies that

$$
\frac{\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]}{\big(1-\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]\big)} \geq \frac{\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}{\big(1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]\big)} \qquad \text{(D13)}
$$

In conjunction with $\mathrm{E}\big[\tilde{R}_A|x\big] > 0$, (D13) implies that the first component of (D10) is ≥ 0.

With incomplete disclosure of one of the funds $i \in \big\{A, B\big\}$, the portfolio in (D11) is risky conditional on $\tilde{x}$, and (D11) is strictly positive. Therefore, $DBJ_A\big(x\big) > DBJ_B\big(x\big)$, provided that $\Sigma\big(\tilde{s}_A|x\big) \geq \Sigma\big(\tilde{s}_B|x\big)$. With full disclosure of both funds, this portfolio is risky provided that the return of fund A cannot be replicated by an investment in fund B and the bond. Altogether, these arguments imply that $DBJ_A > DBJ_B$ for $\Sigma\big(\tilde{s}_A|x\big) \geq \Sigma\big(\tilde{s}_B|x\big)$, provided that fund A cannot be replicated by an investment in fund B. This proves statement (iii). Q.E.D.

Appendix E

Proof of Statement (i): If the manager is uninformed, her holdings, $\tilde{w}$, and her disclosure, $\tilde{x}$, are both independent from $\tilde{R}$. To verify that $DBS\big(x\big) \leq \mu_E/\sigma_E$ in this case, consider a portfolio consisting of a long position of \$1 of the fund, a short position of \$ $\mathrm{E}\big[\tilde{R}_P|x\big]/\mu_E$ of the benchmark asset and a long position of \$ $\mathrm{E}\big[\tilde{R}_P|x\big]/\mu_E$ of the bond. The variance of this portfolio, conditional on x, is:

$$\begin{aligned}
&\mathrm{var}\Big(\tilde{w}'\tilde{R} - \frac{\mathrm{E}\big[\tilde{R}_P|x\big]}{\mu_E}\alpha'\tilde{R}\big|x\Big) \\
&\quad = \mathrm{var}\big(\tilde{R}_P|x\big) + \frac{\mathrm{E}\big[\tilde{R}_P|x\big]^2}{\alpha'\mu\mu'\alpha}\alpha'\Sigma\alpha - 2\frac{\mathrm{E}\big[\tilde{R}_P|x\big]}{\alpha'\mu}\mathrm{cov}\big(\tilde{w}'\tilde{R}, \alpha'\tilde{R}|x\big) \;\geq\; 0 \qquad \text{(E1)}
\end{aligned}$$

Since the benchmark is efficient with respect to unconditional information, $\alpha = \frac{1}{\lambda}\Sigma^{-1}\mu$. Because of the independence of $\tilde{R}$ from $\tilde{w}$ and $\tilde{x}$, (E1) simplifies to:

$$\begin{aligned}
&\mathrm{var}\Big(\tilde{w}'\tilde{R} - \frac{\mathrm{E}\big[\tilde{R}_P|x\big]}{\mu_E}\alpha'\tilde{R}\big|x\Big) \\
&\quad = \mathrm{var}\big(\tilde{R}_P|x\big) + \frac{\mathrm{E}\big[\tilde{R}_P|x\big]^2}{\big(\mu'\Sigma^{-1}\mu\big)^2}\mu'\Sigma^{-1}\mu - 2\frac{\mathrm{E}\big[\tilde{R}_P|x\big]}{\mu'\Sigma^{-1}\mu}\mathrm{E}\big[\tilde{w}|x\big]'\Sigma\Sigma^{-1}\mu \qquad \text{(E2)} \\
&\quad = \mathrm{var}\big(\tilde{R}_P|x\big) - \frac{\mathrm{E}\big[\tilde{R}_P|x\big]^2}{\mu'\Sigma^{-1}\mu} \;\geq\; 0
\end{aligned}$$

Multiplying (E2) by $\mu'\Sigma^{-1}\mu$ and subsequently taking unconditional expectations leads to:

$$\mathrm{E}\Big[\mathrm{var}\big(\tilde{R}_P|x\big)\Big]\mu'\Sigma^{-1}\mu \geq \mathrm{E}\Big[\mathrm{E}\big[\tilde{R}_P|x\big]^2\Big] \qquad \text{(E3)}$$

Since $\mathrm{E}\big\{\mathrm{E}\big[\tilde{R}_P|x\big]^2\big\} = \mathrm{E}\big[\tilde{R}_P\big]^2 + \mathrm{var}\big(\mathrm{E}\big[\tilde{R}_P|x\big]\big) \geq \mathrm{E}\big[\tilde{R}_P\big]^2$, (E3) implies that $\sqrt{\mathrm{E}\big[\mathrm{var}\big(\tilde{R}_P|x\big)\big]} \geq \mathrm{E}\big[\tilde{R}_P\big]/\sqrt{\mu'\Sigma^{-1}\mu}$. Since $\mu_E/\sigma_E = \sqrt{\mu'\Sigma^{-1}\mu}$, this argument proves statement (i).

Proof of Statement (ii): From (B6) and (D4) it follows that:

$$
\begin{aligned}
\mathrm{E}\big[\mathrm{var}\big(\tilde{R}_P|x\big)\big] &= \mathrm{E}\left[\mathrm{E}\big[\tilde{R}_P|x\big]^2 \frac{\mathrm{E}\big[\psi(\tilde{s})|x\big]}{1-\mathrm{E}\big[\psi(\tilde{s})|x\big]}\right] \\
&= \mathrm{E}\left[\mathrm{E}\big[\tilde{R}_P|x\big]^2 \frac{1}{\lambda \mathrm{E}\big[\tilde{R}_P|x\big]}\right] \\
&= \frac{1}{\lambda}\mathrm{E}\big[\tilde{R}_P\big]
\end{aligned} \tag{E4}
$$

Inserting (E4) into (16) and subsequently using (B6), we get:

$$
DBS\big(x\big) = \sqrt{\mathrm{E}\left[\frac{1-\mathrm{E}\big[\psi(\tilde{s})|x\big]}{\mathrm{E}\big[\psi(\tilde{s})|x\big]}\right]} \tag{E5}
$$

(D7) implies that:

$$
\frac{1-\mathrm{E}\big[\psi(\tilde{s})|x\big]}{\mathrm{E}\big[\psi(\tilde{s})|x\big]} \geq \frac{\mathrm{E}\big[\tilde{R}_E|x\big]^2}{\mathrm{var}\big(\tilde{R}_E|x\big)} \tag{E6}
$$

Since $\mathrm{E}\big\{\mathrm{E}\big[\tilde{R}_E|x\big]^2\big\} = \alpha'\mathrm{E}\big[\big(\mu+\mathrm{E}\big[\tilde{s}|x\big]\big)\big(\mu+\mathrm{E}\big[\tilde{s}|x\big]\big)'\big]\alpha = \mu_E^2 + \mathrm{E}\big[\big(\alpha'\mathrm{E}\big[\tilde{s}|x\big]\big)^2\big] \geq \mu_E^2$ and $\mathrm{var}\big(\tilde{R}_E|x\big) = \alpha'\big[\Sigma\big(\tilde{\gamma}\big)+\Sigma\big(\tilde{s}|x\big)\big]\big)\alpha = \sigma_E^2 - \alpha'\big[\Sigma\big(\tilde{s}\big)-\Sigma\big(\tilde{s}|x\big)\big]\alpha \leq \sigma_E^2$, it follows:

$$
\sqrt{\mathrm{E}\left[\frac{1-\mathrm{E}\big[\psi(\tilde{s})|x\big]}{\mathrm{E}\big[\psi(\tilde{s})|x\big]}\right]} \geq \frac{\mu_E}{\sigma_E} \tag{E7}
$$

With incomplete disclosure, strict inequality holds in (E6) by the same arguments as in Appendix D, and $DBS\big(x\big) > \mu_E/\sigma_E$ in this case. With the exception of no disclosure, $\mathrm{E}\big[\big(\alpha'\mathrm{E}\big[\tilde{s}|x\big]\big)^2\big] = \mu'\Sigma^{-1}\mathrm{E}\big\{\mathrm{E}\big[\tilde{s}|x\big]\mathrm{E}\big[\tilde{s}|x\big]'\big\}\Sigma^{-1}\mu > 0$, and therefore $DBS\big(x\big) > \mu_E/\sigma_E$ in this case. Together, the two arguments imply that $DBS\big(x\big) > \mu_E/\sigma_E$. This proves statement (ii).

Proof of statement (iii): A managed portfolio A is based on more information than B, if $\tilde{s}_A = \tilde{s}_B + \xi$, where $\Sigma\big(\tilde{\xi}\big) \geq 0$ is not the null matrix and $\mathrm{E}\big[\tilde{\xi}|s_B\big] = 0$. The difference of the disclosure-based Sharpe ratios of the two funds from (E5) is:

$$DBS_A - DBS_B \quad = \quad \sqrt{\mathrm{E}\left[\frac{1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}{\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}\right]} - \sqrt{\mathrm{E}\left[\frac{1-\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]}{\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]}\right]} \qquad \text{(E8)}$$

From (D13):

$$\frac{1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}{\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]} \quad \geq \quad \frac{1-\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]}{\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]} \qquad \text{(E9)}$$

Therefore,

$$\sqrt{\mathrm{E}\left[\frac{1-\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}{\mathrm{E}\big[\psi(\tilde{s}_A)|x\big]}\right]} \quad \geq \quad \sqrt{\mathrm{E}\left[\frac{1-\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]}{\mathrm{E}\big[\psi(\tilde{s}_B)|x\big]}\right]}, \qquad \text{(E10)}$$

and the difference of the two disclosure-based Sharpe ratios in (E8) is ≥ 0. By the same arguments as in Appendix D, strict inequality holds in (E9) with incomplete disclosure of one of the funds, and $DBS_A > DBS_B$ in this case. With complete disclosure of both funds, strict equality holds in (E9), provided that the return of fund A cannot be replicated by fund B, implying that $DBS_A > DBS_B$. This proves statement (iii).

Q.E.D.

Appendix F

Since the unconditional expected fund return by the law of iterated expectations is unaffected by different portfolio disclosure, the difference of the disclosure-based alphas using (D3) simplifies to:

$$\begin{aligned}
DBJ_A - DBJ_B &= \left\{ \mathrm{E}\left[\frac{\mathrm{cov}\big(\tilde{R}_P, \tilde{R}_E | x_A\big)}{\mathrm{var}\big(\tilde{R}_E | x_A\big)} \right] - \mathrm{E}\left[\frac{\mathrm{cov}\big(\tilde{R}_P, \tilde{R}_E | x_B\big)}{\mathrm{var}\big(\tilde{R}_E | x_B\big)} \right] \right\} \mu_E \\
&= \left\{ \mathrm{E}\left[\frac{1}{\lambda} \frac{\mathrm{E}\big[\tilde{R}_E | x_A\big]}{\mathrm{var}\big(\tilde{R}_E | x_A\big)} - \frac{1}{\lambda} \frac{\mathrm{E}\big[\tilde{R}_E | x_B\big]}{\mathrm{var}\big(\tilde{R}_E | x_B\big)} \right] \right\} \alpha' \mu \qquad \text{(F1)} \\
&= \frac{\big(\mu'\Sigma^{-1}\mu\big)^2 \mu'\Sigma^{-1}\big[\Sigma(\tilde{s}|x_B) - \Sigma(\tilde{s}|x_A)\big]\Sigma^{-1}\mu}{\mu'\Sigma^{-1}\big[\Sigma(\tilde{\gamma}) + \Sigma(\tilde{s}|x_A)\big]\Sigma^{-1}\mu\mu'\Sigma^{-1}\big[\Sigma(\tilde{\gamma}) + \Sigma(\tilde{s}|x_B)\big]\Sigma^{-1}\mu} \geq 0
\end{aligned}$$

(F1) implies that $DBJ_A > DBJ_B$ for $\Sigma\big(\tilde{s}|x_A\big) > \Sigma\big(\tilde{s}|x_B\big)$. By the same argument, the difference in the disclosure-based Sharpe ratios is:

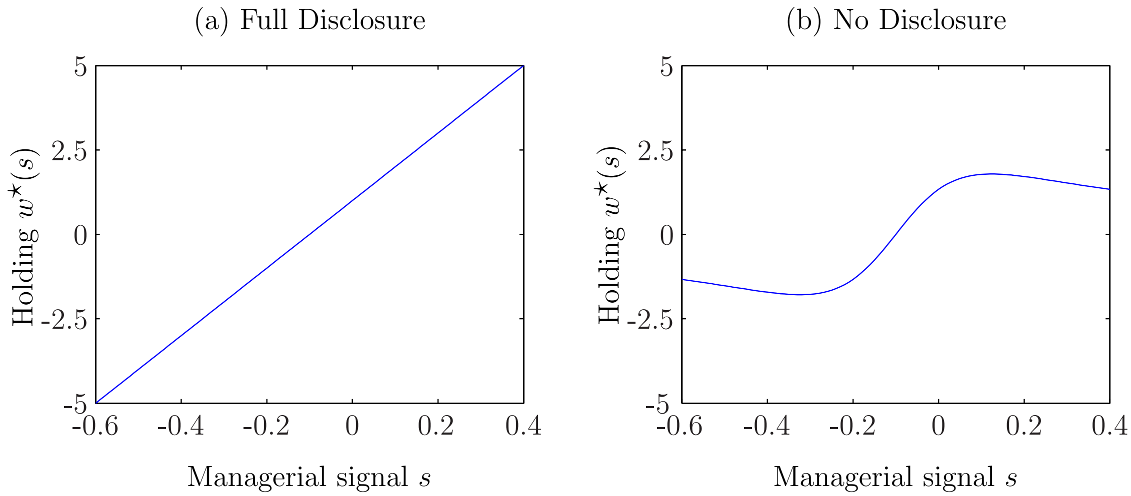
$$\begin{aligned}
&DBS_A - DBS_B \qquad \text{(F2)} \\
&\quad = \frac{\mathrm{E}\big[\tilde{R}_P\big]}{\sqrt{\mathrm{E}\big[\mathrm{var}(\tilde{R}_P|x_A)}} - \frac{\mathrm{E}\big[\tilde{R}_P\big]}{\sqrt{\mathrm{E}\big[\mathrm{var}(\tilde{R}_P|x_A)\big] + \mathrm{E}\big[\mathrm{var}\big(\mathrm{E}\big\{\tilde{R}_P|x_A\big\}|x_B\big)\big]}}
\end{aligned}$$

Since $\mathrm{var}\big(\mathrm{E}\big\{\tilde{R}_P|x_A\big\}\big) > 0$ for some x_B if $x_B \subset x_A$, (F2) implies that $DBS_A > DBS_B$. This proves Corollary 1. Q.E.D.

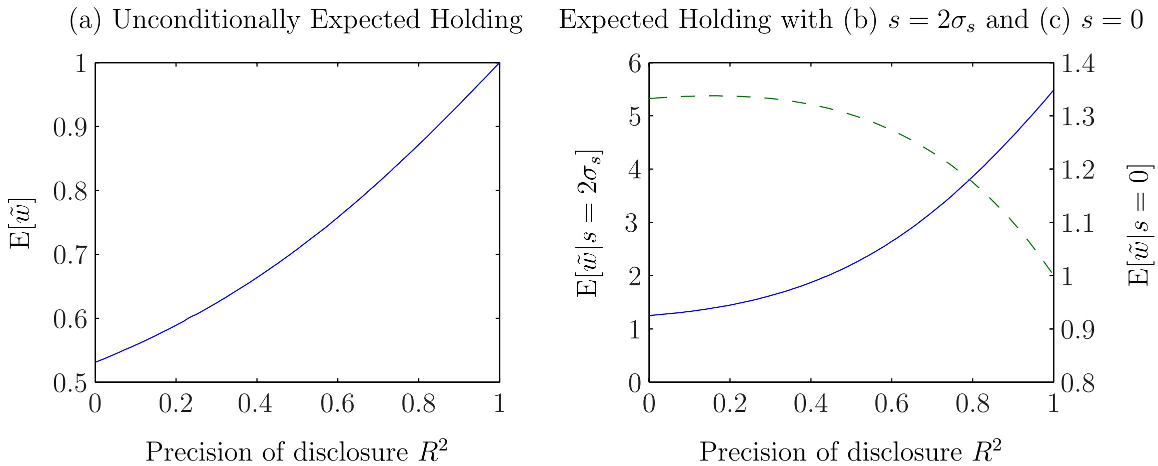
Appendix G Figures

Figure 1 shows for a single stock ($N = 1$) the optimal managed portfolio in the cases of (a) full portfolio disclosure and (b) without portfolio disclosure. The expected stock return is $\mu = 0.1$, the variance of the stock return is $\sigma^2 = 0.1$, the variance of the signal is $\sigma_s^2 = 0.05$, and the parameter of risk aversion is $\lambda = 2$.

Figure 2 shows for a single stock ($N = 1$) (a) the unconditionally expected managed portfolio, (b) the expected managed portfolio with a managerial signal of $s = 2\sigma_s$, and (c) the expected managed portfolio with a signal of $s = 0$ as a function of the precision of portfolio disclosure, $R^2 = 1 - \sigma^2\big(\tilde{s}|x\big)/\sigma_s^2$. The expected stock return is $\mu = 0.1$, the variance of the stock return is $\sigma^2 = 0.1$, the variance of the managerial signal is $\sigma_s^2 = 0.05$, and the parameter of risk aversion is $\lambda = 2$.


(a) Full Disclosure
(b) No Disclosure
Holding $w^{\star}(s)$
Managerial signal s
5
2.5
0
-2.5
-5
-0.6
-0.4
-0.2
0
0.2
0.4

(Figure 1)



(a) Unconditionally Expected Holding
Expected Holding with (b) $s = 2\sigma_s$ and (c) $s = 0$
$E[\tilde{w}]$
$E[\tilde{w}|s = 2\sigma_s]$
$E[\tilde{w}|s = 0]$
Precision of disclosure R^2
Precision of disclosure R^2

(Figure 2)

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