

Applications of Regret Theory to Asset Pricing

Anna Dodonova*

Henry B. Tippie College of Business, University of Iowa

Iowa City, Iowa 52242-1000

Tel.: +1-319-337-9958

E-mail address: anna-dodonova@uiowa.edu

This paper presents a theoretical model of asset pricing that analyses how the behavior of stock returns is affected by the presence of regret averse investors on the market. Regret aversion is a well established psychological theory that suggests that some people have regrets when they see that their decisions turn out to be wrong even if they appeared correct with information available ex-ante. The idea of regret extends naturally to finance by assuming that investors compare their returns with exogenous benchmarks. Using this assumption, the model predicts that the market will over-react on good or bad news, so that there will be an excess volatility of stock returns. It also helps to explain such well-established empirical puzzles as the positive short-run and negative long-run autocorrelation of stock returns and it predicts a positive correlation between future trading volume and the dispersion of the realized stock returns. In addition to that, the framework developed in this paper helps to analyze how an improvement of stock market accessibility for non-professional traders affects the predictability of stock returns. Using recent stock market data the second part of the paper provides an empirical analysis of some of the model's implications.

* I am especially grateful to Roger Gordon for his advice and numerous detailed comments. I also thank Sugato Bhattacharyya, Michael Brennan, Colin Camerer, Joshua Coval, James Hines, David Hirshleifer, George Loewenstein, Tyler Shumway, Richard Thaler, and participants of the SIRIF Conference in Behavioral Finance, Edinburgh 2001 and Summer Institute on Behavioral Economics, Berkeley 2002 for helpful discussions.

Until recently the main assumptions economists made about people's preferences have had their roots in the principles postulated by von Neumann and Morgenstern (1947). These axioms are believed to represent the basis for rational choice under uncertainty. However, there are a number of economic, financial, and experimental data that are not consistent with the rational agent hypothesis. The high mean and volatility of stock returns (Mehra and Prescott (1995)), the positive short-run correlation of stock returns (Jegadeesh and Titman (1993), Conrad and Kaul (1988, 1989)), and the negative long-run correlation of stock returns (De Bond and Thaler (1985, 1987), Fama and French (1988), Poterba and Summers (1988)) are among the puzzles that can not be explained by any existing asset pricing model with fully rational investors.

In order to explain these puzzles a number of researchers try to incorporate ideas from psychology into asset pricing models. The majority of these models assume some kind of irrationality in people's behavior (e.g. overconfidence). Another approach that assumes that people are rational but care not only about their consumption lies in between the two extreme approaches of traditional consumption-based asset pricing models and models involving some irrationality in people's behavior. Prospect theory, proposed by Kahneman and Tversky (1979) is probably the best-known representative of this approach. Regret theory, independently proposed by Bell (1982) and Loomes and Sugden (1982), is another psychological model that considers rational agents whose concerns are not limited to their payoffs. Both prospect and regret theories were used to explain numerous evidences of violations of the expected utility theory axioms documented by

Kahneman and Tversky (1979). Even though these two theories describe two different well documented behavioral biases they both assume that a person compares his well-being (consumption, wealth, portfolio return, etc.) with some benchmark. Prospect theory assumes that this benchmark is defined by the past¹ while in regret theory this benchmark is not fixed *ex-ante* but rather depends on the future state of the world. So, the main assumption of regret theory is that people after making their decisions under uncertainty may have regrets if their decisions turn out to be wrong even if they appeared correct with information available *ex ante*. This very intuitive assumption implies that person's utility function among other things should depend on the realization of not chosen, and in this sense irrelevant, alternatives. That is why I believe that regret theory is very appropriate to the analysis of investors' behavior. Indeed, in reality, an investor may observe not only his own portfolio performance but also returns on other stocks or portfolios in which he was able to invest but decided not to. So, it seems very natural to assume that the investor may feel joy/disappointment if his own portfolio outperformed/underperformed some benchmark portfolio or portfolios. This paper is aimed to analyze how possible regrets affect investors' portfolio decisions and, thus, the behavior of stock returns.

In the rest of the introduction I make a comparison between prospect and regret theories, review the existing papers that apply the results of prospect theory to asset pricing, and provide the basic intuition for my model. In Part 2 of this paper I present a theoretical model of asset pricing based on the assumption that some investors may be regret averse and discuss its empirical implications. To test whether the model is indeed a good model

¹ Prospect theory assumes that a person's utility depends on his gains/losses in comparison with his wealth

of investors' behavior, in Part 3 of the paper I provide an empirical analysis of some of the model's implications. In Part 4 I conclude.

Before I come to the explaining of the underlying intuition for my model it is important to show how regret theory differs from prospect theory and how these differences may help us to say something new about the stock market behavior.

In contrast to the expected utility theory, prospect theory assumes that people's utility is defined over their gains or losses in comparison with some reference point and not over the value of their final assets. It also assumes that people's utility from gain w is lower than their disutility from the same loss w and that people are risk-averse over gains and risk-loving over losses. In addition to these loss aversion assumptions, prospect theory assumes that people tend to overweight low probabilities and underweight high probabilities.

In its turn, regret theory assumes that people's utility depends on their wealth (in the same way as conventional expected utility theory does). However, it also takes into account the fact that people may have regrets when their decisions turn out to be the wrong even if they appeared correct at the time they were made. So, as I have already mentioned, this assumption implies that person's utility function among other things should depend on the realization of not chosen, and in this sense irrelevant, alternatives.

Decision regret can be illustrated by a simple example. Assume that a person has a choice between lotteries L_1 and L_2 . Lottery L_1 gives him \$2 if the result of a fair coin toss is “heads” and \$0 if it is “tails”. Lottery L_2 gives a certain payoff of \$1. Regret theory predicts that if the person chooses lottery L_2 (a certain payoff of \$1), he receives higher utility when the result of the coin toss is “tails” than when it is “heads”. Prospect theory, however, does not distinguish these two alternatives since the reference point in prospect theory does not depend on the future realization of irrelevant (not chosen) alternatives.

Similar example deals with the stock market. Assume that a regret averse investor chooses to invest in S&P 500 and gets 9% return. In this case he feels better about his investment decision if he knows that during the same period NASDAQ (that was another investment possibility) gave 4% than if he knows that NASDAQ gave 15%.

There are several papers that try to explain the puzzling behavior of asset prices using the results of prospect theory. Benartzi and Thaler (1995) use the ideas of prospect theory to explain the equity premium puzzle. They consider long-term investors who myopically evaluate their portfolios and make myopic decisions from time to time. Using simulations, they find that if investors evaluate their portfolios annually then the size of the equity premium is consistent with estimated parameters of prospect theory.

Barberis, Huang, and Santos in their 1999 paper “Prospect Theory and Asset Prices” continue to pursue this prospect theory approach. Their theory is based on the standard Lucas asset-pricing model (1978) and incorporates the ideas of prospect theory and the evidence of Thaler and Johnson (1990) on the influence of prior gains or losses on risky choice. They construct a model with only one risky asset that helps to explain the high

mean, volatility, and long-run negative correlation of aggregate market returns. This approach, however, fails to say anything about the behavior of individual stock returns. This happens because prospect theory does not distinguish sources of gains and losses. Thus, a change in an agent's risk aversion has the same effect on the price of any particular security. So, for example, if the whole market performed well then the model of Barberis, Huang, and Santos (1999) predicts a decrease in an agent's risk aversion and an increase in prices of all securities (even of those that performed poorly).

To be able to say anything about individual stock returns prospect theory should be augmented with a theory of mental accounting. An attempt to build such a theory was made by Barberis and Huang (2000). They propose a model that tries to explain the high mean, volatility, and negative long-run correlation of returns on an individual asset. In addition to the assumptions about investors' behavior made by Barberis, Huang, and Santos (1999), they adopt the idea of the "separate mental accounting" (Thaler [1985]). Barberis and Huang (2000) assume that an investor values each stock return separately. In particular, they allow the possibility for the investor to have different risk aversion while he invests in different stocks at the same time. This paper makes an important step in the right direction. It recognizes that people implicitly keep track of different transactions in different mental accounts and that any theory that does not take this fact into account is incomplete².

In reality by the time investors evaluate their portfolio performances they already have information about the performance of every stock traded on the market and are able to

make a comparison between their portfolio performance and the performance of any other hypothetical portfolio. So, the benchmark with which they compare their returns is not fixed *ex ante* and there is a lot of room for regret since it is reasonable to assume that an investor feels the worse the larger the difference between his portfolio return and the best *ex post* return he could have received if he made a different investment decision. These effects of the cross sectional distribution of returns on the people's utility cannot be captured by prospect theory³ but are taken into account by regret theory.

This paper presents a new approach to the problem of explaining the high mean, volatility, and time series correlation of stock returns based on the ideas of regret theory.

The intuition behind my model is the following:

Assume that some asset performs well at $t=1$ and that an investor initially did not invest much in it. The situation that delivers him maximum regrets is the one in which at $t=2$ the asset performs well again since in this case he missed the "right" stock two times in a row. To insure himself against this situation, the investor has an incentive to purchase more of this first-period-good asset right after he gets news about it. This incentive leads to the upward shift of the aggregate demand function for that asset and, therefore, to the higher price for it at $t=1$. Thus, possible regrets lead to more volatile prices in comparison with the results produced by the standard CAPM model. If combined with people's risk aversion, higher price volatility leads to the larger equity premium.

² See Dodonova (2002) who also uses the ideas of prospect theory and mental accounting in the context of portfolio choice, portfolio management and asset pricing.

³ Prospect theory assumes that a person's utility depends only on changes of his wealth, i.e., it depends only on his portfolio return and not on the performance of each particular asset (so, in this sense prospect theory does not distinguish the sources of gains or losses)

Moreover, such an overpricing of the asset that performed well leads to the negative long-run correlation of stock returns. The positive short-run correlation comes from the fact that initially the market does not know how regret-averse investors are or how many of regret averse investors are on the market. This uncertainty produces an additional risk, and, therefore, risk-averse investors who does not suffer from regret aversion bias demand an additional risk premium in the short run⁴.

2 Model

Assume that investors live during 3 periods only. Denote these periods as $t=0$, $t=1$, and $t=2$. There are 2 risky securities. Each risky security is a share of a firm whose value of the assets in place is \$1. Without loss of generality, we can assume that the supply of each security is exogenous and equal to 1. Each firm in periods $t=1$ and $t=2$ generates profits of D or $-D$ with equal probabilities. Each firm is liquidated at time $t=2$ with liquidation value of \$1. The profits are perfectly negatively correlated across firms at each time period⁵ and independent across time. All profits and the liquidation value are paid at $t=2$. The risk-free interest rate is zero.

There are 2 types of investors: active investors and passive investors. Active investors invest in stocks to earn money, they trade frequently and they are completely rational with an increasing concave utility function $u_a(c)$ of their consumption at $t=2$. Passive investors consider stocks as an instrument of saving and trade only if they feel that they

⁴ This intuition will become more clear after the model it stated.

made a wrong portfolio allocation decision in the past. In addition passive investors care not only about their consumption but also about the fact that they may feel regrets if their investment decisions turn out to be the wrong ones *ex post*. Their utility function is given by

$$u_p(c) = \alpha u_a(c) - (1 - \alpha) \nu(\max\{1 + \pi_{1,1} + \pi_{1,2}, 1 + \pi_{2,1} + \pi_{2,2}\} - c)$$

where $\pi_{i,j}$ is the profit of firm i at time $t = j$; ν is an increasing convex function that measures investor's regrets (so that passive investors are risk-averse in regrets⁶); and α is a random variable between zero and one⁷. Here, I compare a person's payoff c with the maximum payoff he could have received if at $t=0$ he invested all his wealth in the best *ex post* security⁸ and did not change his portfolio at $t=1$. This assumption can be justified in the following way: The investor compares his portfolio return with the maximum possible return he could have had if at $t=0$ he made the best *ex post* investment decision. Thus, the investor considers the possibility of trade at $t=1$ as a possibility to correct his investment mistakes made at $t=0$ and not as a possibility to reallocate his portfolio in order to receive additional gains. Since he compares his return with the "best return" (return that he could have received if at $t=0$ he made the best *ex post* decision), he does not consider the possibility of portfolio reallocation at $t=1$ as the possibility to beat the

⁵ The qualitative results of the model will be the same for any correlation between profits. I assume perfectly negative correlation just to simplify the algebra because this assumption allows me to get rid of the wealth effect and allow interest rate to be equal to 0 (exogenous).

⁶ See Bell (1982) and Bell (1983) for arguments in favor of risk-aversion in regrets.

⁷ The results of the model will be the same if we assume that α is constant (i.e. the degree of regret aversion is known) but the number of regret-averse investors who decide to trade on the stock market is random. Furthermore, the "long-run" results of the model do not require such an assumption at all.

⁸ The qualitative results of the model will be the same for any endogenous benchmark portfolio that gives different weights to the best and the worst *ex post* portfolios.

“best return”. Since passive investors consider stocks only as a method of savings, I do not allow them to make short sales and to buy or sell options. I also assume that when passive investors make their investment decisions at $t=0$ they do not realize that they are regret averse⁹.

Assume that both active and passive investors have an equal initial wealth of \$1 and let the number of investors of each type (active and passive) be normalized to 1.

Consider the following sequence of events:

- 1) At $t=0$ trade takes place at the market. At this time the price of each asset is $p_{i,0} = 1$ and all investors put $\frac{1}{2}$ of their wealth in asset 1 and $\frac{1}{2}$ of their wealth in the second asset¹⁰.
- 2) At $t=1$ each firm i generates profit $\pi_{i,1}$. Investors observe these profits and trade takes place. However, only active investors trade at the market at this time.
- 3) At $t = 1 + \varepsilon$ regret aversion parameter α of passive investors is realized. Trade takes place. Both active and passive investors trade at the market.
- 4) At $t=2$ each firm i generates profit $\pi_{i,2}$. Then both firms are liquidated and the entire value of the firm i , equal to $(1 + \pi_{i,1} + \pi_{i,2})$, is paid to its shareholders.

Consider how stock prices at $t=1$ and at $t = 1 + \varepsilon$ react on the realized profits $\pi_{1,1} = D$ and $\pi_{2,1} = -D$ (i.e., good news about firm #1 and bad news about firm #2).

⁹ This assumption is needed only to simplify algebra and to have that initially all investors hold identical portfolios. This assumption does not affect the qualitative results.

¹⁰ This is so since there is no systematic risk in the model and the expected terminal payoff is 1.

If all investors are rational, then at $t=1$ and at $t=1+\varepsilon$ prices are the same. These prices can be found from the following three equations:

Investors maximize their objective function:

$$\left\{ \begin{array}{l} \max_{\gamma} E \left\{ u_a \left(\frac{\gamma w}{P_{1,1+\varepsilon}^{rat}} (1 + D + \pi_{1,2}) + \frac{(1-\gamma)w}{P_{2,1+\varepsilon}^{rat}} (1 - D + \pi_{2,2}) \right) \right\} \\ s.t. : w = P_{1,1+\varepsilon}^{rat} + P_{2,1+\varepsilon}^{rat} \end{array} \right\} \quad (1)$$

equilibrium condition for investors' portfolio allocation (share of investors' wealth invested in the first asset):

$$\gamma = \frac{P_{1,1+\varepsilon}^{rat}}{P_{1,1+\varepsilon}^{rat} + P_{2,1+\varepsilon}^{rat}}; \quad (2)$$

and equilibrium (no arbitrage) condition:

$$P_{1,1+\varepsilon}^{rat} + P_{2,1+\varepsilon}^{rat} = 2. \quad (3)$$

The first order condition of investors' maximization problem (1) together with the distribution of $\pi_{i,2}$ and no-arbitrage condition (3) is given by:

$$\begin{aligned} & \left(\frac{1+2D}{P_{1,1+\varepsilon}^{rat}} - \frac{1-2D}{P_{2,1+\varepsilon}^{rat}} \right) \cdot u'_a \left(\frac{\gamma}{P_{1,1+\varepsilon}^{rat}} (1+2D) + \frac{1-\gamma}{P_{2,1+\varepsilon}^{rat}} (1-2D) \right) + \\ & + \left(\frac{1}{P_{1,1+\varepsilon}^{rat}} - \frac{1}{P_{2,1+\varepsilon}^{rat}} \right) \cdot u'_a \left(\frac{\gamma}{P_{1,1+\varepsilon}^{rat}} + \frac{1-\gamma}{P_{2,1+\varepsilon}^{rat}} \right) = 0 \end{aligned} \quad (4)$$

Substitution of (2) and (3) into (4) allows me to receive:

$$\left(\frac{2+2D}{P_{1,1+\varepsilon}^{rat}} - \frac{2-2D}{P_{2,1+\varepsilon}^{rat}} \right) \cdot u'_a \left(\frac{2}{P_{1,1+\varepsilon}^{rat} + P_{2,1+\varepsilon}^{rat}} \right) = 0 \quad (5)$$

and in combination with $p_{1,1+\varepsilon}^{rat} + p_{2,1+\varepsilon}^{rat} = 2$ equation (5) implies that stock prices under the assumption of rational behavior are given by (6) and (7):

$$p_{1,1+\varepsilon}^{rat} = 1 + D \quad (6)$$

$$p_{2,1+\varepsilon}^{rat} = 1 - D \quad (7)$$

Now, consider the case in which there are regret-averse investors on the market.

In this case stock prices are going to be different from (6) and (7).

I want to find qualitative characteristics of stock prices at $t = 1 + \varepsilon$. To do that, assume that prices at $t = 1 + \varepsilon$ are equal to the prices derived under the assumption that all investors are rational. That is, assume that $p_{1,1+\varepsilon} = p_{1,1+\varepsilon}^{rat} = 1 + D$ and $p_{2,1+\varepsilon} = p_{2,1+\varepsilon}^{rat} = 1 - D$ and find how regret-averse and rational investors would behave if they observe these prices.

As it was shown above, if $p_{1,1+\varepsilon} = 1 + D$ and $p_{2,1+\varepsilon} = 1 - D$, then at time $t = 1 + \varepsilon$ rational investors invest $\$ \frac{1+D}{2}$ in asset #1 and $\$ \frac{1-D}{2}$ in asset #2. In an equilibrium the total investment in firm i should be equal to $p_{i,1+\varepsilon}$, regret-averse investors should also invest

$\$ \frac{1+D}{2}$ in asset #1 and $\$ \frac{1-D}{2}$ in asset #2.

The expected utility of passive (regret-averse) investor is given by

$$U_p(\gamma_p) = \max_{\gamma_p} E\{\alpha u_a(c) - (1-\alpha)v(\max\{1+D+\pi_{1,2}, 1-D+\pi_{2,2}\}-c)\} \quad (8)$$

$$\text{where } c = \frac{\gamma_p}{1+D}(1+D+\pi_{1,2}) + \frac{1-\gamma_p}{1-D}(1-D+\pi_{2,2})$$

Using the distribution of $\pi_{i,2}$, assumptions that $p_{1,1+\varepsilon} = 1+D$ and $p_{1,1+\varepsilon} = 1-D$,

equilibrium condition $\gamma_p = \frac{1+D}{2}$, and the fact that $\gamma_p = \frac{1+D}{2}$ maximizes $u_a(c)$, one

can receive:

$$\frac{\partial U_p(\gamma_p)}{\partial \gamma_p} = \frac{1-\alpha}{2} \left(\frac{1}{1-D} - \frac{1}{1+D} \right) \cdot (v'(2D) - v'(0)) > 0 \quad (9)$$

Therefore, at these prices, regret-averse investors have incentives to invest more in asset #1 and the total investment in asset #1 is larger than $p_{1,1+\varepsilon}$. Since investment in asset #1 depends negatively on $p_{1,1+\varepsilon}$ and positively on $p_{2,1+\varepsilon}$ and in the equilibrium the total investment in asset #1 should be equal to $p_{1,1+\varepsilon}$ one may conclude that it should be the case that:

$$p_{1,1+\varepsilon} > p_{1,1+\varepsilon}^{rat} = 1+D \quad (10)$$

and

$$p_{2,1+\varepsilon} < p_{2,1+\varepsilon}^{rat} = 1-D. \quad (11)$$

Note, that prices $p_{1,1+\varepsilon}$ and $p_{2,1+\varepsilon}$ are random and depend on the realization of the parameter of regret aversion α . Moreover, in the equilibrium regret-averse (passive) investors allocate more of their wealth in the asset that performed well in the past than rational (active) investors do.

Now, consider time period $t=1$. At $t=1$ only active (rational) investors trade on the market. They know, however, that at $t=1+\varepsilon$ prices are going to be $p_{1,1+\varepsilon} > p_{1,1+\varepsilon}^{rat} = 1+D$ and $p_{2,1+\varepsilon} < p_{2,1+\varepsilon}^{rat} = 1-D$. Therefore, at $t=1$ prices differ from rational prices and satisfy equations (12) and (13):

$$p_{1,1} > p_{1,1}^{rat} = 1+D \quad (12)$$

$$p_{2,1} < p_{2,1}^{rat} = 1-D. \quad (13)$$

So, the model predicts that the market will overreact on good or bad news and, as a result, the model predicts excess price volatility (in particular, asset prices are more volatile than the present value of the underlying firm's future profits). In combination with investors' risk aversion, excess price volatility leads to the larger expected returns. Thus, we have the following result:

Proposition 1:

In the presence of regret-averse investors on the market the volatility of stock prices is higher than the volatility of the underlying business characteristics of the firms (such as

future expected profits) and expected stock returns are higher¹¹ than they would be in a market populated only by risk-averse rational investors.

While trading at $t=1$, active investors take $t = 1 + \varepsilon$ prices into account and try to make a profit out of these price differences. However, prices at $t = 1 + \varepsilon$ are random, so, risk-averse investors demand a risk premium. More precisely, active investors want to maximize their expected utility at $t=2$. Thus, the more stock prices at $t = 1 + \varepsilon$ differ from the rational prices, the higher utility they have. Since prices at $t = 1 + \varepsilon$ are random, rational investors want to insure themselves against the situation in which stock prices are close to the rational prices. As a result, they would tend to buy more of asset #2 (the one that performed poorly) and less of asset #1 (the one that performed well) even if it may give them negative expected profits between periods $t=1$ and $t = 1 + \varepsilon$. This is so because such a strategy will give them more wealth in the “bad” state of the world (i.e. when stock prices are close to the rational prices). Therefore, prices at $t=1$ should satisfy (14) and (15):

$$p_{1,1} < Ep_{1,1+\varepsilon} \tag{14}$$

$$p_{2,1} > Ep_{2,1+\varepsilon} \tag{15}$$

Note, that past performance gives no information about future performance, therefore, expected prices at $t=2$ (given that $\pi_{1,1} = D$ and $\pi_{2,1} = -D$) should satisfy (16) and (17):

¹¹ Although in my model the expected return is zero (because all risk are diversifiable), a slight modification of the model that will allow for non-zero systematic risk will result in high expected return.

$$Ep_{1,2} = 1 + D \quad (16)$$

$$Ep_{2,2} = 1 - D \quad (17)$$

Equations (10), (14), and (16) imply that if asset #1 performed well in the past then $p_{1,1} < Ep_{1,1+\varepsilon}$ and $p_{1,1} > Ep_{1,2}$. Therefore, the expected short-run return on asset #1 is positive and its expected long-run return is negative. Equations (11), (15) and (17) imply that if asset #2 performed poorly in the past then $p_{2,1} > Ep_{2,1+\varepsilon}$ and $p_{2,1} < Ep_{2,2}$, i.e., expected short-run return on asset #2 is negative and its expected long-run return is positive. Thus, we have the following result:

Proposition 2:

In the presence of regret-averse investors on the market stock prices should experience a negative long-run correlation. If, in addition, the degree of investors' regret-aversion or the number of regret-averse investors on the market is not known until trade takes place, then stock prices should experience positive short-run correlation.

Another important implication of the model can be found if we look at the difference in the trading patterns of rational and regret-averse investors. Regret-averse investors try to insure themselves against possible risk associated with regrets. As a result, they tend to buy assets that performed well in the past and to sell those that performed poorly. Since total asset supply is fixed, rational investors should behave in the opposite way and the trade takes place between regret-averse and rational investors. Therefore, if the

dispersion of the realized asset returns in the past was large, then one can expect high trading volume today. Thus, we may state the following result:

Proposition 3:

In the presence of regret-averse investors on the market there exists a positive correlation between future market trading volume and the dispersion of the realized stock returns.

One more way to think about stock market participants is to divide them into two groups: professional traders (who derive the main part of their income out of the stock market trading) and non-professional traders (who consider stock market as an instrument of saving and whose wealth is primarily derived from their labor income). In the framework of my model I may assume that professional traders are rational while non-professional traders are regret-averse. It is also seems plausible that professional traders trade more frequently. This framework allows me to analyze how recent changes of the market trading accessibility (like on-line brokerage) affect stock prices. There are two ways in which an increase of the market trading accessibility affects the trading by non-professionals. First, it increases the number of non-professionals on the market and the capital that they invest. Second, it allows non-professionals to trade more frequently. In the framework of my model one can predict, that an increase in the amount of the capital invested by non-professionals leads to an even more severe overreaction on good/bad news, and, thus, to an even higher volatility and mean of returns. Such an overreaction will increase the long-run negative correlation of stock returns even more. The easier and faster market access provided by on-line trading allows some of the regret-averse investors to trade immediately after the arrival of news. In the framework of my model

this can be captured by allowing some of the regret-averse investors to trade at time $t=1$ instead of $t=1+\varepsilon$. Such a modification will decrease the difference between stock prices at $t=1$ and $t=1+\varepsilon$, i.e. it will decrease the positive short-run correlation of stock returns. Since on-line trading has a much greater effect on the “same-day” access to the market than it has on the “next-day” access, the model predicts the larger effect of the better on-line trading accessibility on the autocorrelation of the daily returns than on the autocorrelation of weekly or monthly returns. The discussion above can be summarized in the following result:

Proposition 4:

In the presence of regret-averse investors on the market an introduction of on-line trading will lead to a higher mean and volatility of stock returns, higher long-run negative correlation of stock returns and higher dependence of future market trading volume on the dispersion of realized stock returns. If, in addition, the degree of investors’ regret-aversion or the number of regret-averse investors on the market is not known until trade takes place, then an introduction of on-line trading will also decrease the positive short-run correlation of stock returns.

The model described above considers an economy with only two risky assets, but it can be easily generalized to the case of many assets. Though this generalization lies beyond the scope of this paper, I want to discuss several possible ways of doing that. The key issue in the multi-asset model is the mechanism that investors use to determine the benchmark portfolio. It is no longer plausible to expect an investor to compare his return with the best ex-post return among all the assets because it is not feasible for him to

process all the information available on the market and it is highly unlikely that he will feel regret if some asset he never heard of (e.g., shares in a small firm in Uruguay) performs extremely well.

In the spirit of regret theory, the return on the benchmark portfolio must be easily observable and an investor should consider the benchmark portfolio as an alternative that was available to him in the past but which he did not choose. In other words, there is a small subset of assets that investors use to construct the “best ex-post benchmark portfolio”. One possible way to construct this subset is to restrict investors’ attention only to the well-known market indices (e.g. NASDAQ,, S&P 500, and DOW). Another possibility is to restrict investors’ attention to the stocks of well-known companies (e.g. the ones with the highest market values or with the highest historical growth level). One more possibility is to allow the investor to form his benchmark portfolio only out of the assets that he investigated in the past. This approach is even more appealing because it allows different investors to have different benchmark portfolios.

The application of regret theory to investors’ behavior in the multi-asset setting will allow one to draw a number of additional empirical implications about the stock price behavior and portfolio allocation. For example, the behavior of stock returns (mean and volatility) may depend on whether or not this stock belongs to the set of stocks that can be used to construct a benchmark portfolio. In particular, one may draw some conclusions about the effect of firm’s market value on the behavior of its stock returns. Multi-asset setup of the model may also allow one to explain why uninformed investors do not diversify enough, and, in particular, it may help to explain the home bias effect.

3 Empirical test of the model

The fact that stock returns exhibit high mean and volatility as well as negative long-run and positive short-run correlation is documented by a number of studies, and there are a number of theoretical models (both with fully rational and bounded rational investors) that try to explain these phenomena. The model presented in this paper is differentiated from the other models by its predictions about the effect of the on-line trading on the time-correlation of stock returns and by its prediction about the dependence of the trading volume on the dispersion of the lagged realized stock returns. The empirical analysis presented below is aimed to test these new predictions.

For this analysis I have chosen the CRSP data on the value-weighted, equal-weighted, NASDAQ and S&P500 market indices during the 1989-2000 period. Since the year 1995 might be taken as a benchmark year when on-line trading became popular, my dataset consists of 6-year data periods “with” and “without” significant on-line trading. In addition to these four indices I also considered the fifty stocks which were most traded as of January 1995 and that were traded during the whole 1989-2000 period.

Unfortunately, the size of the data set does not allow me to analyze the effects of on-line trading on the long-run autocorrelation of stock returns, which, I believe, are of higher magnitude than the effects of on-line trading on the short-run autocorrelation of returns. In order to check the effect of an introduction of on-line trading on the short-run correlation of stock return, I have estimated the following model using OLS estimation:

$$R_t = \alpha_0 + \alpha_1 \cdot R_{t-1} + \alpha_2 \cdot ind_t + \alpha_3 \cdot Ri_t + \varepsilon_t \quad (18)$$

where R_t is the return on chosen index (or portfolio) at time t, R_{t-1} is the return at time t-1, ind_t is an indicator function which is set to be equal to 1 for the 1995-2000 time period and equal to 0 for the 1989-1994 time period, and $Ri_t = R_{t-1} * ind_t$. Table 1 presents the estimation results for daily, weekly and monthly data for the value-weighted, equal-weighted, NASDAQ and S&P500 indices and for the portfolio of the fifty most traded (as of January 1995) stocks.

In order to check the effect of on-line trading on the autocorrelation of individual stock returns, I have examined the return on “buy winners and sell losers” strategy. The strategy I used in my analysis is the following. Among the fifty stocks that I have chosen for my analysis, each period I have located five stocks that had the highest return and five stocks that had the lowest return in the previous period. The strategy is to buy the shares (equally-weighted) of these five winners and short-sell the shares (equally-weighted) of these five losers (so that each period the portfolio worth is zero) and hold such a portfolio for 1 period. Using daily, weekly, and monthly data, I estimated the following regression:

$$R_t = \beta_0 + \beta_1 \cdot ind_t + \varepsilon_t \quad (19)$$

where R_t is the return on this investment strategy at time t and ind_t is an indicator function which is set to be equal to 1 for the 1995-2000 time period and to 0 for the 1989-1994 time period.

The model predicts that an introduction of on-line trading should decrease the short-run correlation of stock returns, i.e. it predicts negative estimations of α_3 (in regression (18)) and β_1 (in regression (19)). Indeed, for the daily returns, all of the estimations of α_3 (Table 1A) and the estimation of β_1 (Table 2A) are negative and significant at the 8% level, and 4 out of 6 of these estimations are significant at the 2% level. All the weekly (Tables 1B and 2B) and monthly (tables 1C and 2C) estimation results, however, have insignificant estimations of both α_3 and β_1 . This fact, again, is consistent with the model because the model predicts a much larger effect of an introduction of on-line trading on the daily data than its effect on the weekly or monthly data¹².

Another prediction that makes my model different from the other theoretical models that deal with autocorrelation of stock returns is the prediction about the effect of the dispersion of realized stock returns on the future trading volume. To test this prediction I have chosen the same 50 stocks (that were the most traded stocks as of January 1995 and

¹² One may come up with another, non-behavioral reasoning for why short-run correlation decreased over the past several years. In particular, since on-line trading leads to more frequent trading, the effect of non-synchronous trading (one of the factors contributing to the positiveness of short-run correlation of stock returns) became less significant in the past several years. The important question of finding which factors (and at what degree) contributed to the observed decrease in the short-run correlation of stock returns lies beyond the scope of this paper. However, I do not think that changes in the non-synchronous trading can explain such a decrease alone. In particular, the return on the portfolio of most traded (as of January 1995) stocks experienced a significant reduction in the short-run autocorrelation despite the fact that the stocks belonging to this portfolio were actively traded during the whole sample period (only three of the stocks had one non-trading day during the whole sample period and two out of these three days were in the 1995-2000 subperiod).

existed during the whole 1989-2000 period) as I did for the previous hypotheses. I estimated 2 regression models.

First, I divided the data into 2 sub-periods: the 1989-1994 time period (period with small number of on-line investors) and the 1995-2000 time period (period with large number of on-line investors) and estimated the regression:

$$\ln(Trade_t) = \gamma_0 + \gamma_1 \cdot time_t + \gamma_2 \cdot RV_{t-1} + \varepsilon_t \quad (20)$$

where $Trade_t$ is the number of shares (total for the 50 chosen stocks) traded at period t , $time_t = t$ is the time elapsed from the beginning of the sample (in number of periods), RV_{t-1} is the dispersion of the lagged realized stock returns defined as

$$RV_{t-1} = \sqrt{\sum_{i=1}^{50} (r_{i,t-1} - \overline{r_{t-1}})^2}, \text{ where } r_{i,t-1} \text{ is the return on asset } i \text{ at time } t-1 \text{ and}$$

$$\overline{r_{t-1}} = \frac{1}{50} \sum_i^{50} r_{i,t-1} \text{ is the equal-weighted return on these fifty stocks at time } t-1.$$

Second, I pooled the data together and estimated the following regression:

$$\ln(Trade_t) = \gamma_0 + \gamma_1 \cdot time_t + \gamma_2 \cdot RV_{t-1} + \gamma_3 \cdot ind_t + \gamma_4 \cdot RVi_t + \varepsilon_t \quad (21)$$

where $Trade_t$, $time_t$ and RV_{t-1} are the same as defined above, ind_t is an indicator function which is set to be equal to 1 for the 1995-2000 time period and to 0 for the 1989-1994 time period, and $RVi_t = RV_{t-1} * ind$.

Table 3 presents estimation results for regressions (20) and (21) using daily, weekly and monthly data. Consistent with the model's prediction, the majority of estimations of γ_2 are positive and significant at the 5% level with the exception of weekly data results for the 1989-1994 time period (which is also positive but significant only at the 10% level) and monthly data for 1989-1994 and pooled 1989-2000 periods (which are insignificant). The positive (at the 1% significance level) estimation of γ_4 implies that the effect of the dispersion of the lagged realized stock returns on the trading volume becomes larger during 1995-2000 time period. This result is also consistent with the model because the larger number of non-professional traders (resulted from the better access to the market) results in the larger reaction of the trading activity on the dispersion of the lagged realized returns.

4 Conclusion

This paper presents a model of asset pricing under the assumption that some investors may have regrets. It considers 2 types of investors: rational active investors whose goal is to make money by trading on the market, and regret-averse passive investors who consider the stock market as an instrument of saving. The model does not assume any information asymmetry among investors, nor it assumes the existence of a signal of any

kind about future returns or any consistent pattern in earnings and profitability of underlying firms. The model predicts that the market will over-react on good or bad news and explains the high mean and volatility of stock returns as well as positive short-run and negative long-run correlation of stock returns. It also predicts the positive correlation between future market trading volume and the dispersion of the realized stock returns. My model considers how stock market accessibility affects stock price behavior and predicts that an improvement in the stock market accessibility for non-professional traders leads to an even higher mean and volatility of stock returns and to the larger negative long-run correlation and smaller positive short-run correlation of returns. The empirical results presented in the paper are consistent with the predictions from the theory that better stock market accessibility gained by non-professional traders through on-line trading decreases the short-run correlation of stock returns, and that future trading volume depends positively on the dispersion of the realized stock returns.

Table 1

Short-run correlation of stock returns

	Const	R_{t-1}	Ind_t	Ri_t
A: Daily returns				
Value-weighted return	.0004157 (0.070)	.1168285 (0.000)	.0003155 (0.330)	-.0696189 (0.079)
Equal-weighted return	.0007617 (0.000)	.3473132 (0.000)	.0000233 (0.920)	-.0923455 (0.015)
NASDAQ	.0003605 (0.300)	.2462348 (0.000)	.0005596 (0.255)	-.2211642 (0.000)
S&P 500	.0003663 (0.128)	.010002 (0.582)	.0004098 (0.229)	-.0418061 (0.061)
50 stocks portfolio	.0010771 (0.001)	.1274989 (0.000)	-.0000187 (0.966)	-.1144868 (0.002)
B: Weekly returns				
Value-weighted return	.002483 (0.031)	-.0711928 (0.292)	.0016431 (0.313)	-.0076682 (0.928)
Equal-weighted return	.0041103 (0.000)	.2921197 (0.000)	-.0000269 (0.986)	-.0745798 (0.366)
NASDAQ	.0022875 (0.196)	.0518162 (0.523)	.0028109 (0.261)	-.120175 (0.200)
S&P 500	.0020234 (0.077)	-.1273701 (0.050)	.0020354 (0.210)	.0409698 (0.622)
50 stocks portfolio	.0062997 (0.000)	-.041214 (0.481)	-.0007913 (0.726)	-.0125351 (0.878)
C: Monthly returns				
Value-weighted return	.0098318 (0.050)	-.0691226 (0.609)	.0070616 (0.322)	.0152812 (0.930)
Equal-weighted return	.0057729 (0.304)	.3825296 (0.003)	.0034595 (0.660)	-.1476263 (0.372)
NASDAQ	.0076913 (0.351)	.2170581 (0.197)	.0114325 (0.327)	.1721847 (0.376)
S&P 500	.0079744 (0.096)	-.1606063 (0.215)	.0098264 (0.154)	.0270384 (0.873)
50 stocks portfolio	.0223102 (0.002)	.067214 (0.577)	.0012345 (0.903)	-.1142407 (0.500)

This table presents the estimation results of the OLS regression of portfolios returns on the lagged return (Ri), indicator ($ind=1$ for the 1995-2000 time period and $ind=0$ for the 1989-1994 time period), and indicator times lagged return ($Ri=ind*Ri$). The significance levels for each of the estimations are given in the brackets.

Table 2
Return to buying winners and selling losers

	Const	Ind _t
A: Daily return	.0005694 (0.320)	- .0026331 (0.001)
B: Weekly return	- .0115385 (0.000)	.0033804 (0.346)
C: Monthly return	.0298492 (0.018)	- .0254025 (0.151)

This table presents the estimation results of the OLS regression of returns on the “buying winners and selling losers” investment strategy on indicator ($ind = 1$ for the 1995-2000 time period and $ind = 0$ for the 1989-1994 time period). The significance levels for each of the estimations are given in the brackets.

Table 3
Trading volume and returns volatility

	Const	Time _t	RV _{t-1}	Ind _t	Rvi _t
A: Daily data					
1989-1994 time period	17.02232 (0.000)	.0006026 (0.000)	10.31227 (0.000)		
1995-2000 time period	16.47276 (0.000)	.001004 (0.000)	9.869469 (0.000)		
1989-2000 time period	16.87575 (0.000)	.0007777 (0.000)	10.93801 (0.000)	.0249051 (0.436)	4.304862 (0.001)
B: Weekly data					
1989-1994 time period	18.80062 (0.000)	.0029773 (0.000)	1.675224 (0.094)		
1995-2000 time period	18.10962 (0.000)	.0050625 (0.000)	3.94036 (0.000)		
1989-2000 time period	18.63484 (0.000)	.0038533 (0.000)	2.358154 (0.021)	.1625275 (0.012)	4.94807 (0.000)
C: Monthly data					
1989-1994 time period	20.35391 (0.000)	.0124455 (0.000)	-.045173 (0.675)		
1995-2000 time period	19.56622 (0.000)	.020804 (0.000)	.3212076 (0.000)		
1989-2000 time period	20.22119 (0.000)	.0157323 (0.000)	.0277971 (0.792)	.3506786 (0.001)	.6441277 (0.000)

This table presents the estimation results of the OLS regression of the logarithm of the number of shares traded at the market on time elapsed from the beginning of the sample period (*time*, in number of periods), lagged variance of returns (*RVI*), indicator (*ind* =1 for the 1995-2000 time period and *ind*=0 for the 1989-1994 time period), and indicator times lagged variance in returns ($RVli=ind*RVI$). The significance levels for each of the estimations are given in the brackets.

References

- 1) Ang, Andrew, Geert Bekaert, and Jun Liu (2001), "Why Stocks May Disappoint," working paper, Columbia University and UCLA
- 2) Barberis, N., M. Huang, and J. Santos (1999), "Prospect Theory and Asset Prices," *Quarterly Journal of Economics* 116, 1-53. Barberis, Nicholas and Huang, Ming (2000), "Mental Accounting, Loss Aversion, and Individual Stock Returns," *Journal of Finance*, 56, 1247-1292.
- 3) Bell, David (1982), "Regret in Decision Making under Uncertainty," *Operations Research* 30, 961-981.
- 4) Bell, David (1983), "Risk Premium for Decision Regret", *Management Science* 29, 1156-1166.
- 5) Benartzi, Shlomo and Richard Thaler (1995), "Myopic Loss Aversion and the Equity Premium Puzzle," *Quarterly Journal of Economics*, CX, 73-92.
- 6) Conrad, C., and G. Kaul (1988), "Time-Variation in Expected Returns", *Journal of Business*, 61, 409-425.
- 7) Conrad, C., and G. Kaul (1989), "Mean-Reversion in Short-Horizon Expected Returns", *Review of Financial Studies*, 2, 225-240
- 8) Chopra, Lakonishok, and Ritter (1992), "Measuring abnormal performance. Do Stock overreact?" *Journal of Financial Economics*, 31
- 9) De Bond, Werner and Thaler, Richard (1985), "Does the Stock Market Overreact?" *Journal of Finance*, 40.
- 10) De Bond, Werner and Thaler, Richard (1987), "Further Evidence on Investors Overreaction and Stock Market Seasonality," *Journal of Finance*, 42.

- 11) Dodonova, Anna (2002), "Portfolio Allocation and the Choice of Benchmarks: Why Investors do not Diversify Enough?" working paper, University of Michigan
- 12) Fama, Eugene and French, Kenneth (1988), "Permanent and Temporary Component of Stock Prices," *Journal of Political Economics*, 31
- 13) Grinblatt, Mark and Han, Bin (2001), "The Disposition effect and Momentum," working paper, Anderson Graduate School of Management, UCLA
- 14) Hirshleifer, David (2001), "Investor Psychology and Asset Pricing", *working paper*.
- 15) Jegadeesh, Narasimhan and Titman, Sheridan (1993), "Returns to Buying Winners and Selling Losers: Implication for stock Market Efficiency", *Journal of Finance*, 48.
- 16) Kahneman, Daniel and Tversky, Amos (1979), "Prospect Theory: an Analysis of decision under Risk," *Econometrica* 47, 263-291.
- 17) Loomes, Graham and Sugden, Robert (1982), "Regret Theory: an Alternative Theory of Rational Choice under Uncertainty," *The Economic Journal* 92, 805-824.
- 18) Lucas, Robert (1978), "Asset Prices in an Exchange Economy," *Econometrica* 46, 1419-1446.
- 19) Mehra, Rajnish and Edward Prescott (1985), "The Equity Premium Puzzle," *Journal of Monetary Economics*, XV, 145-161.
- 20) Odean, T. (1998), "Are investors reluctant to realize their losses", *Journal of Finance*, 53, 1775-1798.
- 21) Poterba, James M. and Lawrence H. Summers (1988), "Mean Reversion in Stock Prices," *Journal of Financial Economics* 22, 27-59

- 22) Shumway, T. (1998), "Explaining returns with loss aversion", *University of Michigan Business School Mimeo*.
- 23) Thaler, R. H. (1985), "Mental Accounting and consumer choice", *Marketing Science*, 4, 199-214
- 24) Thaler, Richard H. and Eric J. Johnson (1990), "Gambling with the House Money and Trying to Break Even: The Effect of Prior Outcomes on Risky Choice," *Management Science* 36, 643-660
- 25) Von Neumann, J and Morgenstern, O (1947), "Theory of Games and Economic Behavior," Ed.2. Princeton University Press, Princeton, N.J.