Counterfactual Thinking, Trading, and Market Inefficiency

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Abstract

This study examines the effects of counterfactual thinking on asset pricing and market efficiency in a noisy rational expectation model. Emotional traders with counterfactual thinking trade an equity with informed and uninformed rational traders. An equilibrium exists wherein shocks to emotional traders' counterfactuals are aggregated and are incorporated into equity price. Counterfactual thinking reduces the informational efficiency of the equity market. The stronger traders' counterfactual thinking, or the noisier the shocks to counterfactuals are, the lower the price informativeness. Counterfactual thinking also reduces price responsiveness and market liquidity.

Keywords: counterfactual thinking, regret, asset pricing, informational efficiency
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1. Introduction

Counterfactual thinking that compares a chosen option with foregone opportunities can cause regret and reduce decision satisfaction. Both experimental and empirical studies indicate that counterfactual thinking has a strong influence on decision-making. Based on regret theory developed by Bell (1982) and Loomes and Sugden (1982), this study constructs a model of counterfactual thinking and trading. In the model, emotional traders trade a risky asset with rational traders on the equity market. An emotional trader compares the chosen position on the equity with a counterfactual investment on other assets. If the counterfactual outperforms/underperforms the equity, the emotional trader feels regret/rejoice that affects perceived utility. There are informed and uninformed rational traders. Informed traders have private information regarding the value of the equity, whereas uninformed traders do not have private information, but can partially infer equity value by observing market price. In a setting of the noisy rational expectation equilibrium (noisy REE) model developed by Grossman and Stiglitz (1980), we demonstrate that an equilibrium exists, wherein the shocks to emotional traders' counterfactuals are aggregated and incorporated into equity price.

Employing the pricing formula derived in equilibrium, we examine the influence of counterfactual thinking on market efficiency. In this model, counterfactual thinking causes traders to react to otherwise irrelevant shocks, adding noise to equity price. We define a measure of market efficiency according to the model's informational structure. Through comparative static analysis, we demonstrate that counterfactual thinking reduces the informational efficiency of the equity market, indicating that stronger traders' counterfactual thinking or noisier counterfactuals lower informational efficiency. Moreover, counterfactual thinking reduces price responsiveness and market liquidity.

This paper contributes to the literature on regret and asset pricing. A growing number of experimental and empirical studies provide supporting evidence for the effect of regret aversion on investor behavior and asset price in financial markets. For example, Frydman and Camerer (2016) demonstrate that regret aversion can cause the "repurchase effect," Fogel and Berry (2006) use regret aversion to explain the "disposition effect," Deuskar et al (2021) provide empirical evidence regarding the influence of regret on individual investors' order choice, Fioretti et al. (2022) show that regret aversion affects individuals' dynamic trading strategy, and Ballinari and Müller (2022) illustrate that regret aversion can explain cross-sectional returns. Theoretical models are also developed. For example, Dodonova and Khoroshilov (2005) demonstrate that regret causes return auto-correlation in a two-period consumption-based capital asset pricing model (CAPM), Gollier and Salanié (2006) introduce regret aversion into an Arrow-Debur economy, Solnik and Zuo (2012) apply regret aversion to international CAPM to explain "home-bias," and Qin (2020) expands standard CAPM to include regret aversion. Nevertheless, there are minimal theoretical models of regret and

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asset pricing. Based on previous research analyses, this study is the first to introduce regret into a noisy REE model.

This paper also contributes to the literature on market efficiency. Since Fama (1970) formally proposed the efficient markets hypothesis (EMH), it has been a pillar of modern finance theory. Nevertheless, empirical findings revealing various "anomalies" in equity markets indicate the inefficiency of financial markets. Fama (1991) and Lo (2008) review the literature on EMH, proposing potential reasons for market inefficiency. The present paper contributes to this literature by showing the possible effect of counterfactual thinking on informational efficiency. Considering the growing influence of individual investors, and the increasing importance of alternative investment options, such as cryptocurrency, real estate, commodities, and other emerging opportunities, we argue that the proposed model provides an intuitive and plausible explanation to market inefficiency.

Finally, this study belongs to a growing body of literature applying regret theory to various phenomena in financial markets, such as asset allocation (Muermann et al., 2006), insurance demand (Fujii et al., 2021), currency hedging strategy (Michenaud and Solnik, 2008), herding (Qin, 2015), and risk attitude (Somasundaram and Diecidue, 2017). This study is the first to address the influence of regret on market efficiency.

2. Setting

In the equity market, one risky asset is traded among rational traders and emotional traders at date $t = 0{,}1$. At $t = 2$, each share of the equity pays an amount of $V = v + e$ and all traders' positions are cleared. $v \sim N(\mu_V, \sigma_v^2)$ represents the fundamental value that is realized at date 2, and $e \sim N(0, \sigma_e^2)$ is a random shock at date 1 that is independent to v.

In each round of trading, a rational trader takes an optimal position on the equity to maximize expected utility, represented by a mean-variance utility function. The utility maximizing problem is

$$\max_{x_t} E[x_t(V - P_t)|\mathcal{F}_t] - \frac{\gamma}{2} var(x_t(V - P_t)|\mathcal{F}_t) \quad (1)$$

where P_t denotes the equity price at date t, x_t is the trader's position on the equity, and $\gamma > 0$ is a parameter that controls the magnitude of risk aversion. $\mathcal{F}_t$ denotes the trader's information set at date t. At date 0, no rational trader has private information. At date 1, some rational traders observe e and become "informed traders." The remaining rational traders do not observe e and are "uninformed traders."

Emotional traders' utility depends on the return of equity investment; however, in contrast to rational traders, emotional traders are also affected by counterfactual thinking. We assume that each emotional trader compares the investment on the equity market with a counterfactual, which is a foregone investment opportunity on other assets. Loewenstein et al. (2015) propose a general theory of emotions and decision making, wherein an individual compares the chosen option with an "affective optimum." Following Loewenstein et al. (2015), Y_i in equation (2) can be explained as the emotional trader's affective optimum.

Traders' counterfactual thinking can cause regret or rejoice. More specifically, according to the setting of the equity market in this model, we assume that regret or rejoice occurs in the following manner. Emotional trader i buys x shares of the equity at price of P dollars per share, the payoff from this investment is xV. If the emotional trader had invested the same amount of money on the counterfactual, xY_i would have been received, where Y_i denotes the payoff for each P dollars invested on trader i's counterfactual. At date 2, if trader i finds that $xY_i > xV$, indicating that the counterfactual outperforms the equity, the trader will feel regret investing on equity, whereas, if $xY_i < xV$, the trader will rejoice.

Following regret theory developed by Bell (1982) and Loomes and Sugden (1982), we assume that the impact of regret/rejoice on utility is measured by a "regret–rejoice function." For technical simplicity, we assume a linear regret–rejoice function as below.

$$f(x, Y_i, V) = -\delta(xY_i - xV), \quad (2)$$

where $\delta > 0$ is a parameter controlling for the strength of counterfactual thinking. Under the above assumptions, emotional trader i faces the following decision-making problem:

$$\max_{x_t} E\left[x_t(V - P_t)\middle|\mathcal{F}_{i,t}\right] - \frac{\gamma}{2} var\left(x_t(V - P_t)\middle|\mathcal{F}_{i,t}\right) - \delta E\left[x_t(Y_i - V)\middle|\mathcal{F}_{i,t}\right], \quad (3)$$

where $\mathcal{F}_{i,t}$ denotes the trader's information set at date t. In the modified utility function in equation (3), $E[x_t(V-P_t)|\mathcal{F}_{i,t}]-\frac{\gamma}{2}var(x_t(V-P_t)|\mathcal{F}_{i,t})$ represents the trader's utility of equity investment return, and $\delta E[x_t(Y_i-V)|\mathcal{F}_{i,t}]$ reflects the influence of anticipated regret/rejoice. We further assume $Y_i=y_i+\varepsilon_i$, where $y_i \sim N(\mu_{Yi},\sigma_{yi}^2)$ represents the fundamental value that is realized at date 2 and ε_i is a shock that occurs at date 1. We assume that only emotional trader i observes ε_i at date 1, and rational traders and other emotional traders do not observe ε_i. To simplify the analysis, we also assume that ε_i is independent to v, e and $\{y_i\}$.

The total number of traders in the equity market is $N \equiv N_A+N_I+N_U$, where N_A denotes the number of emotional traders, N_I is the number of informed traders, and N_U is the number of uninformed traders; hence, the proportion of each type of trader is $n_A \equiv \frac{N_A}{N}$, $n_R \equiv \frac{N_R}{N}$ and $n_U \equiv \frac{N_U}{N}$, respectively. At date 0, the per capita supply of equity is scaled to be one share. At date 1, the per capita supply of the equity is $1+z$, where $z \sim N(0,\sigma_z^2)$ represents a supply shock. To simplify the analysis, we assume that all investors observe z at date 1. Moreover, we assume that z is independent to v, e, $\{y_i\}$ and $\{\varepsilon_i\}$.

3. Equilibrium price and market efficiency

Let $x_{I,t}$ denote the optimal position for an informed trader at date t, $x_{U,t}$ for an uninformed trader, and $x_{Ai,t}$ for emotional trader i. Because there is no informational asymmetry among rational traders, at date 0, informed and uninformed traders take the same optimal positions as below:

$$x_{I,0}=x_{U,0}=\frac{\mu_V-P_0}{\gamma(\sigma_e^2+\sigma_v^2)}. \tag{4}$$

Emotional trader i's optimal position on the risk asset is solved from equation (3):

$$x_{Ai,0}=\frac{\mu_V-P_0-\delta(\mu_{Yi}-\mu_V)}{\gamma(\sigma_e^2+\sigma_v^2)}. \tag{5}$$

The market clearing condition is as follows:

$$n_A x_{A,0}+n_I x_{I,0}+n_U x_{U,0}=1, \tag{6}$$

where $x_{A,0} \equiv \frac{1}{N_A}\sum_{i=1}^{N_A} x_{Ai,0}$ is emotional traders' average position on the equity. The equilibrium price at date 0 is obtained from equations (4)–(6):

$$P_0=\mu_V-\gamma(\sigma_e^2+\sigma_v^2)-n_A\delta(\mu_Y-\mu_V), \tag{7}$$

where $\mu_Y \equiv \frac{1}{N_A}\sum_i^{N_A}\mu_{Yi}$.

In the pricing formula in equation (7), $\gamma(\sigma_e^2+\sigma_v^2)$ is the risk premium of the equity. Note that both rational and emotional investors are risk averse; thus, a risk premium is required for investors to hold the equity in equilibrium. $n_A\delta(\mu_Y-\mu_V)$ represents the effects of counterfactual thinking on equity price. In the case of $\mu_Y>\mu_V$, which indicates that emotional traders' counterfactuals, on average, have higher expected returns than the equity, counterfactual thinking leads to underpricing. If $\mu_Y<\mu_V$, then counterfactual thinking will cause equity overpricing.

At date 1, shock e occurs to the equity and $\{\varepsilon_i\}$ occurs to emotional traders' counterfactuals. Informed traders observe e; therefore, the optimal position for an informed trader is

$$x_{I,1}=\frac{\mu_V+e-P_1}{\gamma\sigma_v^2}. \tag{8}$$

Uninformed traders do not observe e, but they can partially infer e from the price of the equity. An uninformed trader's optimal position is

$$x_{U,1}=\frac{E[V|P_1]-P_1}{\gamma var(V|P_1)}. \tag{9}$$

Emotional traders do not observe e. To simplify the analysis, we assume that emotional traders are naïve in the sense that they cannot infer e through Bayesian learning. Each emotional trader i observes ε_i, the shock occurs to the counterfactual, and other investors do not observe ε_i. Under these assumptions, emotional trader i's optimal position at date 1 is

$$x_{Ai,1}=\frac{\mu_V-P_1-\delta(\mu_{Yi}+\varepsilon_i-\mu_V)}{\gamma(\sigma_e^2+\sigma_v^2)}. \tag{10}$$

The marketing clearing condition is

$$n_A x_{A,1}+n_I x_{I,1}+n_U x_{U,1}=1+z \tag{11}$$

where $x_{A,1} \equiv \frac{1}{N_A}\sum_i^{N_A} x_{Ai,1}$.

A rational expectation equilibrium is defined as a price function, $P_1(e,\{\varepsilon_i\})$, which satisfies equations (8)–(11). The following proposition demonstrates that a linear equilibrium exists where $P_1(e,\{\varepsilon_i\})$ is a linear function of the stochastic variables.

Proposition 1. An equilibrium exists as shown below:

$$P_1 = \mu_V - \lambda_0 - \lambda_Z(1+z) + \lambda_V e - \lambda_Y \varepsilon \tag{12}$$

where

$$\varepsilon = \frac{1}{N_A}\sum_i^{N_A} \varepsilon_i, \tag{13}$$

$$\lambda_0 = \frac{n_A\sigma_v^2}{n_A\sigma_v^2 + n_I(\sigma_v^2+\sigma_e^2) + n_U\frac{\sigma_e^2(\sigma_v^2+\sigma_e^2)^2 + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^4\sigma_\varepsilon^2}{\sigma_e^2(\sigma_v^2+\sigma_e^2) + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^2\sigma_\varepsilon^2}}\delta(\mu_Y - \mu_V), \tag{14}$$

$$\lambda_Z = \frac{\sigma_v^2+\sigma_e^2}{n_A\sigma_v^2 + n_I(\sigma_v^2+\sigma_e^2) + n_U\frac{\sigma_e^2(\sigma_v^2+\sigma_e^2)^2 + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^4\sigma_\varepsilon^2}{\sigma_e^2(\sigma_v^2+\sigma_e^2) + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^2\sigma_\varepsilon^2}}\gamma\sigma_v^2, \tag{15}$$

$$\lambda_V = \frac{n_I(\sigma_v^2+\sigma_e^2) + n_U\frac{\sigma_e^2(\sigma_v^2+\sigma_e^2)^2}{\sigma_e^2(\sigma_v^2+\sigma_e^2) + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^2\sigma_\varepsilon^2}}{n_A\sigma_v^2 + n_I(\sigma_v^2+\sigma_e^2) + n_U\frac{\sigma_e^2(\sigma_v^2+\sigma_e^2)^2 + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^4\sigma_\varepsilon^2}{\sigma_e^2(\sigma_v^2+\sigma_e^2) + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^2\sigma_\varepsilon^2}}, \tag{16}$$

$$\lambda_Y = \frac{n_A\delta\sigma_v^2\left[1+\frac{n_U}{n_I}\cdot\frac{\sigma_e^2(\sigma_v^2+\sigma_e^2)}{\sigma_e^2(\sigma_v^2+\sigma_e^2) + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^2\sigma_\varepsilon^2}\right]}{n_A\sigma_v^2 + n_I(\sigma_v^2+\sigma_e^2) + n_U\frac{\sigma_e^2(\sigma_v^2+\sigma_e^2)^2 + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^4\sigma_\varepsilon^2}{\sigma_e^2(\sigma_v^2+\sigma_e^2) + \left(\frac{n_A}{n_I}\delta\right)^2\sigma_v^2\sigma_\varepsilon^2}}. \tag{17}$$

The price formula in equation (12) is a linear function of stochastic variables. The shock to asset value, e, enters equilibrium price P_1 through the informed traders' orders. Shocks to emotional traders' counterfactuals, which are also aggregated into ε, are incorporated into price as well. Because shocks to counterfactuals are irrelevant to the value of the equity, ε is a "noise" that reduces the informativeness of equity price. Supply shock z enters price as well; however, because z is observed by all traders, it does not affect price informativeness.

As the equity equilibrium price includes both private information and uninformative noise, our model is similar to Grossman and Stiglitz (1980) and many other noisy REE models. Nevertheless, one feature of our model is worth noting, as ε is not exogenously added to the market clearing condition; rather, it is incorporated into price through emotional traders' trading activities. To demonstrate this, we note that in the special case of $n_A = 0$, the price is fully informative.

Equity market informational efficiency generally refers to the extent to which equity price reveals information regarding the underlying asset value. In our model, equity market informational efficiency is measured by $\frac{var(e)-var(e|P_1)}{var(e)}$, which is the proportion of information of e that is revealed by market price P_1. Based on the pricing function in equation (12), we have the following:

$$\frac{var(e)-var(e|P_1)}{var(e)} = \frac{\sigma_e^2}{\sigma_e^2 + \left(\frac{n_A}{n_I}\cdot\frac{\sigma_v^2}{\sigma_v^2+\sigma_e^2}\delta\right)^2\sigma_\varepsilon^2}. \tag{18}$$

Using this measure, we can analyze how emotional traders' counterfactual thinking affects the informational efficiency of the equity market. Corollary 1 summarizes the results of comparative static analysis.

Corollary 1. The following results hold.

(i) $\frac{var(e)-var(e|P_1)}{var(e)}$ decreases in $\frac{n_A}{n_I}$;

(ii) $\frac{var(e)-var(e|P_1)}{var(e)}$ decreases in δ;

(iii) $\frac{var(e)-var(e|P_1)}{var(e)}$ decreases in σ_ε^2;

(iv) $\frac{var(e)-var(e|P_1)}{var(e)}$ decreases in σ_v^2.

Statement (i) indicates that a larger population of emotional traders in proportion to informed traders results in less market efficiency. If there is no emotional trader, we have $\frac{var(e)-var(e|P_1)}{var(e)} = 1$. In this special case, EMH holds in the equity market because all available information of equity value is revealed by equity price. Except for this special case, EMH does not holds. Moreover, market efficiency decreases as more emotional traders participate in equity trading. Statement (ii) indicates that the stronger an emotional trader's counterfactual thinking, the less efficient the equity market will be. Statement (iii) demonstrates that the noisier emotional traders' counterfactuals are, the less efficient the equity market is. By equation (18), $\frac{var(e)-var(e|P_1)}{var(e)} \to 0$ as $\sigma_\varepsilon^2 \to \infty$, indicating informational efficiency is extremely low when traders' counterfactuals are extremely volatile.

Statement (iv) indicates that the more volatile the fundamental value of the equity is, the less informational efficiency the market has. Note that in this model, although v is the fundamental value of the asset, no trader has private information about v. As a result, the pricing formula in equation (12) does not include v; therefore, the informational efficiency of the equity market does not depend on the revelation of v. However, statement (iv) suggests that when the fundamental value v becomes more volatile, informational efficiency becomes lower. In other words, the market is less efficient exactly when there is more uncertainty and informational efficiency is needed. The intuition for this result is that rational traders reduce their trading position when they face higher risk, causing emotional traders to have a larger influence, which makes the market less efficient.

4. Price responsiveness

Proposition 1 indicates that equilibrium price is a linear function of e, z, and ε, where e is a shock to equity value, z is a supply shock, and ε aggregates shocks to emotional traders' counterfactuals. As a further look at market efficiency, we examine equity price's responsiveness to e and z. Because the pricing formula in Proposition 1 is a complex function of the parameters, in this section, we assume $\sigma_e = \sigma_v$, which means that informed traders observe half of the information regarding equity value. In this special case, the following corollaries hold.

Corollary 2. Strength of counterfactual thinking, measured by δ, affects equity price's responsiveness in the following way:

(i) λ_V decreases in δ;

(ii) $\frac{\lambda_V}{\lambda_Y}$ decreases in δ.

Statement (i) of Corollary 2 claims that the stronger the counterfactual thinking, the smaller the price responsiveness to e. Statement (ii) examines $\frac{\lambda_V}{\lambda_Y}$, which can be explained as the "relative responsiveness" to e with respect to ε. Statement (ii) shows that the stronger counterfactual thinking is, the smaller the relative responsiveness.

Corollary 3. The volatility of emotional traders' counterfactuals, measured by σ_ε^2, affects the equity price's responsiveness in the following manner:

(i) λ_V decreases in σ_ε^2;

(ii) $\frac{\lambda_V}{\lambda_Y}$ does not depend on σ_ε^2.

Statement (i) indicates that when emotional traders' counterfactuals are more volatile, equity price responds less to e. Nevertheless, relative responsiveness $\frac{\lambda_V}{\lambda_Y}$ remains unchanged.

In this model, market liquidity is measured by λ_Z, the sensitivity of price to supply shock. The following corollary indicates that emotional traders' counterfactual thinking also affects liquidity.

Corollary 4. Strength of counterfactual thinking, measured by δ, and the volatility of counterfactuals, measured by σ_ε^2, affects market liquidity in the following manner:

(i) λ_Z increases in δ;

(ii) λ_Z increases in σ_ε^2.

The first statement of Corollary 4 illustrates that the stronger the counterfactual thinking is, the lower is the liquidity. The second statement indicates that the noisier emotional traders' counterfactuals are, the less liquidity in the equity market.

5. Conclusion

This study examines the effects of counterfactual thinking on asset pricing and market efficiency in a noisy REE model, demonstrating that an equilibrium exists wherein shocks to emotional traders' counterfactuals are aggregated and incorporated into equity price. Counterfactual thinking reduces the informational efficiency of the equity market. The stronger the traders' counterfactual thinking is, or the noisier the shocks to their counterfactuals are, the lower is the price informativeness. Counterfactual thinking also reduces price responsiveness and market liquidity.

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