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SHOULD SMART INVESTORS BUY FUNDS WITH HIGH RETURNS IN THE PAST

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Should smart investors buy funds with high returns in the past?*

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Abstract

Newspapers and weekly magazine catering to the investing crowd often rank funds according to the returns generated in the past. Aside from satisfying sheer curiosity, these numbers are probably also the basis on which investors pick a fund to invest in. In this article, we fully characterize the equilibrium in a game between a mutual fund manager of unknown ability who controls the riskiness of his portfolio and investors who only observe realized returns. We derive conditions under which *(i)* investors invest in the fund if the realized return falls within some interval, i.e., is neither too low nor too high, *(ii)* a good mutual fund manager picks a portfolio of minimal riskiness and *(iii)* a bad mutual fund manager will pick a portfolio with higher risk, "gambling" on a lucky outcome. We also show that regulating the maximum risk a mutual fund is allowed to take may actually decrease rather than increase the expected return to investors, even if the market price of risk is zero: the regulation ends up forcing the investor to pick the bad fund more often.

Keywords: Heterogenous abilities, Interval of performances, Portfolio riskiness.
JEL Classification: D82, D84, G20.

1 Introduction

Newspapers and weekly magazine catering to the investing crowd often produce tables showing "rat races" of mutual funds. They rank funds according to the returns generated in the previous year or over a period of several years. Aside from satisfying sheer curiosity, these numbers are probably also the basis on which investors pick a fund to invest in. Empirical work shows that flows in and out of funds are indeed positively correlated with past performances (see See Ippolito (1992), Sirri and Tuffano (1993), Chevalier and Ellison (1997) and Lettau (1997)).

Should smart investors buy funds with high returns in the past? To answer this question, we shall build on the premise that mutual fund managers differ in their ability to generate high returns, and that these abilities are persistent at least in the short run so that returns in year t can be indicative of performances in year $t + 1$ (See Grinblatt and Titman (1992), Hendrick, Patel and Zeckhauser (1993), Brown and Goetzmann(1995) and Carhart (1997)[1]). Mutual fund managers with asset-based compensation schemes[2] are surely aware of the signalling function of their past performance, and will thus choose their portfolio strategies accordingly. For the sake of the argument, suppose, that investors always pick the fund which generated the highest return in the past. Knowing this, a fund manager with an inferior ability may be tempted to gamble, i.e. to invest in risky portfolios, hoping to generate the highest return in the crowd. But if that is indeed the case, high past returns are not indicative of high ability: rather, they indicate overly risky portfolios. Smart investors should thus avoid the top-performing funds.

The contribution of this paper is not only to make this intuition precise, but to fully characterize the equilibrium in a game between a mutual fund manager and investors, when only returns are observable. We assume that mutual fund managers can be either bad or good, and are thus able to realize either a low or a high return on investment on average. Mutual fund managers control the riskiness of their portfolio. The investors observe a realization of the fund return, and invest in the fund, if it is sufficiently likely that the mutual fund manager is good. The manager will choose the riskiness of his to-be-observed portfolio return in order to maximize the chance that the investor will invest with him.

We obtain the following results, summarized in Theorem 1. Under some conditions

[1]Evidence of persistent under-performance seem to be stronger than that of over-performance

[2]See Khorana (1996, section 2)

on the parameters of our model, the investor will invest in the fund, if the realized return falls within some interval, i.e., is neither too low nor too high. A good mutual fund manager picks a portfolio of minimal riskiness. A bad mutual fund manager will pick a portfolio with higher risk, "gambling" on a lucky outcome.

Such results are consistent with those of Carhart (1997) who shows that "the funds in the top decile differ substantially each year, with more than 80 percent annual turnover in the composition. In addition, last year's winners frequently become next year's losers and vice versa, which is consistent with gambling behavior by mutual funds".

We also show that regulating the maximum risk a mutual fund is allowed to take may actually decrease rather than increase the expected return to investors, even if the market price of risk is zero: the regulation ends up forcing the investor to pick the bad fund more often.

The paper proceeds as follows. Section 2 discusses related literature. Section 3 provides a simple two-quality model, and provides the key results in theorems 1 and 2. Section 4 provides analyzes a more general framework. Section 5 studies some numerical examples. Section 6 investigates the effects of regulating mutual fund riskiness. section 7 concludes.

2 Related literature

Our paper is substantially different from the existing literature. In particular, the upper bound is the novel feature of our paper. The most related models are those of Huddart (1999), Palomino (1998), Palomino and Prat (1998), and Raahauge (1999).

Huddart (1999) studies a two-period model in which, at the end of the first period, risk-averse investors reallocate their wealth between two funds after having observed the performance of each fund. It is shown that in the first, both an informed and an uninformed fund choose overly risky investment strategies; and in the second period investors should always invest in the fund that has realized the higher return in the first period.

There are several differences between Huddart's model and ours. First, Huddart assumes that portfolios are observable while we do not. Huddart's assumption implies that he studies a standard signalling model in which some additional information is given by realized returns. If portfolios are not observable, as in our model, managers' skills can only be derived from statistical inference. Furthermore, we do not find the assumption of observable portfolios very appealing since managers window-dress their portfolio around disclosure dates in practice (see Lakonishok, Thaler, Shleifer and Vishny (1991) in the case of pension funds and Musto (1999) in the case of taxable money funds). Second, Huddart's assumption makes it very "easy" for an uninformed manager to obtain exactly the same return as an informed manager. Hence, there is not much information an investor can gather from observed returns.

Palomino (1998) and Palomino and Prat (1998) focus on the consequences of the use of relative performance as a fund picking device by investors. Palomino shows that with imperfectly competitive market, relative performance objectives lead to both overly-risky investment and herding in the acquisition of information. Palomino and Prat analyze the competition between two money managers over two investment periods in a competitive environment when managers observe performances at the end of the first period while investors do not. They show that in first period, managers maximize their expected return. In the second period, if managers have ranking-based objectives (as in a tournament), they do not maximize their expected return.

The main difference between these two models and ours is that they consider a more complex game played by managers (either market power or multiple investment decision) but take the behaviour of investors as given. Conversely, we study a model in which managers are price takers and make only one investment decision but investors are strategic agents.

Finally, Raahauge, in the sixth chapter of his thesis (1999), investigates the ability of the principal-agent problem between investors and mutual fund managers to account for the observed equity premium. In contrast to us, a "gamble for resurection" after the first half of a period is key in his model. Furthermore, he does not actually characterize the equilibrium.

Other papers such as Das and Sundaram (1998a) have focussed on e.g. the fee structure as a way to signal skills. Heinkel and Stoughton (1994) also analyze the interplay between a portfolio manager and an investor: there, the focus is to extract the right effort from the manager by conditioning a continued relationship on the observed return.

On the empirical side, investors' smartness in fund picking has been studied by Gruber (1996) and Zhen (1999). Both articles show that newly invested money performs better than the entire stock of money invested in actively managed funds. However, newly invested money in actively managed equity funds underperforms index funds. This suggests that investors' ability to select funds is rather limited. Massa (1997) shows that the fund-picking by investors is dictated by their position on a relative ranking of funds performances rather than the absolute value of the return generated by the funds: the latter is insignificant, if the former is included. This lends mild empirical support to Theorem 1: if returns are already sufficiently high to land you on top of the heap, it does not help to achieve even higher returns[3].

3 The Model

There is a single mutual fund and a continuum of investors. The mutual fund manager is of good quality with some probability ψ and of bad quality with probability $1-\psi$. The mutual fund manager picks a portfolio, which generates the return

$$R = \mu + \sigma\epsilon,\ \epsilon \sim \mathcal{N}(0;1) \tag{1}$$

We assume that $\mu = \mu_b$ if the manager is of bad quality, and $\mu = \mu_g > \mu_b$, if the manager is of good quality. In picking the portfolio, the mutual fund manager only controls the riskiness $\sigma \geq \underline{\sigma} > 0$ of the portfolio. I.e., the mutual fund manager cannot reduce the risk in his portfolio below some positive lower bound, but he can add as much risk as he wants. For simplicity, we have assumed that the market price of this risk is zero, i.e., that changing the riskiness of the portfolio does not affect its mean return. This is not restrictive in principle: if there is a market price for risk, rewrite everything in risk-adjusted terms, i.e. do a change of measure so that assets can be compared by comparing their expected returns only, using the new measure. Of course, while this is a standard and elegant procedure in theory, it may makes comparisons to the data tricky.

The investors only observe the return, but not the choice σ or the quality of the manager. Based on the observed return, the investors calculate the probability $P(\text{“}g\text{”} \mid R)$ that the mutual fund manager is indeed of good quality. They will invest in the fund, if that probability exceeds some treshold $\tau \in (0,1)$, which we take to be an exogenous parameter of the model. The mutual fund manager aims at maximizing the probability that the investors invest with him. Note that all investors have the same information and make the same decision. We are interested in the sequential

[3]We are grateful to Massimo Massa for pointing this out to us.

equilibria of this game.

This is an extremely simple model aimed at providing a more precise underpinning of the intuition described in the introduction. For simplicity sake and on purpose, the model ignores some potentially important aspects. First, the rather mechanical decision by the investors shortcuts a much lengthier derivation of the portfolio choice based on first principles in some multiperiod, multifund model. Such a derivation would likely complicate the analysis in an unnecessary way. Second, the objective of the mutual fund manager can be underpinned by assuming that the mutual fund manager is paid on a percentage basis of the funds under his management for some second, unmodelled period. Again, this would only complicate the model. Third, the parameters, in particular the treshold probability τ are taken to be exogenous, although they may well be considered as endogenous in a more complicated version of the model: indeed, we will endogenize τ later on, in Section 5. Finally, we have completely ignored an important multiperiod aspect: investors should take into account, that the manager will have an incentive to signal good quality also in the *future*, using the investors resources to do so. The latter provides for additional interesting interactions which we hope to analyze in future work.

We analyze the game backwards, searching for the equilibrium (pure-strategy) portfolio risks σ_g^* to be picked by the good manager and σ_b^* to be picked by the bad manager.

In the last stage of the game, observing the realized return R and in knowledge of the equilibrium strategies (σ_g^*, σ_b^*), the investors can calculate the likelihood ratio $L(R; \sigma_g^*, \sigma_b^*)$, that the manager is bad as opposed to good,

$$\begin{aligned} L(R; \sigma_g^*, \sigma_b^*) &= \frac{P(R \mid \text{“}b\text{”})}{P(R \mid \text{“}g\text{”})} \\ &= \frac{\sigma_g^*}{\sigma_b^*} e^{(R-\mu_g)^2/(2\sigma_g^{*2}) - (R-\mu_b)^2/(2\sigma_b^{*2})} \end{aligned}$$

Using Bayes rule, the probability of good manager having realized the return R computes to

$$\begin{aligned} P(\text{”}g\text{”} \mid R) &= \frac{P(R \mid \text{“}g\text{”}) P(\text{“}g\text{”})}{P(R \mid \text{“}b\text{”}) P(\text{“}b\text{”}) + P(R \mid \text{“}g\text{”}) P(\text{“}g\text{”})} \\ &= \frac{\psi}{\psi + (1-\psi) L(R; \sigma_g^*, \sigma_b^*)} \end{aligned}$$

The investors invest with the fund, if

$$P(\text{“}g\text{”} \mid R) \geq \tau \tag{2}$$

This is equivalent to demanding that the investor invest with the fund, if the ex-post expected return exceeds some treshold level μ^*,

$$P(\text{“}g\text{”} \mid R)\mu_g + P(\text{“}b\text{”} \mid R)\mu_b \geq \mu^* \tag{3}$$

provided, μ^* and τ satisfy the relationship

$$\tau = \frac{\mu^* - \mu_b}{\mu_g - \mu_b} \tag{4}$$

In sections 4 and 5, we will find the alternative formulation (3) more useful, but we will stick with the "τ"-formulation here.

Given the equilibrium strategies (σ_g^*, σ_b^*), the fund will now pick σ so as to maximize his chances of receiving investors,

$$\max_\sigma P(\frac{\psi}{\psi + (1-\psi)L(R; \sigma_g^*, \sigma_b^*)} \geq \tau), \tag{5}$$

where the return distribution of R depends both on σ as well as on the quality of the manager via the mean μ_g or μ_b, see equation (1).

A strategy pair (σ_g^*, σ_b^*) is an *equilibrium*, iff

$$\sigma_x^* = \text{argmax}_\sigma P(\frac{\psi}{\psi + (1-\psi)L(R; \sigma_g^*, \sigma_b^*)} \geq \tau) \;\; \text{s.t.} \;\; R = \mu_x + \sigma\epsilon, \; \epsilon \sim \mathcal{N}(0; 1)$$

for $x = g, b$. We are now ready to state our main results.

Theorem 1 *Suppose, the parameters $\mu_g, \mu_b, \underline{\sigma}, \psi, \tau$ satisfy*

$$\frac{(\mu_g - \mu_b)^2}{2\underline{\sigma}^2} > \log\left(\frac{\psi(1-\tau)}{1-\psi}\right) > 0 \tag{6}$$

Then there exists an equilibrium (σ_g^*, σ_b^*) with the following features:

1. *The good manager picks the minimal feasible risk level, $\sigma_g^* = \underline{\sigma}$.*

2. *The bad manager picks a risk level, which is strictly greater than the feasible minimum, $\sigma_b^* > \underline{\sigma}$.*

3. *The investor invests in the fund, if the return R falls in the interval $[R_l, R_h]$ for some bounds R_l, R_h solving some quadratic equation, and satisfying*

$$\mu_b < R_l < \mu_g < R_h < \infty$$

The proof is in appendix A.

Theorem 2 *Suppose, the parameters $\mu_g, \mu_b, \underline{\sigma}, \psi, \tau$ satisfy*

$$\log\left(\frac{\psi(1-\tau)}{1-\psi}\right) > \frac{(\mu_g-\mu_b)^2}{2\underline{\sigma}^2} \tag{7}$$

Then there exists an equilibrium (σ_g^*, σ_b^*) with the following features:

1. *Both managers pick the minimal feasible risk level, $\sigma_g^* = \sigma_b^* = \underline{\sigma}$.*

2. *The investor invests in the fund, if the return R is larger than some threshold $\underline{R}$ with*

$$\underline{R} = \frac{\mu_g+\mu_b}{2} - \frac{\underline{\sigma}^2}{\mu_g-\mu_b}\log\left(\frac{\psi(1-\tau)}{1-\psi}\right) \leq \mu_b \tag{8}$$

The proof is in appendix A.

Theorem 1 states that when the probability that a fund manager is good is high (the second inequality of (6) holds) and the difference of skills between a good and a bad manager is large (the first inequality of (6) holds) then an investor should not invest in the fund if its return is either too large or too small.

Figure 1 illustrates this result (with the parameters of Table 2, row 1 in Section 5). The grey area and the bell-shaped line represent the densities of return generated by a bad fund manager and a good fund manager, respectively. The two vertical lines represent the lower and the upper bound (i.e., R_l and R_h) for realized returns between which investors decide to invest in the fund.

[Insert Figure 1]

The equilibrium proposed by Theorem 2 is more "conventional": pick the fund which generates the highest returns. The first inequality in (6) thus provides the dividing line between a "naive" and a "sophisticated" reading of mutual fund return rankings. Such fund picking strategy should be implemented when the fraction of good fund managers is large (the second inequality of (6) holds) and the skill difference between good and bad managers is small (the first inequality of (6) does not hold).

Under the conditions of the two theorems above, there also is another equilibrium, in which the investor always invests with the fund, no matter what return is observed: this is discussed in appendix B.

4 The general case

The preceeding section concentrated on the highly restrictive case, that there are only two types of qualities for the manager. We shall now proceed to the general case of fairly arbitrary a priori qualities. Our aim is now more modest: we want to state sufficient conditions under which we can *rule out*, that a smart investor should always pick the fund with the highest return, i.e. we want to state conditions, under which the answer to the question in the title is negative.

Assume, that the quality of the manager is measured by the mean return μ he can achieve, which is drawn according to some prior probability measure $\pi(d\mu)$ with compact support $[\underline{\mu}, \bar{\mu}]$. The manager picks σ within a given interval $[\underline{\sigma}, \bar{\sigma}]$, $0 < \underline{\sigma} < \bar{\sigma}$ and realizes the return

$$R = \mu + \sigma\epsilon$$

where $\epsilon \sim N(0,1)$. The investor observes R and forms posterior beliefs π_R for the managerial quality μ. He will invest in the fund iff

$$E_{\pi_R}[\mu] \geq \mu^*$$

where μ^* is some treshold level return.

Our general result is as follows.

Theorem 3 *Suppose that, a priori,*

$$E_\pi[\mu] < \mu^*$$

Then, for $\bar{\sigma}$ sufficiently large, there is no equilibrium, in which the smart investor will invest if $R \geq \underline{R}$ for some $\underline{R}$.

The proof is in appendix C. The theorem essentially says, that whenever it is not a good idea to buy the managed funds a priori, then the investor should always interpret very large returns as a sign of a bad fund "gambling" rather than a sign of good ability. Such a result is consistent with those of Carhart (1997) on the lack of persistence of top performance and on the gambling behavior of mutual fund managers.

One should note that the result above is consistent with Theorem 2. Note that equation (7) implies

$$\frac{\psi(1-\tau)}{1-\psi} > 1$$

Replace τ with (4) and rewrite the above equation as

$$\psi\mu_g + (1-\psi)\mu_b > \psi\mu^* + (1-\psi)\mu_g$$

and observe that the right hand side is larger than μ^*, since μ_g must be larger than μ^* for this inequality to have a chance to hold at all. Put differently, the conditions under which Theorem 2 hold, violate the conditions under which Theorem 3 hold, which is how it should be.

To gain further insights, quantitative, numerical examples are needed. This is the purpose of the next section, in which we revert to the the two-quality situation, envisioned in the previous section.

5 Some illustrative examples

This section provides some numerical examples to illustrate the nature of the solution, and to shed further light on our theory.

We consider a situation in the spirit of Ippolito (1992). The economy contains two funds, an actively managed fund which charges high management fees and an index fund which charges low management fees. Denote c the difference in fees and μ_o the expected return of the index fund. We imagine that the investor chooses the actively managed fund if he expects to earn a higher return after fees than with the index fund,

$$P(\text{“}g\text{”}|R)\mu_g + P(\text{“}b\text{”}|R)\mu_b > \mu^* = \mu_o + c$$

This is equivalent to

$$P(\text{“}g\text{”}|R) > \frac{\mu_o + c - \mu_b}{\mu_g - \mu_b}$$

The treshold probability τ can be calculated with equation (4), restated here for convenience:

$$\tau = \frac{\mu_o + c - \mu_b}{\mu_g - \mu_b}$$

The average yearly return of the SP500 over the period 1990-1998 is 1.17 and standard deviation of this return is 0.1414. So, in the following examples, we assume that $\mu_o = 1.18$.

Table 1 illustrates the effect of changes of μ_g (everything else held equal) on the variance of the portfolio chosen by a manager of type b (σ_b), the bounds within the investor pick the actively managed fund (R_l and R_h), the probability that the investors chooses the actively managed fund ($P(I)$), the probability that the investor invets in a good fund $P(\text{“}g\text{” and } I)$, the probability of having selected a good fund given that an actively managed fund has been chosen ($P(\text{“}g\text{”}|I)$) and the expected return of investing $E(Ret)$ given the probabilities $P(I)$ and $P(\text{“}g\text{”}|I)$.

μ_g	μ_b	ψ	σ_b	R_l	R_h	τ	$P(I)$	$P(\text{“}g\text{” and } I)$	$P(\text{“}g\text{”}\|I)$	$E(Ret)$
1.22	1.15	0.7	0.125	1.153	1.537	0.57	0.67	0.52	0.78	1.2
1.24	1.15	0.7	0.116	1.15	1.863	0.44	0.72	0.57	0.79	1.212
1.26	1.15	0.7	0.123	1.15	1.793	0.36	0.75	0.60	0.80	1.226
1.28	1.15	0.7	0.138	1.153	1.69	0.31	0.77	0.63	0.81	1.241
1.30	1.15	0.7	0.163	1.157	1.625	0.27	0.79	0.65	0.82	1.255

Table 1: $\mu_o = 1.18$, $c = 0.01$, $\underline{\sigma} = 0.1$

We observe that as μ_g increases, the probability of selecting a fund of type "g" given that an actively managed fund has been selected increases. This is fairly intuitive, the larger the difference in expected returns between bad and good funds, the easier it is for an investor to sort them out based on observed returns. The effect on the portfolio volatility chosen by a manager of type "b" is unclear. The reason is the following. If R_l decreases then σ_b decreases since the lower bound gets closer to μ_b (Remember that for any set of parameters such that Theorem 1 holds, $R_l > \mu_b$). Reciprocally, if a manager of type "b" decreases σ_b then investors will lower R_l. Hence, an increase in μ_g may result in a lower σ_b. Conversely, if investors increase R_l as μ_g increases, then the response of a manager of type "b" will be to increase σ_b. Reciprocally, the best response of an investor to an increase of σ_b is to increase R_l. Table 1 illustrates that this can create a nonmonotonic relationship between the exogenous variable μ_g and the endogenous values for σ_b, R_l and R_h.

Table 2 illustrates the influence of variations of ψ. We observe that as ψ increases, σ_b decreases. The reason is that the ex-ante probability for the investor of choosing a fund of type "b" when investing in an actively managed fund decreases. Therefore, the investor can widen the interval of realizations of returns for which he chooses an actively managed fund, i.e., R_l decreases and R_h increases. It follows that a manager of type "b" has less incentives to take a high level of risk. Hence, as ψ increases, σ_b decreases.

μ_g	μ_b	ψ	σ_b	R_l	R_h	τ	$P(I)$	$P($"g"and $I)$	$P($"g"$\|I)$	$E(Ret)$
1.30	1.15	0.6	0.179	1.182	1.554	0.27	0.69	0.52	0.76	1.241
1.30	1.15	0.65	0.173	1.169	1.583	0.27	0.74	0.59	0.79	1.2482
1.30	1.15	0.7	0.163	1.157	1.625	0.27	0.79	0.65	0.82	1.255
1.30	1.15	0.75	0.14	1.15	1.763	0.27	0.82	0.70	0.85	1.262
1.30	1.15	0.8	0.105	1.15	4.367	0.27	0.85	0.75	0.88	1.268

Table 2: $\mu_o = 1.18$, $c = 0.01$, $\underline{\sigma} = 0.1$

Table 3 illustrates the influence of μ_b. The effects of variations of μ_b are similar to those produced by variations of μ_g. For the set of parameters considered, we observe that as μ_b increases, the difference $R_l - \mu_b$ decreases. As a consequence, a manager of type "b" has less incentives to take risk and he decreases σ_b as a response to a decrease of $R_l - \mu_b$. Now, the best response of an investor to a decrease of σ_b is to decrease the difference $R_l - \mu_b$. Again, the resulting behaviour of R_l and R_h is nonmonotonic.

μ_g	μ_b	ψ	σ_b	R_l	R_h	τ	$P(I)$	$P($"g"and $I)$	$P($"g"$\|I)$	$E(Ret)$
1.24	1.06	0.7	0.214	1.149	1.432	0.72	0.64	0.55	0.86	1.206
1.24	1.09	0.7	0.187	1.148	1.452	0.67	0.67	0.56	0.84	1.207
1.24	1.12	0.7	0.159	1.145	1.491	0.58	0.70	0.58	0.82	1.21
1.24	1.15	0.7	0.116	1.15	1.863	0.44	0.72	0.57	0.79	1.212

Table 3: $\mu_o = 1.18$, $c = 0.01$, $\underline{\sigma} = 0.1$

6 Regulation issues

One may argue that the mutual fund industry is highly regulated and that managers do not have the freedom to choose a level of risk as high as they would wish given their incentives. In other words, regulation impose an upper bound $\bar{\sigma}$ on the level of risk a manager can choose. A natural question to ask is whether such a regulation is in the interest of investors, i.e., does the expected return from investment increases when $\bar{\sigma}$ decreases?

If the conditions of Theorem 1 are met, then if $\bar{\sigma} < \sigma_b^*$, a manager of type "b" will choose $\sigma_b = \bar{\sigma}$ in equilibrium. Therefore, when choosing $\bar{\sigma}$, the regulator has to take into account the reaction of investors to a decrease of σ_b, since both R_l and R_h are functions of σ_b.

Investors' expected return $E(Ret)$ can be rewritten as

$$E(Ret) = \mu_o + P(\text{``}g\text{''and } I)(\mu_g - \mu_o) - P(\text{``}b\text{''and } I)(\mu_b - \mu_o)$$

Hence, the expected return can be split into three pieces: the expected return of the index fund, the gain from investing in a fund of type "g" rather than in the index fund and last, the cost of investing in a fund of type "b" rather than in the index fund. The regulation influences both $P(\text{``}g\text{''and } I)$ and $P(\text{``}b\text{''and } I)$, and is beneficial (detrimental) to investors is the variation in gains (costs) generated by limiting the riskiness of portfolios selected by managers exceeds the variation in costs (gains).

Analyzing the marginal impact of $\bar{\sigma}$ on $E(Ret)$ analytically turns into a messy exercise without clear results. We resort to numerical illustration instead. We provide two examples showing that limiting the amount of risk a manager can take can either increase or decrease investors' expected return $E(Ret)$.

In the first example, $\mu_g = 130$, $\mu_b = 115$, $\psi = 0.7$ and all the other parameters are as in the previous section. In such a case, in the absence of regulation, $\sigma_b^* = 0.163$ (see Table 1). As the maximum amount of risk allowed decreases, the interval $[R_l, R_h]$ "moves" in the direction of higher returns (see Figures 2 and 3). A direct consequence is that both the probability of investing in a fund of type "b" and the probability of investing in a fund of type "g" decrease (see, Figures 4 and 5, respectively). Hence, the regulation decreases both the gain from investing in a good fund and the cost of investing in a bad fund. In this example, the reduction in gains exceeds the reduction of costs and the net effect is a lower expected return for investors (Figure 6). Therefore, limiting the level of risk a manager of type "b" takes is welfare decreasing.

[Insert Figures 2 to 6]

In the second example we consider, $\mu_g = 130$, $\mu_b = 86$, $\psi = 0.8$ and all the other parameters are as in the previous section. In such a case, in absence of regulation $\sigma_b^* = 0.4465$. As Figure 7 illustrates, R_l is not monotonic in $\bar{\sigma}$. However, for a large reduction in the maximum level of risk, R_l decreases, R_h increases (Figure 8), the probability of investing in funds of type "b" decreases (Figure 9) and the probability of investing in a fund of type "g" increases (Figure 10). The direct consequence is an increase of investors' expected return (Figure 11). In such a case, a regulation limiting strongly the maximum amount of risk managers can take is beneficial to investors.

[Insert Figures 7 to 11]

7 Conclusion

This paper provided a simple, highly stylized theory of the game between a mutual fund manager and a collection of investors. Mutual fund managers can be either bad or good, and are thus able to realize either a low or a high return on investment on average. Mutual fund managers control the riskiness of their portfolio. The investors observe a realization of the fund return, and invest in the fund, if it is sufficiently likely that the mutual fund manager is good. The manager will choose the riskiness of his to-be-observed portfolio return in order to maximize the chance that the investor will invest with him.

We obtained the following results. Under some conditions on the parameters of our model, the investor will invest in the fund, if the realized return falls within some interval, i.e., is neither too low nor too high. A good mutual fund manager picks a portfolio of minimal riskiness. A bad mutual fund manager will pick a portfolio with higher risk, "gambling" on a lucky outcome. Thus, smart investors may not want to buy the fund with the highest returns in the past. We show also that the implementation of a regulation limiting the extent of the gambling activity by bad managers is not always in the interest of rational investors who react optimally to managers' portfolio selection.

Our results on portfolio selection by fund managers are consistent with those of Carhart (1997) on the lack of persistence in performances by mutual funds. Hence, investment advisors making recommendations on the basis of funds' past returns should tell investors to choose a good performer but not a top performer.

Appendix

A Proofs for the two-quality case.

Proof of Theorem 1

The proof proceeds in several steps. We concentrate on finding equilibria, satisfying $\sigma_g^* \leq \sigma_b^*$. We will make ample use of this inequality, which obviously needs to be verified in the end.

1. **The investment decision of the investors.**

   The criterion (2) can be written as

$$(R-\mu_g)^2/(2\sigma_g^{*2}) - (R-\mu_b)^2/(2\sigma_b^{*2}) \leq \log\left(\frac{\sigma_b^*}{\sigma_g^*}\frac{\psi(1-\tau)}{1-\psi}\right)$$

   or, equivalently,

$$q(R;\sigma_g^*,\sigma_b^*) \leq 0 \tag{9}$$

   where $q(R;\sigma_g^*,\sigma_b^*)$ is a quadratic function in R, given by

$$\begin{aligned} q(R;\sigma_g^*,\sigma_b^*) &= \left(\frac{1}{2\sigma_g^{*2}} - \frac{1}{2\sigma_b^{*2}}\right)R^2 \qquad (10) \\ &\quad - \left(\frac{\mu_g}{\sigma_g^{*2}} - \frac{\mu_b}{\sigma_b^{*2}}\right)R + \left(\frac{\mu_g^2}{2\sigma_g^{*2}} - \frac{\mu_b^2}{2\sigma_b^{*2}}\right) - \log\left(\frac{\sigma_b^*}{\sigma_g^*}\frac{\psi(1-\tau)}{1-\psi}\right) \end{aligned}$$

   Inequality (9) is satisfied, iff

$$R \in [R_l(\sigma_g^*,\sigma_b^*), R_h(\sigma_g^*,\sigma_b^*)] \tag{11}$$

   where $R_l(\sigma_g^*,\sigma_b^*) \geq R_h(\sigma_g^*,\sigma_b^*)$ are the two solutions to the quadratic equation

$$q(R;\sigma_g^*,\sigma_b^*) = 0 \tag{12}$$

   The second inequality of (6) implies, that (12) only has real solutions: this is tedious but uninteresting to check, and we therefore skip the details. Furthermore, we note that for $\sigma_g^* = \sigma_b^*$, the coefficient on the lead quadratic term becomes zero. The solutions then take the form

$$\begin{aligned} R_h &= \infty \\ R_l &= \underline{R}(\sigma_g^*) \end{aligned}$$

   where

$$\underline{R}(\sigma_g^*) = \frac{\mu_g+\mu_b}{2} - \frac{\sigma_g^{*2}}{\mu_g-\mu_b}\log\left(\frac{\psi(1-\tau)}{1-\psi}\right) \tag{13}$$

2. **A first-order condition for the fund manager.**
With (11), the objective (5) of the fund manager with quality $x = g, b$ can be rewritten as

$$\max_{\sigma} f(\sigma; \sigma_g^*, \sigma_b^*) \tag{14}$$

where $f(\sigma; \sigma_g^*, \sigma_b^*)$ is the integral

$$f(\sigma; \sigma_g^*, \sigma_b^*) = \int_{R_l(\sigma_g^*, \sigma_b^*)}^{R_h(\sigma_g^*, \sigma_b^*)} \frac{1}{\sqrt{2\pi}\sigma} e^{-(R-\mu_x)^2/(2\sigma^2)} dR$$

To find the optimum, it is useful to differentiate f with respect to σ,

$$\frac{df}{d\sigma} = \frac{1}{\sigma} I(\sigma; R_l(\sigma_g^*, \sigma_b^*), R_h(\sigma_g^*, \sigma_b^*))$$

where $I(\sigma; R_l, R_h)$ is the integral

$$I(\sigma; R_l, R_h) = \int_{\frac{R_l - \mu_x}{\sigma}}^{\frac{R_h - \mu_x}{\sigma}} (\epsilon^2 - 1) \frac{1}{\sqrt{2\pi}} e^{-\epsilon^2/2} d\epsilon \tag{15}$$

Standard results about normal distributions imply immediately that

$$I(\sigma; -\infty, \infty) = I(\sigma; 0, \infty) = I(\sigma; -\infty, 0) = 0 \tag{16}$$

Furthermore, note that the integrand $(\epsilon^2 - 1)$ in (15) is negative if $| \epsilon | < 1$. These relationships will prove useful in the next step.

3. **When do we have $\sigma_g^* = \underline{\sigma}$?**
From the preceeding analysis, we see that (14) is solved at $\sigma = \underline{\sigma}$, if

$$I(\sigma; R_l(\sigma_g^*, \sigma_b^*), R_h(\sigma_g^*, \sigma_b^*)) < 0$$

for all $\sigma \geq \underline{\sigma}$. With (16) and the remark following it, it is straightforward to check, that this is the case if $R_l \leq \mu_x \leq R_h$. This in turn is true iff $q(\mu_x; \sigma_g^*, \sigma_b^*) \leq 0$. For $x = g$, this can be rewritten as

$$q(\mu_g) = -\frac{(\mu_g - \mu_b)^2}{2\sigma_b^{*2}} - \log\left(\frac{\sigma_b^*}{\sigma_g^*} \frac{\psi(1-\tau)}{1-\psi}\right) \leq 0.$$

The second inequality of (6) is sufficient for this inequality to hold. This shows, that $\sigma_g^* = \underline{\sigma}$, as claimed.

4. **When do we have $\underline{\sigma} < \sigma_b^* < \infty$?**

From the previous step, we deduce that we have an equilibrium with $\sigma_g^* = \underline{\sigma}$ and $\sigma_b^* > \underline{\sigma}$ if we can rule rule out $\sigma_b^* = \underline{\sigma}$ via

$$I(\underline{\sigma}, R_l(\underline{\sigma}, \underline{\sigma}), R_h(\underline{\sigma}, \underline{\sigma})) > 0 \tag{17}$$

and show, that for some $\sigma > \underline{\sigma}$, we have

$$I(\sigma, R_l(\underline{\sigma}, \sigma), R_h(\underline{\sigma}, \sigma)) < 0 \tag{18}$$

An interior solution must then exist by the mean value theorem.

Inequality (17) is equivalent to $\underline{R}(\underline{\sigma}) > \mu_b$ which is in turn equivalent to the first inequality of (6). For inequality (18), note that the integrand in equation (15) is negative for $| \epsilon |< 1$. Thus, (18) follows, if

$$-1 < \frac{R_l(\underline{\sigma}, \sigma) - \mu_b}{\sigma} \leq \frac{R_h(\underline{\sigma}, \sigma) - \mu_b}{\sigma} < 1$$

for some σ. Rewrite this as

$$\mu_b - \sigma < R_l(\underline{\sigma}, \sigma) \leq R_h(\underline{\sigma}, \sigma) < \mu_b + \sigma$$

which, in turn, is equivalent to

$$q(\mu_b - \sigma, \underline{\sigma}, \sigma) > 0,\ q(\mu_b + \sigma, \underline{\sigma}, \sigma) > 0$$

for some σ. However, inspecting (10), it is easy to see that

$$q(\mu_b - \sigma, \underline{\sigma}, \sigma) \rightarrow \infty$$

and

$$q(\mu_b + \sigma, \underline{\sigma}, \sigma) \rightarrow \infty$$

as $\sigma \rightarrow \infty$, completing the proof.

Proof of Theorem 2

Follow the proof of theorem 1 above, except for the last step. Instead of inequality (17), we now get

$$I(\underline{\sigma}, R_l(\underline{\sigma}, \underline{\sigma}), R_h(\underline{\sigma}, \underline{\sigma})) < 0 \tag{19}$$

as a consequence of (7). It follows that $\sigma_b^* = \underline{\sigma}$ also. Finally, combine (7) and (8) to see that $\underline{R} < \mu_b$. □

B Existence of other equilibria

There are also equilibria such that the investor always invests in the fund. Tracing through the proof above of theorem 1, one can see that such an equilibrium will result, if

$$q(R, \sigma_g^*, \sigma_b^*) < 0 \text{ for all } R \tag{20}$$

In that case, the fund manager is indifferent between all choices for σ, regardless of his type, since his choice does not influence the probability of the investor investing with him. So, any σ_g^*, σ_b^* satisfying (20) is an equilibrium.

Given ψ, τ, μ_b, μ_g and $\underline{\sigma}$, we shall now show, that such σ_g^* and σ_b^* can always be found, provided that

$$\log\left(\frac{\psi(1-\tau)}{1-\psi}\right) > 0 \tag{21}$$

(note that this conditions is assumed to hold also for theorems 1 and 2). To see this, first note that (20) requires $\sigma_b^* < \sigma_g^*$. Given this inequality, (20) can be rewritten as

$$(\mu_g - \mu_b)^2 - 2(\sigma_g^{*2} - \sigma_b^{*2})\log\left(\frac{\psi(1-\tau)\sigma_b^*}{(1-\psi)\sigma_g^*}\right) < 0 \tag{22}$$

after some algebra. Let $\rho = \sigma_g^*/\sigma_b^*$: note that we need to keep $\rho > 1$. Rewrite equation (22) as

$$(\mu_g - \mu_b)^2 - 2\sigma_b^{*2}(\rho^2 - 1)\log\left(\frac{\psi(1-\tau)}{(1-\psi)\rho}\right) < 0 \tag{23}$$

With (21), find $\rho > 1$ close enough to 1, so that

$$\log\left(\frac{\psi(1-\tau)}{(1-\psi)\rho}\right) > 0$$

Next, find σ_b^* large enough so that inequality (23) is satisfied. Calculate $\sigma_g^* = \rho\sigma_b^*$ to find an equilibrium of the desired form.

C The proof for the general case

Proof of Theorem 3

Suppose to the contrary, that there was an equilibrium, where the investor always invests, if $R \geq \underline{R}$ for some $\underline{R}$. We will show, that there is some $R \geq \underline{R}$ (perhaps requiring some sufficiently large $\bar{\sigma}$), so that

$$E_{\pi_R}[\mu] < \mu^* \tag{24}$$

which is a contradiction.

As in the proof of theorem 1, the fund manager will maximize the probability that $R \geq \underline{R}$ via his choice of σ. It is easy to check, that he will choose $\sigma = \underline{\sigma}$, if $\mu \geq \underline{R}$ and $\sigma = \bar{\sigma}$, if $\mu < \underline{R}$. The posterior probability distribution therefore has the form

$$\pi_R(d\mu) = \phi(R, \bar{\sigma}) \left(m_A(d\mu; R, \bar{\sigma}) + m_B(\mu; R, \bar{\sigma}) \right)$$

where m_A is a measure with support $[\underline{\mu}, \underline{R})$ and given by

$$m_A(d\mu; R, \bar{\sigma}) = \frac{1}{\bar{\sigma}} \exp\left(-\frac{(\mu - R)^2}{2\bar{\sigma}^2} \right) \pi(d\mu),$$

where m_B is a measure with support $[\underline{R}, \bar{\mu}]$ and given by

$$m_B(d\mu; R, \bar{\sigma}) = \frac{1}{\underline{\sigma}} \exp\left(-\frac{(\mu - R)^2}{2\underline{\sigma}^2} \right) \pi(d\mu),$$

and where $\phi(R, \bar{\sigma})$ is chosen so that π_R is a probability measure.

We now distinguish two cases, $\underline{R} > \underline{\mu}$ and $\underline{R} \leq \underline{\mu}$.

1. **Case:** $\underline{R} > \underline{\mu}$

   Consider first the case $\underline{R} > \underline{\mu}$. In that case, the measure μ_A has positive mass, since $\pi(\mu < \underline{R}) > 0$.

   Note that the lead term in the exponential expression in m_A is $-R^2/(2\bar{\sigma}^2)$, whereas it is $-R^2/(2\underline{\sigma}^2)$ in the exponential expression for m_B. Since $\bar{\sigma} > \underline{\sigma}$, it follows that m_B vanishes relative to m_A as $R \to \infty$, $\bar{\sigma} \to \infty$, $R/\bar{\sigma} \equiv$ const.. More precisely, for any $\nu > 0$, one can find some suffiently large R as well as some $\tilde{\sigma}$, so that for all $\bar{\sigma} > \tilde{\sigma}$, we have that

   $$\mid E_{\phi(R,\bar{\sigma})m_A(\cdot;R,\bar{\sigma})}[\mu] - E_{\pi_R}[\mu] \mid < \nu,$$

   holding $R/\bar{\sigma} \equiv$ const. Fix $R/\bar{\sigma}$. One can see that

   $$E_{\phi(R,\bar{\sigma})m_A(\cdot;R,\bar{\sigma})}[\mu] \to E_\pi[\mu \mid \mu < \underline{R}]$$

   as $\bar{\sigma} \to \infty$. Put these two pieces together and use

   $$E_\pi[\mu \mid \mu < \underline{R})] \leq E_\pi[\mu] < \mu^*$$

   to demonstrate (24).

2. **Case:** $\underline{R} \leq \underline{\mu}$

   Next, consider the case $\underline{R} \leq \underline{\mu}$. In that case, the fund manager will choose $\sigma = \underline{\sigma}$, regardless of his type μ. Now suppose that the investor observes $R = \underline{\mu}$: note that he will invest. In that case,

$$E_{\pi_R}[\mu] = \frac{\int \mu e^{-(\mu-\underline{\mu})^2/(2\underline{\sigma}^2)}\pi(d\mu)}{\int e^{-(\mu-\underline{\mu})^2/(2\underline{\sigma}^2)}\pi(d\mu)} \leq E_\pi[\mu] < \mu^*,$$

   (where the first inequality can be seen to hold, since the posterior puts larger weight on smaller μ's), yielding the contradiction. This contradiction does not require the probability-zero event of exactly observing $R = \underline{\mu}$: the inequality above also remains for R near $\underline{\mu}$ by continuity.

□

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Figure 1

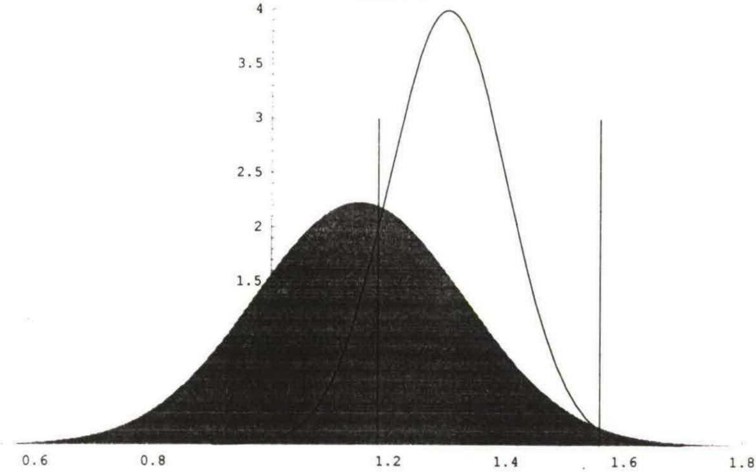
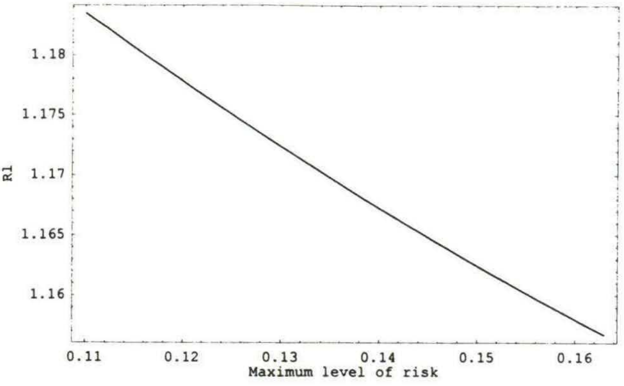


Figure 2



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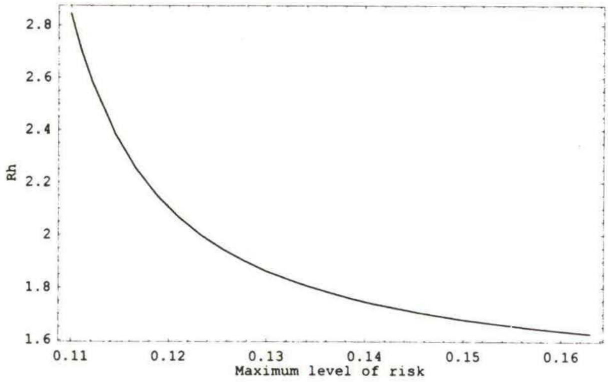

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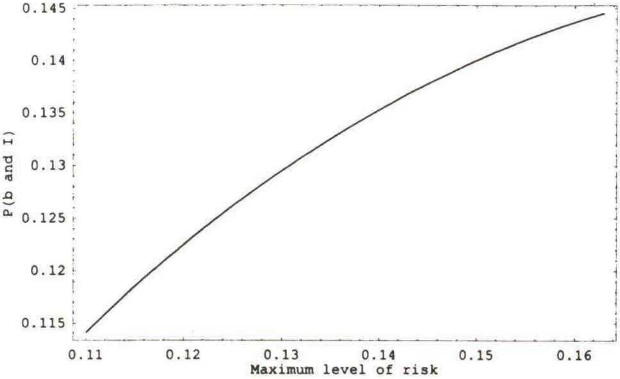

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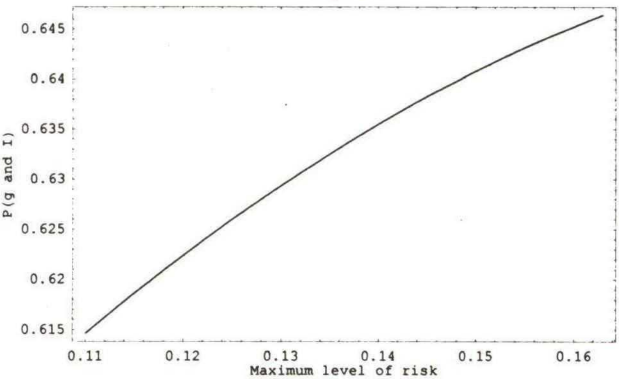

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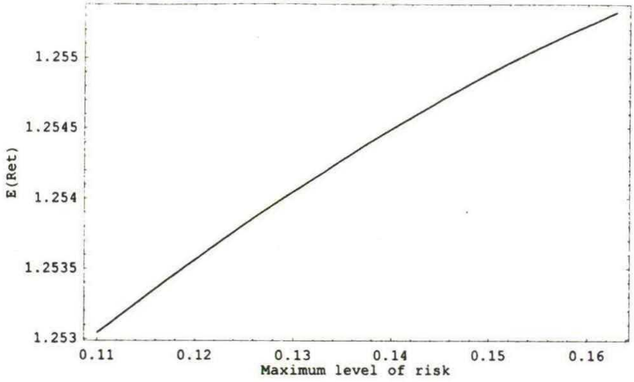
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1.2535
1.253
E(Ret)
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0.12
0.13
0.14
0.15
0.16
Maximum level of risk

Figure 7

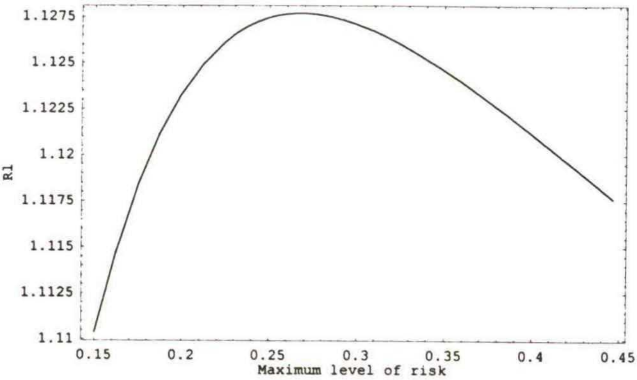


Figure 8

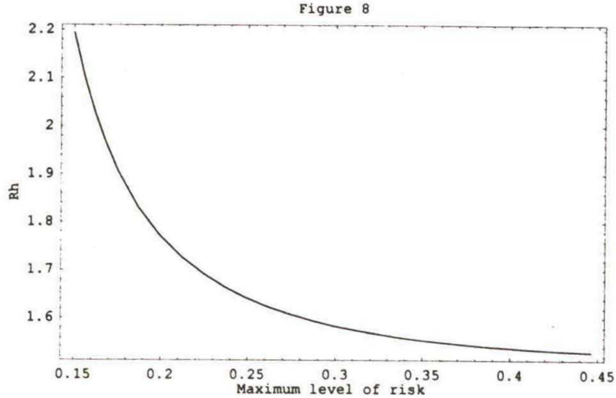


Figure 9

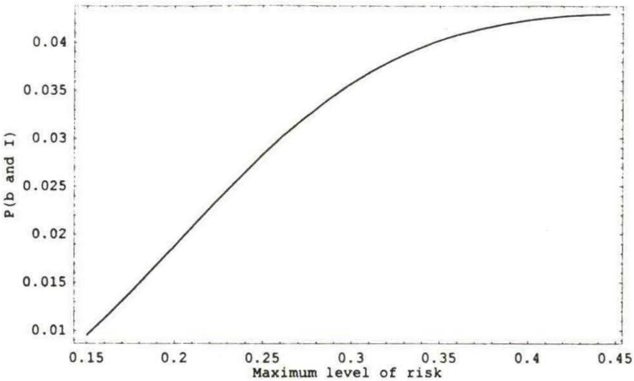


Figure 10

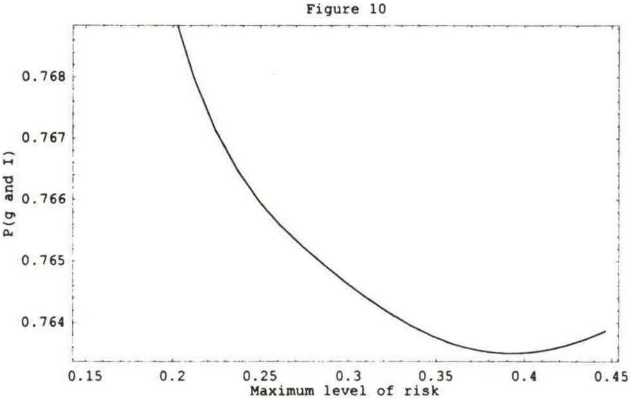
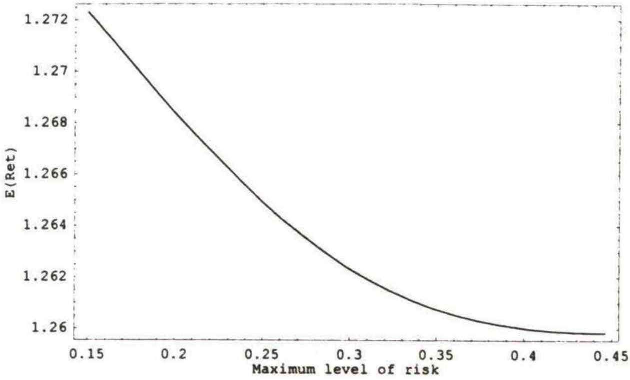


Figure 11



1.272
1.27
1.268
1.266
1.264
1.262
1.26
E(Ret)
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Maximum level of risk

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