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Research Article

Regret Theory and Equilibrium Asset Prices

Jiliang Sheng,[1] Jian Wang,[2] and Jun Yang[3]

[1] *School of Information Technology, Jiangxi University of Finance and Economics, Nanchang 330013, China*
[2] *School of Business Administration, Northeastern University, Shenyang 110819, China*
[3] *School of Business Administration, Acadia University, Wolfville, NS, Canada B4P 2R6*

Correspondence should be addressed to Jun Yang; jun.yang@acadiau.ca

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Regret theory is a behavioral approach to decision making under uncertainty. In this paper we assume that there are two representative investors in a frictionless market, a representative active investor who selects his optimal portfolio based on regret theory and a representative passive investor who invests only in the benchmark portfolio. In a partial equilibrium setting, the objective of the representative active investor is modeled as minimization of the regret about final wealth relative to the benchmark portfolio. In equilibrium this optimal strategy gives rise to a behavioral asset pricing model. We show that the market beta and the benchmark beta that is related to the investor's regret are the determinants of equilibrium asset prices. We also extend our model to a market with multibenchmark portfolios. Empirical tests using stock price data from Shanghai Stock Exchange show strong support to the asset pricing model based on regret theory.

1. Introduction

The traditional asset pricing models that assume investors are homogeneous cannot explain many anomalies in the financial markets such as the equity premium puzzle [1] and the risk-free rate puzzle [2]. They cannot depict the complex behaviors and ignore the diversification of psychology of different investors.

Behavioral asset pricing theories have emerged and grown during the past two decades in part as a reaction to the phenomena described above. Based on the behavioral theories such as Tversky and Kahneman [3] and assuming investors have heterogeneous beliefs, several behavioral asset pricing models have been proposed that revise the investor's utility from different perspectives. For example, Bakshi and Chen [4] care about the investor's relative social status, Constantinides [5], Abel [6] and Campbell and Cochrane [7] consider the habit formation of investors, Barberis et al. [8] focus on investors' loss aversion, while Abel [9] and Gollier [10] explore the envy between investors. Shefrin and Statman [11] derive a behavioral model based on the noise trading theory. In their model, there are two kinds of traders, information traders and noise traders, who interact and affect asset prices. Many of these studies assume that all investors are the same and do not consider the actual investing process of different types of investors. In this study we assume that investors are heterogeneous: there are two kinds of representative investors in a frictionless market, a representative passive investor and a representative active investor. The representative passive investor invests only in the benchmark and the representative active investor selects his own optimal portfolio based on the regret theory.

Regret theory is developed by Bell [12] and Loomes and Sugden [13]. Regret aversion is a well-established psychological theory suggesting that people often have regrets when they see that their decisions turn out to be wrong even if they appeared correct with information available exante. The idea of regret extends naturally to finance by assuming that investors compare their returns with exogenous benchmarks. Clarke et al. [14] argue that investors optimize the tracking error due to regret aversion. Wagner [15] develops an asset selection model assuming the investor's utility is based on the regret theory. The model is labeled as the mean-variance-covariance (EVC) criterion. Dodonova and Khoroshilov [16] present a theoretical model of asset pricing that analyses how the behavior of stock returns is affected by the presence of regret-averse investors in the market. Gollier and Salanié [17] assume that agents are subject to regret and show that regret reduces the equity premium when the macrorisk is positively skewed. In this study we examine the consequences of investors' regret aversion on the optimal decisions under risk, the allocation of risk in the economy, and equilibrium asset prices.

Our paper complements and extends the extant literature of Brennan [18], Gómez and Zapatero [19], Cornell and Roll [20], Cuoco and Kaniel [21], and Brennan et al. [22]. In this paper the objective of the representative active investor is modeled as minimization of regret about final wealth relative to the benchmark portfolio in a partial equilibrium setting. Our research differs from the study of Dodonova and Khoroshilov [16] who focus on the impact on volatility and autocorrelation of stock returns and trading volumes.

The rest of the paper is organized as follows. In Section 2 we present our portfolio selection model based on the regret theory. Equilibrium asset prices are analyzed in Section 3. In Section 4 we extend the pricing model to a market with a riskless asset. We also extend the model to multibenchmark in Section 5. Section 6 offers some empirical tests of the asset pricing model. Concluding remarks and possible future research are collected in Section 7.

2. Portfolio Selection Based on Regret Theory

We assume that P and B are the portfolios of the investor and the benchmark, respectively. The utility of investor is $U(W_P, W_B)$, where W_P and W_B are the final wealth after one period. $U(W_P, W_B)$ is twice continuously differentiable. Generally one can measure regret by the change in utility $U(W_P, W_B)$ with respect to a change in the hypothetical final wealth W_B. According to Bell [12] and Loomes and Sugden [13], we define regret as

$$R = -\frac{\partial U(W_P, W_B)}{\partial W_B} \geq 0. \tag{1}$$

According to the classical setting, utility is assumed to be a strictly increasing and concave function of final wealth W_P; that is,

$$\frac{\partial U(W_P, W_B)}{\partial W_P} > 0, \qquad \frac{\partial^2 U(W_P, W_B)}{\partial W_P^2} < 0. \tag{2}$$

With respect to regret R, we assume that the utility function also obeys the following restriction:

$$\frac{\partial R}{\partial W_P} = -\frac{\partial^2 U(W_P, W_B)}{\partial W_P \partial W_B} \leq 0. \tag{3}$$

We assume that there are n risky assets, no riskless asset (which will be introduced in Sections 4 and 5), and the return of the risky assets is $\tilde{r}_i$ $(i = 1, 2, \ldots, n)$. The representative investor selects his optimal portfolio using the regret theory. We assume that the utility function of the investor is quadratic. Expanding the utility function $U(W_P, W_B)$ as per Taylor series, we get

$$\begin{aligned} E[U(W_P, W_B)] &= U[E(W_P), E(W_B)] \\ &\quad + \frac{1}{2} U''_{W_P W_P}[E(W_P), E(W_B)] \operatorname{Var}(W_P) \\ &\quad + \frac{1}{2} U''_{W_B W_B}[E(W_P), E(W_B)] \operatorname{Var}(W_B) \\ &\quad + \frac{1}{2} U''_{W_P W_B}[E(W_P), E(W_B)] \operatorname{Cov}(W_P, W_B), \end{aligned} \tag{4}$$

where $E(W_B)$ and $\operatorname{Var}(W_B)$ are constants because the benchmark portfolio B is given exogenously. According to Wagner [15], to maximize the utility, the problem that the investor needs to solve is

$$\begin{aligned} \max_{w} \quad & w^T \mu - \frac{1}{2}\tau_1 w^T V w + \tau_2 w^T V w_B \\ \text{s.t.} \quad & w^T I = 1, \end{aligned} \tag{5}$$

where w is the weight vector of risky assets in the portfolio of investor, μ is the vector of expected returns, $\mu = (\bar{r}_1, \bar{r}_2, \ldots \bar{r}_n)$, w_B is the weight vector of risky assets in benchmark portfolio, and τ_1 (> 0) and τ_2 (≥ 0) are the coefficients of absolute risk aversion and regret aversion of the representative investor, respectively. The Lagrange function of (5) is

$$L(w; \lambda) = w^T \mu - \frac{1}{2}\tau_1 w^T V w + \tau_2 w^T V w_B - \lambda \left(w^T I - 1\right), \tag{6}$$

where λ is the Lagrange multiplier. According to the first order condition, we get

$$w = \frac{\tau_2}{\tau_1} w_B + \frac{1}{\tau_1} V^{-1} (\mu - \lambda I). \tag{7}$$

Substituting for w in the constraint condition $w^T I = 1$ from (7), we get

$$\lambda = \frac{\tau_2 - \tau_1}{I^T V^{-1} I} + \frac{\mu^T V^{-1} I}{I^T V^{-1} I}, \tag{8}$$

where $(\mu^T V^{-1} I / I^T V^{-1} I)$ and $I^T V^{-1} I$ are the expected return and variance of the global minimum variance portfolio of risky assets. We use the notation g to represent the global minimum variance portfolio, and $\bar{r}_g$ and $\operatorname{Var}(\tilde{r}_g)$ are its expected return and variance. From (7) and (8), we get

$$w = \frac{\tau_2}{\tau_1} w_B + \frac{1}{\tau_1} V^{-1} \left[\mu - \left(\bar{r}_g + \frac{\tau_2 - \tau_1}{\operatorname{Var}(\tilde{r}_g)}\right) I\right]. \tag{9}$$

Equation (9) shows that in the investor's optimal allocation the weight on the benchmark portfolio increases as his regret aversion increases.

3. Equilibrium Asset Prices

From now on we consider an economy with heterogeneous investors. There are two representative investors in a frictionless market, a representative passive investor and a representative active investor. We assume M is the market portfolio, and w_M is the weight vector of risky assets in the market portfolio. φ ($0 \leq \varphi \leq 1$) is the fraction of the representative passive investor who invests only in the benchmark, and $1-\varphi$ is the fraction of representative active investor who selects his optimal portfolio based on the regret theory. When the market clears, we have

$$w_M = \phi w_B + (1-\phi)\, w. \tag{10}$$

Multiplying both sides by the covariance matrix V and substituting (9) into (10) yield

$$\begin{aligned} V w_M = {} & \left[\phi + \frac{\tau_2}{\tau_1}(1-\phi)\right] V w_B \\ & + \frac{1}{\tau_1}(1-\phi)\left[\mu - \left(\overline{r}_g + \frac{\tau_2 - \tau_1}{\operatorname{Var}(\widetilde{r}_g)}\right)\right] I. \end{aligned} \tag{11}$$

Premultiplying (11) by w_M gives the variance of the market portfolio:

$$\begin{aligned} \operatorname{Var}(\widetilde{r}_M) = {} & \left[\phi + \frac{\tau_2}{\tau_1}(1-\phi)\right] w^T V w_B \\ & + \frac{1}{\tau_1}(1-\phi)\left[\overline{r}_M - \overline{r}_g - \frac{\tau_2 - \tau_1}{\operatorname{Var}(\widetilde{r}_g)}\right]. \end{aligned} \tag{12}$$

Based on Lemma A.1 as in the Appendix, we have

$$\beta_{/M} \operatorname{Var}(\widetilde{r}_M) = V w_M, \qquad \beta_{/M} \operatorname{Var}(\widetilde{r}_B)\, V w_B, \tag{13}$$

where $\beta_{/M}$ and $\beta_{/B}$ are the vectors of individual asset betas with respect to the market portfolio and the benchmark portfolio, respectively, and $\operatorname{Var}(\widetilde{r}_B)$ is the variance of the benchmark return.

Substituting $\operatorname{Var}(\widetilde{r}_M)$ into (13) gives the vector equation that describes the cross-sectional relationship between betas and expected returns:

$$\begin{aligned} & \mu - \left[\overline{r}_g + \frac{\tau_2 - \tau_1}{\operatorname{Var}(\widetilde{r}_g)}\right] I \\ & = \beta_{/M}\left[\overline{r}_M - \overline{r}_g - \frac{\tau_2 - \tau_1}{\operatorname{Var}(\widetilde{r}_g)}\right] + K\left(\beta_{/M}\beta_{M/B} - \beta_{/B}\right), \end{aligned} \tag{14}$$

where $\beta_{M/B} = \operatorname{cov}(\widetilde{r}_M, \widetilde{r}_B)/\operatorname{var}(\widetilde{r}_B)$. The jth entry in the system of (14) is

$$\overline{r}_j - \overline{r}_g - k_0 = \beta_{j/M}\left(\overline{r}_M - \overline{r}_g - k_0\right) + K\left(\beta_{j/M}\beta_{M/B} - \beta_{j/B}\right), \tag{15}$$

where $k_0 = (\tau_2 - \tau_1)/\operatorname{Var}(\widetilde{r}_g)$, $K = (((\tau_1 - \tau_2)\varphi + \tau_2)/(1-\varphi))\operatorname{Var}(\widetilde{r}_B)$, and $\beta_{j/P}$ is the beta for asset j computed against portfolio P.

Equation (15) is the asset pricing model based on regret theory that determines the equilibrium asset prices. From (15) we have the following observations.

(1) In equilibrium two types of risk are priced in the market, the market risk and the benchmark risk. $\beta_{j/M}\beta_{M/B} - \beta_{j/B}$ is the beta for the benchmark risk. By construction it is orthogonal to the market risk, which deals with the fact that the market portfolio and the benchmark portfolio are likely correlated. In this way the two risk factors are independent from each other. The benchmark beta can be positive or negative. Generally speaking $\beta_{j/M}\beta_{M/B} - \beta_{j/B}$ is positive for assets that are more correlated with the market portfolio than with the benchmark.

(2) When the benchmark is the same as the market portfolio, $\beta_{M/B} = 1$ and $K(\beta_{j/M}\beta_{M/B} - \beta_{j/B}) = 0$, then (15) is similar to the traditional CAPM.

(3) Everything else being equal and assuming $\tau_1 > \tau_2$, the more passive investors in the market (i.e., the greater φ), the greater the impact of the benchmark risk (i.e., the greater K). This is because passive investors invest in the benchmark portfolio only.

4. Asset Pricing Model with Riskless Asset

We do not consider a riskless asset in Section 3. With the introduction of a riskless asset in the frictionless market as Section 2, the optimal portfolio selection problem of the investor is

$$\max w^T \mu + \left(1 - w^T I\right) r_f - \frac{1}{2}\lambda_1 w^T V w + \lambda_2 w^T V w_B, \tag{16}$$

where r_f is the return rate of the riskless asset. The first order condition now becomes

$$w = \frac{\tau_2}{\tau_1} w_B + \frac{1}{\tau_1} V^{-1}\left(\mu - r_f I\right). \tag{17}$$

When the market clears we obtain

$$\begin{aligned} w_M & = \varphi w_B + (1-\varphi)\, w \\ & = \left(\phi + \frac{\tau_2}{\tau_1}(1-\phi)\right) w_B + \frac{1}{\tau_1}(1-\phi)\, V^{-1}\left(\mu - r_f I\right). \end{aligned} \tag{18}$$

Similar to (14), we have

$$\mu - r_f I = \beta_{/M}\left(\overline{r}_M - r_f\right) + K\left(\beta_{/M}\beta_{M/B} - \beta_{/B}\right). \tag{19}$$

The jth entry in the system of (19) is

$$\overline{r}_j - r_f = \beta_{j/M}\left(\overline{r}_M - r_f\right) + K\left(\beta_{j/M}\beta_{M/B} - \beta_{j/B}\right). \tag{20}$$

Equation (20) is the asset pricing model based on regret theory when there is a riskless asset in the market. If the market portfolio is same as the benchmark, (20) is the traditional CAPM.

5. Pricing Model with Multi-Benchmark

In Sections 3 and 4 there is only one benchmark in the market. In this section we investigate the situation when the investor's wealth of portfolio is measured against two benchmarks B_1 and B_2. This is common in the investment industry, for instance, when an investment manager is assessed against a market portfolio as well as an internal benchmark (Wang [23]). The utility function of investor $U(W_P, W_{B_1}, W_{B_2})$ is assumed to be a strictly increasing concave function of final wealth W_P:

$$\frac{\partial U\left(W_P, W_{B_1}, W_{B_2}\right)}{\partial W_P} > 0, \qquad \frac{\partial^2 U\left(W_P, W_{B_1}, W_{B_2}\right)}{\partial W_P^2} < 0. \tag{21}$$

We define investor's regret to benchmark B_1 and B_2 as

$$\begin{aligned} R_1 &= -\frac{\partial U\left(W_P, W_{B_1}, W_{B_2}\right)}{\partial W_{B_1}} \geq 0, \\ R_2 &= -\frac{\partial U\left(W_P, W_{B_1}, W_{B_2}\right)}{\partial W_{B_2}} \geq 0. \end{aligned} \tag{22}$$

As the situation with just one benchmark in the market, with respect to regret R_1 and R_2, we assume that the utility function obeys the following restrictions:

$$\begin{aligned} \frac{\partial R_1}{\partial W_P} &= -\frac{\partial^2 U\left(W_P, W_{B_1}, W_{B_2}\right)}{\partial W_P \partial W_{B_1}} \leq 0, \\ \frac{\partial R_2}{\partial W_P} &= -\frac{\partial^2 U\left(W_P, W_{B_1}, W_{B_2}\right)}{\partial W_P \partial W_{B_2}} \leq 0. \end{aligned} \tag{23}$$

Assuming the utility function is quadratic and expanding it in Taylor series, we obtain

$$\begin{aligned} &E\left[U\left(W_P, W_{B_1}, W_{B_2}\right)\right] \\ &\quad = U\left[E\left(W_P\right), E\left(W_{B_1}\right), E\left(W_{B_2}\right)\right] \\ &\qquad + \frac{1}{2} U''_{W_P W_P}\left[E\left(W_P\right), E\left(W_{B_1}\right), E\left(W_{B_2}\right)\right] \operatorname{Var}\left(W_P\right) \\ &\qquad + \frac{1}{2} U''_{W_{B_1} W_{B_1}}\left[E\left(W_P\right), E\left(W_{B_1}\right), E\left(W_{B_2}\right)\right] \operatorname{Var}\left(W_{B_1}\right) \\ &\qquad + \frac{1}{2} U''_{W_{B_2} W_{B_2}}\left[E\left(W_P\right), E\left(W_{B_1}\right), E\left(W_{B_2}\right)\right] \operatorname{Var}\left(W_{B_2}\right) \\ &\qquad + \frac{1}{2} U''_{W_P W_{B_1}}\left[E\left(W_P\right), E\left(W_{B_1}\right), E\left(W_{B_2}\right)\right] \operatorname{Cov}\left(W_P, W_{B_1}\right) \\ &\qquad + \frac{1}{2} U''_{W_P W_{B_2}}\left[E\left(W_P\right), E\left(W_{B_1}\right), E\left(W_{B_2}\right)\right] \operatorname{Cov}\left(W_P, W_{B_2}\right) \\ &\qquad + \frac{1}{2} U''_{W_{B_1} W_{B_2}}\left[E\left(W_P\right), E\left(W_{B_1}\right), E\left(W_{B_2}\right)\right] \operatorname{Cov}\left(W_{B_1}, W_{B_2}\right). \end{aligned} \tag{24}$$

Benchmarks B_1 and B_2 are exogenously given, so $E(W_{B_i})$, $\operatorname{Var}(W_{B_i})$ $(i = 1, 2)$ and $\operatorname{Cov}(W_{B_1}, W_{B_2})$ are constants to investors in their portfolio selection problem.

5.1. Model without Riskless Asset. Similar to the method in Section 2, to maximize his utility, the problem that the active investor needs to solve is

$$\begin{aligned} \max \quad & w^T \mu - \frac{1}{2}\tau_1 w^T V w + \tau_2 w^T V w_{B_1} + \tau_3 w^T V w_{B_2} \\ \text{s.t.} \quad & w^T I = 1, \end{aligned} \tag{25}$$

where w is the weight vector of risky assets in the investor's portfolio, μ is the vector of expect return, w_{B_1} and w_{B_2} are the weight vectors of risky assets in benchmark portfolios B_1 and B_2, respectively, τ_1 (> 0) is the coefficient of absolute risk aversion, and τ_2 (≥ 0) and τ_3 (≥ 0) are the coefficients of regret aversion of the representative investor to benchmark portfolio B_1 and B_2, respectively. The optimal portfolio selection of the investor is

$$w = \frac{\tau_2}{\tau_1} w_{B_1} + \frac{\tau_3}{\tau_1} w_{B_2} + \frac{1}{\tau_1} V^{-1}\left[\mu - \left(\bar{r}_g + \frac{\tau_2 + \tau_3 - \tau_1}{\operatorname{Var}\left(\tilde{r}_g\right)}\right) I\right]. \tag{26}$$

We assume that φ_1 $(0 \leq \varphi_1 \leq 1)$ and φ_2 $(0 \leq \varphi_2 \leq 1)$ are the factions of representative passive investors who only invest in benchmark portfolios B_1 and B_2, respectively. Then $1-\varphi_1-\varphi_2$ is the faction of the representative active investor who selects his own optimal portfolio based on the regret theory. When the market clears, we get

$$\begin{aligned} w_M = &\left[\phi_1 + \frac{\tau_2}{\tau_1}\left(1 - \phi_1 - \phi_2\right)\right] w_{B_1} \\ &+ \left[\phi_2 + \frac{\tau_3}{\tau_1}\left(1 - \phi_1 - \phi_2\right)\right] w_{B_2} \\ &+ \frac{1}{\tau_1}\left(1 - \phi_1\right) V^{-1}\left[\mu - \left(\bar{r}_g + \frac{\tau_2 + \tau_3 - \tau_1}{\operatorname{Var}\left(\tilde{r}_g\right)}\right) I\right]. \end{aligned} \tag{27}$$

Similar to Section 3, the jth entry in the system of (27) is

$$\begin{aligned} \bar{r}_j - \bar{r}_g - k_0 = &\beta_{j/M}\left(\bar{r}_M - \bar{r}_g - k_0\right) \\ &+ K_1\left(\beta_{j/M}\beta_{M/B_1} - \beta_{j/B_1}\right) \\ &+ K_2\left(\beta_{j/M}\beta_{M/B_2} - \beta_{j/B_2}\right), \end{aligned} \tag{28}$$

where

$$\begin{aligned} k_0 &= \frac{\tau_2 + \tau_3 - \tau_1}{\operatorname{Var}\left(\tilde{r}_g\right)}, \\ K_1 &= \frac{\left(\tau_1 - \tau_2\right)\varphi_1 - \tau_2\varphi_2 + \tau_2}{1 - \varphi_1 - \varphi_2} \operatorname{Var}\left(\tilde{r}_{B_1}\right), \\ K_2 &= \frac{\left(\tau_1 - \tau_3\right)\varphi_1 - \tau_3\varphi_1 + \tau_3}{1 - \varphi_1 - \varphi_2} \operatorname{Var}\left(\tilde{r}_{B_2}\right). \end{aligned} \tag{29}$$

The structure of (28) is similar to that of (15), but it has one more risk factor. Besides the market risk, in equilibrium the expected return also depends on two benchmark risks, which, by design, are independent of the market risk.

5.2. Model with Riskless Asset. In Section 5.1 we do not consider a riskless asset, but now we assume there is a riskless asset in the frictionless market, and r_f is its return. The optimal portfolio selection problem is

$$\begin{aligned}\max\, & w^T \mu + \left(1 - w^T I\right) r_f \\ & - \frac{1}{2}\tau_1 w^T V w + \tau_2 w^T V w_{B_1} + \tau_3 w^T V w_{B_2}.\end{aligned} \tag{30}$$

The optimal portfolio of the investor is

$$w = \frac{\tau_2}{\tau_1} w_{B_1} + \frac{\tau_3}{\tau_1} w_{B_2} + \frac{1}{\tau_1} V^{-1}\left(\mu - r_f I\right). \tag{31}$$

When the market clears we obtain

$$\begin{aligned} w_M &= \varphi_1 w_{B_1} + \varphi_2 w_{B_2} + \left(1 - \varphi_1 - \varphi_2\right) w \\ &= \left[\phi_1 + \frac{\tau_2}{\tau_1}\left(1 - \phi_1 - \phi_2\right)\right] w_{B_1} \\ &\quad + \left[\phi_2 + \frac{\tau_2}{\tau_1}\left(1 - \phi_1 - \phi_2\right)\right] w_{B_2} \\ &\quad + \frac{1}{\tau_1}\left(1 - \phi_1\right) V^{-1}\left(\mu - r_f I\right). \end{aligned} \tag{32}$$

Similar to Section 5.1, we have

$$\begin{aligned} \mu - r_f I = \beta_{/M}&\left(\bar{r}_M - r_f\right) \\ &+ K_1\left(\beta_{/M}\beta_{M/B_1} - \beta_{/B_1}\right) \\ &+ K_2\left(\beta_{/M}\beta_{M/B_2} - \beta_{/B_2}\right). \end{aligned} \tag{33}$$

The jth entry in the system of (33) is

$$\begin{aligned} \bar{r}_j - r_f = \beta_{j/M}&\left(\bar{r}_M - r_f\right) \\ &+ K_1\left(\beta_{j/M}\beta_{M/B_1} - \beta_{j/B_1}\right) \\ &+ K_2\left(\beta_{j/M}\beta_{M/B_2} - \beta_{j/B_2}\right). \end{aligned} \tag{34}$$

The structure of (34) is similar to that of (20) but with the inclusion of two benchmark risk factors that are independent of the market risk.

6. Empirical Tests

6.1. Data. We take the Shanghai Stock Exchange (SSE) 180 index as the benchmark portfolio. The SSE Stock Composite Index (CI) weekly return series is taken as the market portfolio return. For the locally risk-free asset, the weekly return series of the three-month Treasury Bill is used. Our sample begins in January 2006 and extends through December 2012.

As for risky assets, we select the 150 stocks in the SSE 180 index without interruption from January 2006 to December 2012. We select this subsample of SSE 180 to avoid the possible price effect associated with changes in the composition of the index. Thus any abnormal return captured in our test cannot be explained by the assets being added or deleted from the benchmark index.

6.2. Methodology. To test the asset pricing model (20), we take a three-step approach as in Brennan et al. [22] and Gómez and Zapatero [19] in the spirit of Fama and MacBeth [24].

First, in order to eliminate the linear dependence of the market portfolio and the benchmark portfolio, we obtain the residual by means of

$$E\left(\tilde{r}_B\right) - r_f = h_0 + h_1\left(E\left(\tilde{r}_M\right) - r_f\right) + e, \tag{35}$$

where $\tilde{r}_M$ and $\tilde{r}_B$ denote the weekly return of the market portfolio and benchmark portfolio, respectively. The residual from regression (35), $\hat{e}$, represents the component of the benchmark that, by construction, is independent of the market portfolio.

Second, we estimate the betas of the market and benchmark portfolio according to

$$E\left(\tilde{r}_j\right) - r_f = \beta_0 + \beta_{j/M}\left(E\left(\tilde{r}_M\right) - r_f\right) + \beta_{j/e}\hat{e} + \varepsilon_j, \tag{36}$$

where $\beta_{j/e}$ represents the benchmark beta that, by construction, is orthogonal to the market beta $\beta_{j/M}$.

Finally, we run a cross-sectional regression of stocks' expected returns on the estimated betas as

$$E\left(\tilde{r}_j\right) - r_f = \lambda_0 + \lambda_1\hat{\beta}_{j/M} + \lambda_2\hat{\beta}_{j/e} + \eta_j. \tag{37}$$

According to the regret theory, the benchmark risk should be priced in equilibrium stock prices. So we expect λ_2 to be significant.

Following the methodology in Gómez and Zapatero [19], the 150 stocks in SSE 180 index are sorted into 10 portfolios according to their estimated market index beta. We summarize the empirical results of (37) in Table 1.

6.3. Empirical Results. As we can see in Table 1, λ_2 is highly significant for all the portfolios, which supports the prediction of the asset pricing models based on regret theory. When the benchmark risk is taken into account, the market risk, as measured by λ_1, is no longer significant (with the exception of panel 1). This result is consistent with the findings in Chen et al. [25], Wen and Yang [26], Wu [27], and Morelli [28], who report that in Chinese stock markets the market risk is often not priced when other risks (e.g., size, value, liquidity, and skewness) are also considered.

Shanghai stock market displays some unique characteristics compared to stock markets in many developed countries. Among the over 900 stocks listed at SSE, the SSE 180 Index includes the top companies ranked by market capitalization and trading volume in all ten major industries. As industry leaders, the SSE 180 companies have experienced tremendous growth since the index was established in July 2002. According a report from SSE (http://www.sse.com.cn/market/sseindex/bluechips/introduction/), during the period 2006–2010 SSE 180 index experienced an average annual growth rate of 24.64%, higher than the annual return of 19.32% for the SSE Composite Index. At the year end of 2010, SSE 180 has an average P/E ratio of 18.23, compared to 21.61 for SSE CI. This risk and return profile of SSE 180 index is in contrast to

Table 1: Regression results.

	λ_0	λ_1	λ_2	R^2
Panel 1	0.021	−0.521	1.268	
t statistics	1.936	−2.219	5.273	0.536
P-value	0.058	0.030	0.000	
Panel 2	−0.002	−0.259	1.261	
t statistics	−0.213	−1.528	7.263	0.780
P-value	0.832	0.132	0.000	
Panel 3	0.006	−0.254	1.294	
t statistics	0.766	−1.553	7.731	0.804
P-value	0.447	0.126	0.000	
Panel 4	0.002	−0.188	1.246	
t statistics	0.285	−1.054	6.835	0.780
P-value	0.777	0.296	0.000	
Panel 5	0.017	0.110	0.998	
t statistics	1.700	0.510	4.517	0.717
P-value	0.0942	0.669	0.000	
Panel 6	0.002	−0.094	1.237	
t statistics	0.191	−0.410	5.292	0.713
P-value	0.849	0.683	0.000	
Panel 7	−0.000	−0.097	1.243	
t statistics	−0.090	−0.514	6.440	0.785
P-value	0.929	0.609	0.000	
Panel 8	0.005	−0.125	1.267	
t statistics	0.535	−0.634	6.258	0.767
P-value	0.595	0.528	0.000	
Panel 9	−0.000	−0.108	1.334	
t statistics	−0.054	−0.592	7.125	0.816
P-value	0.957	0.560	0.000	
Panel 10	−0.000	−0.023	1.267	
t statistics	−0.089	−0.112	5.929	0.776
P-value	0.930	0.911	0.000	

that of stock market indexes in many developed economies. For instance, S&P 500 companies, also as industry leaders as SSE 180 companies, earn a slightly lower average return than the overall market performance (Brennan et al. [22]). This is because S&P 500 companies are usually large and relatively mature, therefore, are generally deemed as safe investments by investors. Moreover, their stocks have stable demand from index investors, who are willing to accept them in their portfolio despite their lower returns. Due to the relatively larger fraction of individual investors in SSE, its trading has displayed a somewhat high degree of speculative behaviors such as chasing new and small companies with the focus on short-term returns (see Kong [29], a research report sponsored by SSE, and Huang et al. [30]). The empirical results in this study suggest that the benchmark risk is the primary determinant of stock returns at SSE, and this risk factor is independent of the market risk.

7. Conclusion

We assume that there are two investors, a representative passive investor and a representative active investor in a frictionless market. The representative passive investor invests in the benchmark portfolio only and the representative active investor selects his optimal portfolio based on the regret theory. We establish a behavioral asset pricing model when the market clears. The model suggests that the benchmark risk and the market risk are the determinants of capital asset equilibrium returns. The coefficients of absolute risk aversion and regret aversion of the representative investor can affect asset prices. We extend the asset pricing model to situations with a riskless asset and with multiple benchmarks. We test the model with stock price data from Shanghai Stock Exchange. The empirical results show strong support to the asset pricing model based on the regret theory.

Other equilibrium effects (such as on trading volume and price volatility) according to the regret theory are left for future research. It may also be of interest to investigate the impact of some risk constraint (e.g., VaR).

Appendix

Lemma A.1. *Assuming $\beta_{/P}$ is the vector of individual asset betas in portfolio P; that is, the jth element of $\beta_{/P}$ is* $\operatorname{cov}(\tilde{r}_j, \tilde{r}_P)/\operatorname{Var}(\tilde{r}_P)$ *for individual asset j, we have* $\beta_{/P}\operatorname{Var}(\tilde{r}_P) = Vw_P$.

Proof. we assume $w_P = (w_1, w_2, \ldots, w_n)^T$ is the weight vector of risky assets in portfolio P, the interest rate of risky asset i is $\tilde{r}_i$ $(i = 1, 2, \ldots, n)$, and then $\tilde{r}_P = w_1\tilde{r}_1 + w_2\tilde{r}_2 + \cdots + w_n\tilde{r}_n$.

The covariance of $\tilde{r}_j$ and $\tilde{r}_P$ is

$$\begin{aligned}\operatorname{cov}\left(\tilde{r}_j, \tilde{r}_P\right) &= \operatorname{cov}\left(\tilde{r}_j, w_1\tilde{r}_1 + w_2\tilde{r}_2 + \cdots + w_n\tilde{r}_n\right)\\ &= w_1\operatorname{cov}\left(\tilde{r}_j, \tilde{r}_1\right) + w_2\operatorname{cov}\left(\tilde{r}_j, \tilde{r}_2\right)\\ &\quad + \cdots + w_n\operatorname{cov}\left(\tilde{r}_j, \tilde{r}_n\right).\end{aligned} \tag{A.1}$$

The covariance matrix of portfolio P multiplied by the vector of w_P is

$$Vw_P = \begin{pmatrix}\operatorname{cov}(\tilde{r}_1, \tilde{r}_1) & \operatorname{cov}(\tilde{r}_1, \tilde{r}_2) & \cdots & \operatorname{cov}(\tilde{r}_1, \tilde{r}_n)\\ \vdots & \vdots & \vdots & \vdots\\ \operatorname{cov}(\tilde{r}_j, \tilde{r}_1) & \operatorname{cov}(\tilde{r}_j, \tilde{r}_2) & \cdots & \operatorname{cov}(\tilde{r}_j, \tilde{r}_n)\\ \vdots & \vdots & \vdots & \vdots\\ \operatorname{cov}(\tilde{r}_n, \tilde{r}_1) & \operatorname{cov}(\tilde{r}_n, \tilde{r}_2) & \cdots & \operatorname{cov}(\tilde{r}_n, \tilde{r}_n)\end{pmatrix}\begin{pmatrix}w_1\\ w_2\\ \vdots\\ \vdots\\ w_n\end{pmatrix}. \tag{A.2}$$

The jth element of Vw_P is

$$\begin{aligned}&w_1\operatorname{cov}\left(\tilde{r}_j, \tilde{r}_1\right) + w_2\operatorname{cov}\left(\tilde{r}_j, \tilde{r}_2\right) + \cdots + w_n\operatorname{cov}\left(\tilde{r}_j, \tilde{r}_n\right)\\ &\quad = \operatorname{cov}\left(\tilde{r}_j, \tilde{r}_P\right),\end{aligned} \tag{A.3}$$

so $\operatorname{cov}(\tilde{r}_j, \tilde{r}_P) = \beta_{j/P} \operatorname{Var}(\tilde{r}_P)$, that is, Vw_P is the vector of covariance between the portfolio P and individual assets. From the assumptions in Lemma A.1, we have $\beta_{/P} \operatorname{Var}(\tilde{r}_P) = Vw_P$. □

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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