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Asset Mispricing

Carl Barkfeldt

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Abstract

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This dissertation studies the pricing of stocks in capital markets. It comprises five chapters, where the first serves as an introduction. The subsequent four chapters are each written as self-contained research papers. While the theory of efficient markets serves as the theoretical foundation, I approach the research from a conceptual starting point that recognizes market mispricing.

The first paper investigates a testing methodology of market efficiency based on fundamental valuation. The methodology is based on an investment strategy where stocks with high (low) V/P-ratios are assigned into long (short) portfolios. We conjecture that under the assumption of independence between the portfolio assignment and systematic risk, a positive return from such investing strategy is inconsistent with market efficiency. We estimate fundamental values based on a flexible residual income valuation model via the state-space framework and implement the investment strategy on a sample of U.S. stocks spanning 1980–2017. The implementation shows a significant positive monthly return. Moreover, the results are substantiated in a standard five-factor model. In sum, these results appear anomalous with respect to market efficiency, at least as given by the five-factor model.

The second paper examines whether improvements in earnings forecasting translate into improvements in implied cost of capital estimates of expected returns. I attain high-performing earnings forecasting via a machine learning approach. In particular, I implement and evaluate six popular machine learning methods to forecast earnings. The evaluation demonstrates that the machine learning algorithms can generate earnings forecasts that consistently outperform state-of-the-art benchmarks. Moreover, I estimate the implied cost of capital on a sample of U.S. stocks spanning 2000–2017. The general result indicates that improvements in earnings forecasting do not translate into improvements in return predictability. While issues with the implied cost of capital methodology could explain the results, another possible explanation is market mispricing.

The third paper compares the performance between the implied cost of capital and factor model approaches in estimating the cost of capital in an inefficient market. I conduct the comparison in a Monte Carlo simulation experiment. The simulation results indicate that the implied cost of capital approach is more robust to market inefficiency.

The fourth paper analyzes investor learning of cash flow expectations in the context of market efficiency. I argue that the bias-variance tradeoff translates into inefficiencies in market pricing. Moreover, in a simple model, I prove that these inefficiencies can be exploited by an investor aware of whether market prices exhibit a bias or suboptimal variance.

Keywords: Market efficiency, Mispricing, Fundamental valuation

Carl Barkfeldt, Department of Business Studies, Box 513, Uppsala University, SE-75120 Uppsala, Sweden.

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List of Papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

- I. Barkfeldt, C., Sandberg, R. Accounting-based valuation and market efficiency testing. A previous version of this paper was presented at the 42nd Annual Congress of the European Accounting Association (EAA), Paphos, Cyprus, May 2019
- II. Barkfeldt, C., The implied cost of capital: A machine learning approach
- III. Barkfeldt, C., Estimating the cost of capital in inefficient markets
- IV. Barkfeldt, C., Limits of learning

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1 Introduction

This dissertation studies the pricing of stocks in equity markets. It comprises five chapters, where the first chapter serves as an introduction. The subsequent four chapters are each written as self-contained research papers intended to be read standalone. This introductory chapter connects the research papers to the theoretical body known as market efficiency. At the core of the theory lies the efficient market hypothesis.

Fama (1970) proposes the original formulation of the hypothesis, “*A market in which prices always ‘fully reflect’ available information is called ‘efficient’*” (Fama, 1970, p. 383). The original version of market efficiency presupposes a market pricing mechanism that sets stock prices equal to fundamental values (Fama, 1965, 1970, 1976; Samuelson, 1965, 1973). Since such market pricing asserts the impossibility of any arbitrage, the condition is known as the no-arbitrage condition. While Fama (1991) emphasizes the advantages of the original version as a clean and simple benchmark, he acknowledges that it is “*...most surely false...*” (Fama, 1991, p. 1575) due to the existence of information and trading costs. Moreover, he provides an alternative version of the efficient market hypothesis, “*...prices reflect information to the point where the marginal benefits of acting on information (the profits to be made) do not exceed the marginal costs...*” (Fama, 1991, p. 1575).¹ Still, the original version is arguably the most widespread definition of market efficiency (Fama, 1991; Cochrane, 2011). This introductory chapter makes a theoretical contribution by developing the alternative version of the efficient market hypothesis that recognizes the existence of costs for maintaining the market pricing mechanism. Fama refers to the alternative version as “*A weaker and economically more sensible version...*” (Fama, 1991, p. 1575). I suggest using the name – *market efficiency 2.0*.

Grossman and Stiglitz (1980) critique the original version of market efficiency. In particular, they identify a free-rider problem associated with the investors’ information gathering costs. They argue that in a market where prices fully reflect all information, investors have no incentive to gather information since market prices already reflect all information. In fact, there is a

¹The definition follows Jensen’s (1978, p. 96) definition, “*A market is efficient with respect to information set Ω_t if it is impossible to make economic profits by trading on the basis of information set Ω_t .*”

disincentive since information gathering is costly. Hence, no investor would gather information in such a market and, therefore, market prices cannot fully reflect all information. As a solution to this conundrum, they propose an alternative dynamic for capital markets. In essence, they argue that investors must be compensated for the information gathering costs through arbitrage trading. Consequently, there must also exist uninformed investors (with zero information gathering costs) on the other side of the trades, in effect, financing the arbitrage. Moreover, in a simple model, they prove that such arbitrage can be consistent with investor rationality, both concerning the informed and uninformed investors. Hence, market mispricing appears as a central feature even in fully rational capital markets. Grossman and Stiglitz's (1980) conundrum and market dynamics frequently resurface in discussions of market efficiency (Lee, 2001; Ang, 2010; Lee and So, 2014; Sloan, 2019). In addition, their critique appears to motivate Fama's (1991) alternative version of the efficient market hypothesis. Similarly, their alternative market dynamics with arbitrage trading and investor heterogeneity serve as the theoretical basis for market efficiency 2.0.

Notwithstanding this conundrum, the no-arbitrage condition is widely adopted in both empirical and theoretical capital markets research. Lee (2001) and, more recently, Lee and So (2014) develop the argumentation in Grossman and Stiglitz (1980). In addition, they complement the motivation for market mispricing with the theories and empirical findings concerning investor irrationality in the behavioral finance literature.² They conclude that the conceptual starting point for capital market research should accommodate a more complex price discovery process, where market prices are noisy manifestations of fundamental values. Taken as a whole, this dissertation abides by their call. Moreover, Lee *et al.* (1999) provide a formalism consistent with this view. Their proposed market pricing mechanism can be represented as,

$$P_{i,t} = V_{i,t} + \varepsilon_{i,t} \quad 1.1$$

where

$P_{i,t}$ = market price for stock i at time t

$V_{i,t}$ = fundamental value for stock i at time t

$\varepsilon_{i,t}$ = random market mispricing for stock i at time t

While theorizing abounds on market mispricing, representing it as a random variable is arguably appropriate for capturing the haphazard behavior of either uninformed or irrational traders. Moreover, the flexibility of Equation

²See Shleifer (2000) and Barberis and Thaler (2003) for reviews of the behavioral finance literature.

1.1 facilitates the formalization of general characterizations of market dynamics. For instance, Benjamin Graham remarked, *“In the short-run, the market is a voting machine...but in the long-run, the market is a weighing machine”* (Buffett, 1994). This characterization suggests that market prices can diverge in the short-term but converge in the long-term. A possible representation of the *“weighing machine”* would denote the conditional expected value of market mispricing as $\mathbb{E}_t[\varepsilon_{i,t+\tau}] = 0$ where τ denotes the long-run and $\mathbb{E}_t[\cdot]$ denotes the expected value operator, conditioned on all available information. Moreover, the *“voting machine”* would arguably imply high contemporaneous variance and, possibly, the presence of cross-sectional correlation. This view of market pricing has motivated the value investing strand of academic research (Frankel and Lee, 1998; Piotroski, 2000; Mohanram, 2005; Piotroski and So, 2012; Li and Mohanram, 2019). More broadly, the vast literature on cross-sectional return anomalies can be regarded as stemming from such an understanding of the market dynamics (for an overview, see Hou *et al.*, 2020, which replicate 452 return anomalies). Paul Samuelson provides another characterization. He hypothesizes that *“Modern markets show considerable micro efficiency... [and] ...macro inefficiency, in the sense of long waves in the time series of aggregate indexes of security prices below and above various definitions of fundamental values.”* (Jung and Shiller, 2005, p. 221). The characterization of *“macro inefficiency”* suggests a temporal bias in the market mispricing, and could be represented by $\mathbb{E}_t[\varepsilon_{i,t}] = \mu_t$ where μ_t follows some persistent and likely mean-zero-reverting stochastic process. In addition, *“micro efficiency”* suggests small contemporaneous variances and cross-sectional independence. The investor sentiment literature stems from this view of the market dynamics (Baker and Wurgler, 2006; Huang *et al.*, 2015). Moreover, Fama (1965, p. 36) recognizes the existence of market mispricing. He states that *“...market prices need not correspond to intrinsic values. In a world of uncertainty intrinsic values are not known exactly. Thus there can always be disagreement among individuals, and in this way actual prices and intrinsic values can differ. Henceforth uncertainty or disagreement concerning intrinsic values will come under the general heading of ‘noise’ in the market.”* Arguably, Fama’s view can be interpreted as market prices representing the best estimate of fundamental values and, thus, the market mispricing can be expressed as $\mathbb{E}_t[\varepsilon_{i,t}] = 0$ with negligible variances and independence. Fama (1991) reaffirms such a view by arguing that the original definition of market efficiency, including the no-arbitrage condition, is indeed a valid approximation of the pricing in capital markets. This view is ubiquitous in capital market research: for instance, risk factor models (Fama and French, 1992, 2015; Hou *et al.*, 2015), fundamental valuation (Nekrasov and Shroff, 2009; Lyle *et al.*, 2013; Bach and Christensen, 2016), and implied cost of capital (Claus and Thomas, 2001; Gebhardt *et al.*, 2001; Hou *et al.*, 2012; Li and Mohanram,

2014; Callen and Lyle, 2020). For more examples, see Lee (2001) as well as Lee and So (2014).

In Equation 1.1, fundamental value can be conceptualized as the equilibrium price at which an omniscient and fully rational investor would be indifferent between buying and selling a stock. In this context, omniscient includes exact knowledge about the expected value of all future cash flows and appropriate risk adjustment but excludes perfect foresight. Moreover, a defining feature of fundamental value is conformity with the no-arbitrage condition (Rubinstein, 1976; Feltham and Ohlson, 1999; Christensen and Feltham, 2009). In capital markets research, fundamental value is commonly represented as the expected discounted cash flows, also known as the dividend discount model. Lee *et al.* (1999) emphasize that fundamental values are unobservable in practice. Therefore, they must be estimated; hence, the estimates contain a measurement error. Following the exposition in Lee *et al.* (1999), fundamental value estimates can be represented as,

$$\hat{V}_{i,t} = V_{i,t} + \omega_{i,t} \quad 1.2$$

where

$\hat{V}_{i,t}$ = fundamental value estimate for stock i at time t

$\omega_{i,t}$ = random measurement error for stock i at time t

The measurement error captures imprecisions, misspecifications, simplifications and otherwise erroneous assumptions in the fundamental analysis. For instance, Ang and Liu (2004) examine measurement errors connected to simplification of time-varying discount rates to a constant. Hughes *et al.* (2009) examine a similar simplification in the context of implied cost of capital³. In addition, the measurement error includes imprecision from the learning process. Such imprecisions are caused by the noise in the information set. The investor learning literature examines the implication of such noise on capital markets (Timmermann, 1993; Lewellen and Shanken, 2002; Pástor and Veronesi, 2003; Pastor and Veronesi, 2009).

Barberis and Thaler (2003) argue that the mere existence of mispricing does not necessitate an arbitrage opportunity, *i.e.*, an investment strategy with a positive expected abnormal return. They argue in line with Shleifer and Vishny (1997) and point to the inherent risk of arbitrage investing in real capital markets. For instance, the risk in arbitrage stems from a lack of perfect hedges, agency concerns due to delegated investment management, short-sale constraints and forced liquidation. These market dynamics and features imply that market mispricing is governed by a highly complex stochastic process. In addition, Barberis and Thaler (2003) argue that finding arbitrage opportunities

³ I use cost of capital synonymous with discount rates throughout this dissertation.

constitutes an additional challenge for the arbitrageurs. Hence, there can be considerable complexity in the randomness of the measurement error in Equation 1.2. Still, Grossman and Stiglitz (1980) argue that some investors must be able to successfully find and exploit arbitrage opportunities in the capital market as compensation for the information costs.

From a research perspective, there are several benefits with the representation in Equations 1.1 and 1.2. The representation accommodates arbitrage trading, consistent with the existence of information costs (Grossman and Stiglitz, 1980), and allows the possibility of irrational investor behavior through the market mispricing term in Equation 1.1. Moreover, the representation emphasizes the challenges of identifying any arbitrage opportunity with the measurement error in Equation 1.2. Moreover, the mathematical form of mispricing and measurement error as random variables, rather than an arbitrarily crude approximation, facilitates mathematical descriptions and allows for derivations of implications. Also, the representation is amendable to statistical estimation with auxiliary assumptions. As a whole, this representation constitutes the conceptual framework for this dissertation.

In Paper I, we investigate a methodology for testing market efficiency based on Equations 1.1 and 1.2. The methodology involves the value investing investment strategy, where stocks with high (low) V/P-ratios are assigned into long (short) portfolios (Frankel and Lee, 1998; Bach and Christensen, 2016; Li and Mohanram, 2019). We conjecture that, under the assumption of independence between the portfolio assignment and systematic risk, a positive net-zero hedge return from such investing strategy is inconsistent with market efficiency. We implement the investment strategy on a sample of U.S. stocks spanning the period 1980–2017 and find a significantly positive monthly hedge return. To substantiate our results, we estimate Fama and French’s (2015) five-factor regression. We find a significant positive abnormal return (intercept) of the investment strategy. Moreover, the factor loadings in the regression are all insignificant. This suggests that the investment strategy has no exposure to systematic risk. Furthermore, this result indicates independence between the portfolio assignment and systematic risk in our implementation. In sum, these findings appear anomalous with respect to market efficiency, at least as given by the five-factor model.

In addition, we estimate fundamental values based on the residual income valuation model in Gode and Ohlson (2004) via the highly flexible state-space framework. Hence, our estimation accommodates time variations in both discount rates and abnormal earnings dynamics at the firm level. Such flexibility alleviates concerns that time variations in the discount rate induce the return predictability. Moreover, since we estimate fundamental values based on a fully parametric model, the estimates rely neither on any noisy proxies for expected cash flows nor on any factor model to estimate discount rates. Finally, the state-space framework facilitates the estimation of the combined error terms in Equations 1.1 and 1.2.

In Paper II, I examine whether improvements in earnings forecasting translate into improvements in implied cost of capital estimates of expected returns. The implied cost of capital literature relies on the no-arbitrage condition, or that market prices represent the best estimates of fundamental values. Under this assumption, the implied cost of capital infers the cost of capital from the valuation function commonly based on the market prices, earnings forecasts and auxiliary assumptions (Claus and Thomas, 2001; Gebhardt *et al.*, 2001; Gode and Mohanram, 2003; Hou *et al.*, 2012; Li and Mohanram, 2014; Callen and Lyle, 2020). I estimate the implied cost of capital on a sample of U.S. stocks spanning the period 2000–2017 and evaluate the implied cost of capital estimates in both predictive return regressions and portfolio return analysis. The general result is that improvements in earnings forecasting do not translate into improvements in return predictability of the implied cost of capital estimates. Larocque and Lyle (2017) argue that instabilities in the optimization procedure could cause poor performance of the implied cost of capital. Instead, they advocate using linear models of accounting ratios for predicting returns. To examine these concerns, I estimate a simple linear regression of the future return on return-on-equity forecasts and the current book-to-market ratio. However, the general result remains. Another possible methodological issue includes the rudimentary forecasting assumption regarding the balance sheet. Moreover, the representation in Equations 1.1 and 1.2 serves as an explanatory framework as market mispricing provides another possible explanation for the results.

In addition, I attain high-performing earnings forecasting by adopting a machine learning approach similar to Gu *et al.* (2020). In particular, I implement and evaluate six popular machine learning algorithms⁴ based on a set of 194 predictor variables, including accounting, market, macro and industry variables. I show that machine learning algorithms, Gradient Boosted Regression Trees and Artificial Neural Network, can consistently outperform state-of-the-art benchmarks for up to five years ahead. This finding indicates that an earnings forecasting approach based on more flexible and nonlinear models, in conjunction with a comprehensive set of predictor variables, is preferable to parsimonious linear panel regressions.

In Paper III, I compare the performance between the implied cost of capital and factor model approaches in estimating the cost of capital in an inefficient market, where market pricing is given by Equation 1.1. I conduct the comparison in a Monte Carlo simulation experiment, where fundamental values are given by the dividend discount model in Ang and Liu (2004). Moreover, I examine different behaviors of market mispricing ranging from prices as the best estimates of fundamental values to market-wide macro inefficiencies. The

⁴ Elastic Net, Principal Component Regression, Partial Least Squares, Random Forest, Gradient Boosting and Artificial Neural Network (also known as Deep Learning).

simulation results indicate that the implied cost of capital is more robust (less sensitive to model misspecification) to market inefficiencies than the factor model approach. However, the results depend on the experimental setting and are likely best generalizable to stable, dividend-paying firms.

In addition, the study illustrates how Monte Carlo simulations can be useful for evaluating the robustness of quantitative methodologies in capital market research.

In Paper IV, I analyze investor learning of cash flow expectations in the context of market efficiency. The investor learning literature investigates how parameter uncertainty affects the fundamental values and market prices (Timmermann, 1993; Pástor and Veronesi, 2003, 2006; Pastor and Veronesi, 2009). This strand of the capital markets research aligns well with the representation above. In particular, the noise in the investor's, and thus the market's, information set causes the error terms in Equations 1.1 and 1.2. In the study, I argue that investor learning, consistent with market efficiency, must provide market prices that are both unbiased and with minimal estimator variance (*i.e.*, minimal mispricing variance). However, I highlight the estimation theoretic tradeoff between bias and estimator variance. In a simple model, I prove that this tradeoff translates into inefficiencies in market prices that can be exploited by an arbitrageur that is aware of whether market prices exhibit a bias or suboptimal estimator variance. This implication appears challenging to reconcile with market efficiency.

In addition, I derive a closed-form solution for the expected abnormal return of an investment strategy with long (short) positions in undervalued (overvalued) stocks where market prices are given by Equation 1.1, and the investment signal is based on Equation 1.2. The analysis reveals that the abnormal profitability of such an investment strategy depends on the joint distribution of the market mispricing and the measurement error.

2 The foundations of market efficiency

The original formulation of market efficiency is widely adopted in the literature. Fama (1991, p. 1575) argues that the formulation serves as a clean benchmark and that “*Each reader is then free to judge the scenarios where market efficiency is a good approximation....*” In this section, I synthesize the foundational work on market efficiency by Eugene Fama and Paul Samuelson (Fama, 1965, 1970, 1976b; Samuelson 1965, 1973). I distill two central assumptions of market efficiency: perfect learning and perfect risk assessment. Moreover, I briefly discuss the empirical testing of market efficiency and revisit the main argument supporting market efficiency, namely the arbitrage mechanism.

2.1 The original version

The efficient market hypothesis is one of the foundations of capital markets research. The intellectual origin stems from the apparent randomness in stock returns (Bachelier, 1900; Kendall, 1953; Fama, 1965; Samuelson, 1965). The most widespread definition of the hypothesis is attributed to Eugene Fama. In his literature review, Fama (1970, p. 383) states that “*A market in which prices always ‘fully reflect’ available information is called ‘efficient’.*” In his textbook, he elaborates further that: “*An efficient capital market is a market that is efficient in processing information. The prices of securities observed at any time are based on ‘correct’ evaluation of all information available at that time*” (Fama, 1976, p. 133). Moreover, Fama (1976) formalizes the information processing, or learning, in an efficient market by assuming that the market can perfectly learn the true distribution of all future returns conditional on the current information set. Fama (1976) clarifies that the reference to the “*market*” refers to the emergent behavior of market prices from the decisions and interactions of investors. While Samuelson (1965, 1973) provides less elaboration, his work relies essentially on the identical assumption that the market knows the expected values of future dividends conditional on the current information set. The assumption of perfect learning of markets is more generally known as the rational expectations hypothesis. The hypothesis was originally put forward in Muth (1961) and has since gained widespread adoption. I summarize learning in an efficient market in Assumption 1.

Assumption 1 (Perfect learning) Let dividends follow some stochastic process. Then, assume that the expectations conditioned on the information set for all stocks and future periods are known to the market. Formally,

$$\mathbb{E}[D_{i,t+\tau} | \Omega_t] \in \Omega_t \quad \tau = 1, 2, \dots, \infty \text{ and } \forall i \quad 2.1$$

where

$D_{i,t}$ = net dividend for stock i at time t

Ω_t = information set known to the market at time t

Fama (1970) assumes that equilibrium prices in an efficient market can (somehow) be stated in terms of expected returns. Fama (1970) defines such equilibrium expected return as a function of the risk in the corresponding stock over the given holding period. Similarly, Samuelson (1965, 1973) assumes that the discount rate is known. I summarize the risk assessment in an efficient market in Assumption 2.

Assumption 2 (Perfect risk assessment) Let the gross discount rate (denoted by $\mu_{i,\tau|t}$) correspond to one plus the equilibrium compensation for systematic risk, in terms of expected return, that a rational investor would require for holding stock i during the period starting at time $t + \tau$ and ending at time $t + \tau + 1$. Then, assume that the discount rates for the current and all future periods are known to the market. Formally,

$$\mu_{i,\tau|t} \in \Omega_t \quad \text{for } \tau = 0, 1, \dots, \infty \text{ and } \forall i \quad 2.2$$

where

$\mu_{i,\tau|t}$ = gross discount rate for stock i at time t for expected cash flow in period $t + \tau$ to $t + \tau + 1$

Samuelson (1965, 1973) analyzes market prices that are determined by the dividend discount model in the context of market efficiency. The dividend discount model with a time-varying discount rate and a known term structure can be represented as,

$$V_{i,t} = \sum_{\tau=1}^{\infty} \frac{\mathbb{E}[D_{i,t+\tau} | \Omega_t]}{\prod_{\kappa=0}^{\tau-1} \mu_{i,\kappa|t}} \quad 2.3$$

where

$V_{i,t}$ = fundamental value for stock i at date t

The generalized dividend discount model in Equation 2.3 can be reformulated into the more common dividend discount model with an intemporal constant by defining $\mu_{i,\kappa|t} = \mu_i \quad \forall t, \kappa$. Moreover, the dividend discount model is

often reformulated into accounting-based equivalents based on the clean surplus relation. Such accounting-based equivalents include the residual income valuation model and the abnormal earnings growth model (Feltham and Ohlson, 1995, 1996; Ohlson, 1995, 1999; Ohlson and Juettner-Nauroth, 2005). Fundamental valuation models that involve stochastic risk and a more rigorous risk adjustment can be found in Rubinstein (1976), Feltham and Ohlson (1999), and Christensen and Feltham (2009). However, Samuelson (1965, 1973) examines a market that determines prices equal to the traditional dividend discount model. The no-arbitrage condition can be represented as,

$$P_{i,t} = V_{i,t} \quad 2.4$$

where

$P_{i,t}$ = market price for stock i at time t

The dividend discount model in Equation 2.3, in conjunction with the no-arbitrage pricing condition in Equation 2.4, is ubiquitous in capital markets research (Lee, 2001; Lee and So, 2014). Samuelson (1965, 1973) proves that if a market sets prices equal to the dividend discount model and knows the conditional expectations of dividends (Assumption 1) and the term structure of discount rates (Assumption 2), then the future prices follow a martingale process for any stochastic process of dividends. Fama (1970) defines an equivalent characterization of efficient markets known as the fair game property. In particular, the fair game property asserts that the expected return for the next period must equal the current discount rate. I define the fair game property in Property 1. Formally, the abnormal return can be expressed as,

$$r_{ABN,i,t+1} = \mathbb{E}[R_{i,t+1}|\Omega_t] - \mu_{i,t} \quad 2.5$$

where

$r_{ABN,i,t}$ = abnormal return for stock i in period t

$r_{i,t}$ = return for stock i in period t

$\mu_{i,t} = \mu_{i,0|t}$ = current discount rate for stock i at time t

Property 1 (Fair game property) *In an efficient market, prices reflect the information in Ω_t such that,*

$$\mathbb{E}[r_{ABN,i,t+1}|\Omega_t] = 0 \quad 2.6$$

In addition, Fama (1970) argues that the fair game property must hold for all investment strategies. Formally, an investment strategy w can be represented as,

$$\omega(\Omega_t) = [w_1(\Omega_t), w_2(\Omega_t), \dots, w_N(\Omega_t)] \quad 2.7$$

where $w_i(\Omega_t)$ denotes the portfolio weight based on the information set Ω_t for stock $i = 1, 2, \dots, N$ at time t . Positive weights denote long positions, and negative weights denote short positions. Formally, the abnormal return generated from the investment strategy ω can be represented as,

$$r_{ABN,t+1}^{(\omega)} = \sum_{i=1}^N w_i(\Omega_t)(R_{i,t+1} - \mu_{i,t}) \quad 2.8$$

I define the fair game portfolio property in Property 2.

Property 2 (Fair game portfolio property) *Denote the set of all possible investment strategies by \mathcal{W} . In an efficient market, market prices reflect the information in Ω_t such that all possible investment strategies generate zero expected abnormal return. Formally,*

$$\mathbb{E} \left[r_{ABN,t+1}^{(\omega)} | \Omega_t \right] = 0 \quad \forall \omega \in \mathcal{W} \quad 2.9$$

2.2 Empirical testing

The fair game properties (Property 1 and Property 2) are a central implication of market efficiency that can be tested empirically. A point of contention concerns whether the abnormal return from investment strategies is attributable to either systematic risk or irrational investor behavior. Fama (1970, 1991) argue that the validity of the empirical tests of market efficiency hinges on the correct specification of an equilibrium rate of return model. Further, Fama (1991) claims that all tests of market efficiency are joint tests of market efficiency and the specification of a rate of return model. Therefore, one can never conclude if a rejection of the zero abnormal return hypothesis is attributable to market inefficiencies or misspecification of the equilibrium model, i.e., a bad-model problem. He named this problem *the joint-hypothesis problem* (Fama, 1991). However, Jarrow and Larsson (2012) argue that an equilibrium rate of return model is not required for market efficiency testing. Moreover, the problem that a hypothesis cannot be tested in isolation is not unique to market efficiency. In fact, the Duhem-Quine thesis asserts that no scientific hypothesis can be tested in isolation because all tests rely on auxiliary assump-

tions (Quine, 1951). In Paper I, we examine a test methodology based on fundamental values that does not necessitate an equilibrium rate of return model. While the testing methodology is devoid of Fama's joint hypothesis problem, the methodology is naturally subject to the Duhem-Quine thesis.

2.3 The arbitrage mechanism

Friedman (1953) and Fama (1965) argue that the self-interest of sophisticated investors is the ultimate guarantor for the efficient pricing of stocks. The argument goes: If the speculation of noise traders causes any stock to trade below (above) its fundamental value, then sophisticated investors will identify and exploit the opportunity by taking long (short) positions in the stock. Such arbitrage trading will continue until the stock price reaches an equilibrium. Friedman (1953) made an evolutionary extension of the argument. He argues that since the speculation of noise traders is unprofitable, they will eventually run out of money and become extinct in the market. Therefore, the competitive dynamics in capital markets ensure that market prices are (approximately) equal to fundamental values.

3 Market realism

Investor rationality is arguably the most debated assumption in market efficiency (Shleifer, 2000; Barberis and Thaler, 2003). However, the original theory of efficient markets rests on the additional assumptions: perfect learning, perfect risk assessment, and zero costs (over and above systematic risk) for market participants. In this section, I revisit some of the discussions regarding the additional assumptions of market efficiency. Moreover, I summarize some hindrances (or limits) of the arbitrage mechanism in actual capital markets.

3.1 A conundrum

Grossman and Stiglitz (1980) identify a fundamental contradiction in the original formulation of market efficiency. They argue that if market prices fully reflect all available information, there would be no incentive for investors to gather information. In fact, investors would be reluctant to gather information since such a gathering is costly. If no investor gathers information, then the market cannot fully reflect all the available information. In essence, they identify a free-riding problem for investors in the market. An investor can obtain the information for free from market prices rather than gather costly information.

Grossman and Stiglitz (1980) propose an alternative model for the market dynamics with both informed and uninformed investors. In their model, market prices are noisy signals of fundamental values. Moreover, they find an equilibrium point where informed investors are allowed to generate arbitrage profits in the market to compensate for the costly acquisition of information. Thus, the behavior of both the informed and the uninformed investor is rational in their model. Also, the model evades the free-rider problem since market prices only partially reflect the information. They characterize the market as being in an “*equilibrium degree of disequilibrium*” (Grossman and Stiglitz, 1980, p. 393). However, the model assumes that the investors have rational expectations or perfect learning. All in all, their analysis provides a basis for the existence of market mispricing even in rational markets.

3.2 Limits of learning

Perfect learning from noisy data is impossible. An emerging strand of research examines investor learning, for instance, Timmerman (1993), Lewellen and Shanken (2002) and Pástor and Veronesi (2003). This strand examines learning as an endogenous process, and the focus largely revolves around parameter uncertainty. The main theoretical question in investor learning concerns rational learning. In several respects, this question is shared with the statistical literature and, in particular, estimation theory. A key implication of this literature stream is that parameter uncertainty causes any estimate of fundamental value, including market prices, to deviate from fundamental values, or equivalently, a market mispricing. Following this strand of research, I analyze investor learning in the context of market efficiency in Paper IV. The analysis is based on a decision-theoretic foundation, similar to estimation theory (Lehmann and Casella, 1998). I argue that investor learning of expected cash flows results in either biased or imprecise market prices. The main motivation derives from the bias-variance tradeoff (or Stein phenomena) in estimation theory.

McLean and Pontiff (2016) take another approach in examining learning in capital markets. They study the post-publication return of 97 investment strategies that have been documented in academic journals to generate abnormal returns. They find the post-publication return is lower than the pre-publication return. This finding suggests that investors learn about arbitrage investment strategies from academic journals and exploit these opportunities. A more holistic (and also complicated) approach to analyzing investor learning would also include model misspecifications in addition to parameter uncertainty. Moreover, Timmermann and Granger (2004) propose to include such self-destruction of return predictability in the definition of market efficiency. In sum, the market mispricing and the measurement error can be attributable to two sources of imprecisions connected to learning: parameter uncertainty and model misspecification.

3.3 Limits of arbitrage

Barberis and Thaler (2003, p. 1058) state that “*Once one has granted the possibility that a security’s price can be different from its fundamental value, then one must also grant the possibility that future price movements will increase the divergence.*” They base their argument on Shleifer and Vishny (1997), who argue that the arbitrage mechanism, as outlined in Section 2.2, is unlikely to function perfectly in actual markets. While arbitrage, in theory, is both risk-free and requires no capital, in real markets, arbitrage often involves both. In particular, they argue that the risk in arbitrage is caused by a lack of perfect hedges, agency concerns due to delegated investment management, short-sale

constraints and forced liquidation. In a simplified model, Shleifer and Vishny (1997) show the limited effectiveness of the arbitrage mechanism of bringing market prices to equal fundamental values. Hence, particular conditions in the real capital market can amplify any market mispricing.

4 Market efficiency 2.0

Fama (1991, p. 1575) acknowledges that “...*the market efficiency hypothesis is surely false*” due to the existence of information and trading costs. While he provides an alternative version of the efficient market hypothesis, he does not provide any corresponding updates of the central definition, assumptions and implications. In fact, he states that the original version “...*allows me to side-step the messy problem of deciding what are reasonable information and trading costs*” (Fama, 1991, p. 1575). In this section, I outline the notion – *market efficiency 2.0*. Moreover, I discuss two analytical results from my research papers in relation to market efficiency 2.0.

4.1 Market dynamics

I take the statement “...*prices reflect information to the point where the marginal benefits of acting on information (the profits to be made) do not exceed the marginal costs*” (Fama, 1991, p. 1575) to be a starting point for defining market efficiency 2.0. In addition, I assume that the market pricing entails the possibility for all investors to be compensated for all of their costs (including systematic risk) to ensure investor rationality. Hence, market efficiency 2.0 recognizes that the operation of the market pricing mechanism is costly while maintaining the assumption of investor rationality.

The assumption of a costly market pricing mechanism gives rise to the free-rider problem identified by Grossman and Stiglitz (1980). They propose a market dynamic with investor heterogeneity and arbitrage investing as a possible solution. Moreover, Grossman and Stiglitz’s (1980) argument appears to have motivated Fama’s (1991) alternative version of the efficient market hypothesis. I adopt their proposed market dynamics in the outline of market efficiency 2.0.

Suppose there are two types of investors in the market: fundamental investors and noise traders. Let the operations of the fundamental investors include the gathering and analysis of costly information such that the investor can estimate the fundamental value of stocks. Moreover, include decision-making in the operations of the fundamental investor. The fundamental value estimates can be expressed as,

$$\hat{V}_{i,t} = V_{i,t} + \omega_{i,t} \quad 4.1$$

where

$\hat{V}_{i,t}$ = fundamental value estimate for stock i at time t

$V_{i,t}$ = fundamental value for stock i at time t

$\omega_{i,t}$ = measurement error for stock i at time t

The conceptualization of fundamental value as the equilibrium price of an omniscient and rational investor, where fundamental values conform to the no-arbitrage condition, is still valid. Such an investor would have access to an information set containing the true expectations of all future cash flows as well as appropriate risk adjustment. Denote information of such investor set by Ω_t . Moreover, assume the fundamental investors have an unbiased view of the long-term measurement errors, such that $\mathbb{E}[\omega_{i,t+\tau}|\Omega_t] = 0$ where τ denotes the long-term. In addition, let the noise traders only engage in trading activities. Moreover, the noise traders based their trading decision on the information available at zero or negligible cost, such as historical market prices. Hence, the behavior of market prices depends on the interactions and trading between the fundamental investors and the noise traders. Hence, both types of investors have some degree of pricing power. Suppose that the market prices can be expressed as,

$$P_{i,t} = V_{i,t} + \varepsilon_{i,t} \quad 4.2$$

where

$P_{i,t}$ = market price for stock i at time t

$V_{i,t}$ = fundamental value for stock i at time t

$\varepsilon_{i,t}$ = market mispricing for stock i at time t

The fundamental value estimates enable the fundamental investors to identify seemingly undervalued or overvalued stocks. Hence, the fundamental investors can pursue an investment strategy involving long (short) positions in undervalued (overvalued) stocks. Suppose that their unbiased view of the long-term measurement error and the pricing power implies that the market mispricing follows some mean-zero-reverting stochastic process, such that $\mathbb{E}[\varepsilon_{i,t+\tau}|\Omega_t] = 0$ where τ denotes the long-term. Hence, the market dynamics ensures that while market prices and fundamental values can diverge in the short-term, they converge in the long-term (Lee, 2001; Lee and So, 2014).

Assume that the costs of the fundamental investor can be separated into direct and indirect costs. The distinction between direct and indirect costs is most clearly defined in relation to the free-riding problem, where indirect costs are costs susceptible to the free-riding problem, whereas direct costs are not. Information costs are an example of indirect costs, but all indirect costs for the fundamental investors are included. Direct costs include costs related to the

trading activities, including systematic risk, commissions, bid-ask spreads *etc.* Suppose that the fundamental investor and noise trader share the same cost structure regarding direct costs. Moreover, assume that competitive forces keep the direct and the indirect costs at some minimum level. Lee and So (2014) refer to this as the joint equilibrium problem. Let the noise traders be compensated for all their costs via the expected return. I define this notion in Conjecture 1. The conventional stock return can be expressed as,⁵

$$R_{i,t} = \frac{P_{i,t} + D_{i,t}}{P_{i,t-1}} \quad 4.3$$

where

$r_{i,t}$ = stock return for stock i in period t

$D_{i,t}$ = net distributions for stock i in period t

Conjecture 1 (No low-hanging fruits) *Let \mathcal{A}_t denote the set of all available information with zero or negligible acquisition cost up to time t . In an efficient market, prices reflect the information in \mathcal{A}_t such that,*

$$\mathbb{E}[R_{i,t+1}|\mathcal{A}_t] = \mu_{i,t} \quad 4.4$$

where $\mu_{i,t}$ refers to the gross equilibrium compensation for all direct costs (including systematic risk), in terms of expected return, that a rational investor would require for holding stock i during the period starting at time t and ending time $t + 1$.

In addition, market prices reflect the information in \mathcal{A}_t such that all possible investment strategies⁶ with zero or negligible indirect costs generate zero expected abnormal return. Formally,

$$\mathbb{E}[r_{ABN,t+1}^{(w)}|\mathcal{A}_t] = 0 \quad \forall w \in \mathcal{W} \text{ such that } c_t^{(w)} = 0 \quad 4.5$$

where $c_t^{(w)}$ refers to indirect costs for the investment strategy w in period t .

Conjecture 1 is similar to the fair game properties (Property 1 and Property 2), with the caveats of zero or negligible indirect cost of the investment strategies as well as a more comprehensive definition of the discount rate.

Let the fundamental investor be compensated for their indirect costs via arbitrage, *i.e.*, an expected abnormal return. I define this notion in Conjecture

⁵ I follow the convention of denoting gross return by uppercase R and net return in lowercase r such that $R = 1 + r$.

⁶ See Equation 2.7 and 2.8 for a formal definition of investment strategy.

2. First, the decomposition of market price in Equation 4.2 allows for an analog decomposition of stock returns in Equation 4.3. Define a return metric on fundamental value as,

$$R_{FV,i,t} = \frac{V_{i,t} + D_{i,t}}{V_{i,t-1}} \quad 4.6$$

where

$r_{FV,i,t}$ = fundamental return for stock i in period t

Then the analog return decomposition can be represented as,

$$r_{i,t} = r_{FV,i,t} + r_{ABN,i,t} \quad 4.7$$

where

$r_{ABN,i,t}$ = abnormal return for stock i in period t

Conjecture 2 (Costly arbitrage) Let \mathcal{B}_t denote the set of all available information up to time t . The set includes information at zero or negligible acquisition cost as well as costly information, $\mathcal{A}_t \subset \mathcal{B}_t$. In an efficient market, prices reflect information in \mathcal{B}_t such that the expected abnormal return for all possible investment strategies based on any piece of information (or combination of information pieces), denoted \mathcal{I}_t , cannot exceed the corresponding indirect costs. Formally,

$$\mathbb{E} \left[r_{ABN,t+1}^{(\omega)} | \mathcal{I}_t \right] \leq \mathbb{E} \left[c_{t+1}^{(\omega)} | \mathcal{I}_t \right] \quad \forall (\omega, \mathcal{I}_t) \in \mathcal{W} \times \mathbb{P}(\mathcal{B}_t) \quad 4.8$$

where \times denotes the Cartesian product and $\mathbb{P}(\cdot)$ denotes the powerset.

However, the fundamental investor must have the possibility to be compensated for its indirect costs. Therefore, there must exist an investment strategy such that,

$$\mathbb{E} \left[r_{ABN,t+1}^{(\omega)} | \mathcal{B}_t \right] = \mathbb{E} \left[C_{t+1}^{(\omega)} | \mathcal{B}_t \right] \quad \exists \omega \in \mathcal{W} \quad 4.9$$

where $C_t^{(\omega)}$ refers to the aggregate indirect costs in terms of a rate of return of all fundamental investors in the market at time t .

Equation 4.8 represents a formalization of Fama's (1991) definitional statement of the alternative version of market efficiency. In Equation 4.9, note that the mere costly acquisition of information does not necessitate an expected abnormal return. Hence, the market dynamic does not rule out a quasi variant

of fundamental investors that acquires costly information but does not generate any average abnormal return. However, Conjecture 2 asserts the existence of such an investment strategy.

Fama (1970) obtains the fair game property as a mathematical implication based on his assumption, whereas this exposition provides conjectures motivated by issues with the original formulation of market efficiency and that a rational investor requires cost compensation in equilibrium. The *no low-hanging fruit* conjecture (Conjecture 1) resembles Fama's fair game property with two caveats: the investment strategies have zero indirect costs, and the discount rate compensates for all direct costs, not only systematic risk. Hence, the literature on empirical testing of the fair game property remains (approximately) valid in market efficiency 2.0. However, the market dynamics are fundamentally different between the original version and market efficiency 2.0. Market efficiency 2.0 features investor heterogeneity with noise traders and fundamental investors, while the original version assumes homogeneous investors. Moreover, the original version assumes the no-arbitrage condition, whereas market efficiency 2.0 rely on the existence of arbitrage that the fundamental investors can identify and exploit.

4.2 Potential and exploitable arbitrage

The representation of market prices in Equation 4.2 and the mean-zero-reverting mispricing introduce a potential arbitrage that an omniscient investor could fully exploit. The exposition above facilitates the derivation of the expected long-term return and long-term abnormal return of an omniscient investor. Let the expected return on fundamental value, as defined in Equation 4.6, correspond to the equilibrium rate of return defined in Equation 4.4 conditioned on the information set Ω_t . The motivation is that an omniscient and rational investor only incurs direct costs. Formally,⁷

$$\mathbb{E}[R_{FV,i,t+\tau}|\Omega_t] = \mu_{i,\tau}. \quad 4.10$$

where τ denotes the long-term. Based on the assumption of long-term convergent market prices, formally $\mathbb{E}[\varepsilon_{i,t+\tau}|\Omega_t] = 0$, an expression for the expected return can be derived as,

⁷ With a slight abuse of notation, I change the one period ahead notation to τ periods ahead. Also, multi-period returns assume that dividends are instantly reinvested (except the last dividend).

$$\begin{aligned}
\mathbb{E}[r_{ABN,i,t+\tau}|\Omega_t] &= \mathbb{E}[R_{i,t+\tau}|\Omega_t] - \mathbb{E}[R_{FV,i,t+\tau}|\Omega_t] \\
&= \mathbb{E}\left[\frac{P_{i,t+\tau} + D_{i,t+\tau}}{P_{i,t}} \middle| \Omega_t\right] - \mu_{i,\tau} \\
&= \mathbb{E}\left[\frac{V_{i,t+\tau} + \varepsilon_{i,t+\tau} + D_{i,t+\tau}}{P_{i,t}} \middle| \Omega_t\right] - \mu_{i,\tau} \\
&= \frac{\mu_{i,\tau} V_{i,t}}{P_{i,t}} - \mu_{i,\tau} \\
&= \mu_{i,\tau} \left(\frac{V_{i,t}}{P_{i,t}} - 1 \right).
\end{aligned} \tag{4.11}$$

Also,

$$\mathbb{E}[R_{i,t+\tau}|\Omega_t] = \mu_{i,\tau} \frac{V_{i,t}}{P_{i,t}}. \tag{4.12}$$

Naturally, the fair game property emerges under the no-arbitrage condition ($P_{i,t} = V_{i,t}$). In a market where prices are given by Equation 4.2, the V/P-ratio has an interactive effect with the discount rate on expected returns. The intuition is straightforward from Equation 4.12, a V/P ratio above (below) one translates to a positive (negative) abnormal return. A similar derivation appears in Papers I and III.

A more realistic question asks: Under which conditions can an investor that learns a noisy estimate of fundamental value represented in Equation 4.1 exploit the arbitrage in a market with pricing represented in Equation 4.2? In Paper IV, I analyze such a setting in a simple one-period present value model. The setting can be summarized as follows: the market sets market prices to a noisy estimate of the fundamental value, where σ denotes the standard deviation of the log-market mispricing, *i.e.*, the noise. An investor seeking arbitrage estimates a private fundamental value, also a noisy estimate, where σ denotes the standard error of the log-measurement error. Moreover, denote the correlation between log-market mispricing and log-measurement error by ρ . In addition, the investor pursues a net-zero investment strategy with long (short) positions in seemingly undervalued (overvalued) based on the signal $s_{i,T}$ that represent the difference between the investor's fundamental value estimates and the market prices. In such setting, I derive a closed-form solution of the expected abnormal return from that strategy. Formally,

$$\mathbb{E}[z_{i,T+1}|s_{i,T}] = (\sigma - \sigma \rho) \psi \tag{4.13}$$

where $\mathbb{E}[z_{i,T+1}|S_{i,T}]$ denotes the log return of a net-zero hedge investment strategy with long positions in undervalued stocks and short positions in overvalued stocks, and $\psi > 0$. See Paper IV for more details and proof.

From the analysis, I conclude that an investor can exploit the market mispricing if the investor can estimate fundamental values that are less noisy (as measured by σ) than the noise of the market (as measured by σ). In addition, the analysis also reveals an additional avenue for exploitable arbitrage. In particular, if the private fundamental value estimates are less accurate than the market prices but have low correlation (as measured by ρ), then an investor could pursue an investment strategy with a positive expected abnormal return. Hence, the exploitable arbitrage depends on the joint distribution of the stochastic process of both the market mispricing and the measurement error.

5 Concluding remarks

Fama (1991) maintains that the original formulation of market efficiency is preferable as a benchmark, being both simple and a good approximation. In this introductory chapter, I provide an alternative to this benchmark. I argue for the existence of market mispricing even in rational markets. Moreover, I identify two sources of mispricing attributable to investor learning: parameter uncertainty and model misspecification. Also, I revisit some of the arguments that particular conditions in real capital markets can amplify market mispricing. Finally, I summarize the discussion by outlining the notion of market efficiency 2.0 based on Fama's alternative definition. In particular, I formalize two conjectures: *No low-hanging fruits* and *Costly arbitrage*. I focus the analysis on the cost structure of the investors. This discussion serves as the conceptual starting point for the research papers in this dissertation. Whether the alternative framework featuring market mispricing and market efficiency 2.0 provides a "*better simplifying view of the world*" (Fama, 1991, p. 1575) is, of course, ultimately an empirical question.

References

- Ang, A. (2010) 'The Efficient Market Theory and Evidence: Implications for Active Investment Management', *Foundations and Trends® in Finance*, 5(3), pp. 157–242.
- Ang, A. and Liu, J. (2004) 'How to Discount Cashflows with Time-Varying Expected Returns', *The Journal of Finance*, 59(6), pp. 2745–2783.
- Bach, C. and Christensen, P.O. (2016) 'Consumption-based equity valuation', *Review of Accounting Studies*, 21(4), pp. 1149–1202.
- Bachelier, L. (1900) *Théorie de la spéculation*. PhD thesis. University of Paris.
- Baker, M. and Wurgler, J. (2006) 'Investor Sentiment and the Cross-Section of Stock Returns', *The Journal of Finance*, 61(4), pp. 1645–1680.
- Barberis, N. and Thaler, R. (2003) 'A Survey of Behavioral Finance', in *Handbook of the Economics of Finance*. Amsterdam: Elsevier, pp. 1053–1123.
- Buffett, W.E. (1994) 'Chairman's Letter to the Shareholders of Berkshire Hathaway Inc - 1993'.
- Callen, J.L. and Lyle, M.R. (2020) 'The term structure of implied costs of equity capital', *Review of Accounting Studies*, 25(1), pp. 342–404.
- Christensen, P.O. and Feltham, G.A. (2009) 'Equity Valuation', *Foundations and Trends in Accounting*, 4(1), pp. 1–112.
- Claus, J. and Thomas, J. (2001) 'Equity Premia as Low as Three Percent? Evidence from Analysts' Earnings Forecasts for Domestic and International Stock Markets', *The Journal of Finance*, 56(5), pp. 1629–1666.
- Cochrane, J.H. (2011) 'Presidential Address: Discount Rates', *The Journal of Finance*, 66(4), pp. 1047–1108.
- Fama, E.F. (1965) 'The Behavior of Stock-Market Prices', *The Journal of Business*, 38(1), pp. 34–105.
- Fama, E.F. (1970) 'Efficient Capital Markets: A Review of Theory and Empirical Work', *The Journal of Finance*, 25(2), pp. 383–417.
- Fama, E.F. (1976) *Foundations of Finance*. New York: Basic Books.
- Fama, E.F. (1991) 'Efficient Capital Markets: II', *The Journal of Finance*, 46(5), pp. 1575–1617.
- Fama, E.F. and French, K.R. (1992) 'The Cross-Section of Expected Stock Returns', *The Journal of Finance*, 47(2), pp. 427–465.
- Fama, E.F. and French, K.R. (2015) 'A five-factor asset pricing model', *Journal of Financial Economics*, 116(1), pp. 1–22.
- Feltham, G.A. and Ohlson, J.A. (1995) 'Valuation and Clean Surplus Accounting for Operating and Financial Activities', *Contemporary Accounting Research*, 11(2), pp. 689–731.
- Feltham, G.A. and Ohlson, J.A. (1996) 'Uncertainty Resolution and the Theory of Depreciation Measurement', *Journal of Accounting Research*, 34(2), pp. 209–234.
- Feltham, G.A. and Ohlson, J.A. (1999) 'Residual Earnings Valuation With Risk and Stochastic Interest Rates', *The Accounting Review*, 74(2), pp. 165–183.

- Frankel, R. and Lee, C.M.C. (1998) 'Accounting valuation, market expectation, and cross-sectional stock returns', *Journal of Accounting and Economics*, 25(3), pp. 283–319.
- Friedman, M. (1953) 'The Case for Flexible Exchange Rates', in *Essays in Positive Economics*. Chicago: University of Chicago Press, pp. 157–203.
- Gebhardt, W.R., Lee, C.M.C. and Swaminathan, B. (2001) 'Toward an Implied Cost of Capital', *Journal of Accounting Research*, 39(1), pp. 135–176.
- Gode, D. and Mohanram, P. (2003) 'Inferring the Cost of Capital Using the Ohlson–Juettner Model', *Review of Accounting Studies*, 8(4), pp. 399–431.
- Gode, D. and Ohlson, J. (2004) 'Accounting-Based Valuation with Changing Interest Rates', *Review of Accounting Studies*, 9(4), pp. 419–441.
- Grossman, S.J. and Stiglitz, J.E. (1980) 'On the Impossibility of Informationally Efficient Markets', *The American Economic Review*, 70(3), pp. 393–408.
- Gu, S., Kelly, B. and Xiu, D. (2020) 'Empirical Asset Pricing via Machine Learning', *The Review of Financial Studies*, 33(5), pp. 2223–2273.
- Hou, K., van Dijk, M.A. and Zhang, Y. (2012) 'The implied cost of capital: A new approach', *Journal of Accounting and Economics*, 53(3), pp. 504–526.
- Hou, K., Xue, C. and Zhang, L. (2015) 'Digesting Anomalies: An Investment Approach', *Review of Financial Studies*, 28(3), pp. 650–705.
- Hou, K., Xue, C. and Zhang, L. (2020) 'Replicating Anomalies', *The Review of Financial Studies*, 33(5), pp. 2019–2133.
- Huang, D., Jiang, F., Tu, J. and Zhou, G. (2015) 'Investor Sentiment Aligned: A Powerful Predictor of Stock Returns', *Review of Financial Studies*, 28(3), pp. 791–837.
- Hughes, J., Liu, Jing and Liu, Jun (2009) 'On the relation between expected returns and implied cost of capital', *Review of Accounting Studies*, 14(2–3), pp. 246–259.
- Jarrow, R.A. and Larsson, M. (2012) 'The Meaning of Market Efficiency', *Mathematical Finance*, 22(1), pp. 1–30.
- Jensen, M. (1978) 'Some anomalous evidence regarding market efficiency', *Journal of Financial Economics*, 6(2–3), pp. 95–101.
- Jung, J. and Shiller, R.J. (2005) 'SAMUELSON'S DICTUM AND THE STOCK MARKET', *Economic inquiry*, 43(2), pp. 221–228.
- Kendall, M.G. (1953) 'The Analysis of Economic Time-Series-Part I: Prices', *Journal of the Royal Statistical Society*, 116(1), pp. 11–34.
- Larocque, S.A. and Lyle, M.R. (2017) 'Implied Cost of Equity Capital Estimates as Predictors of Accounting Returns and Stock Returns', *Journal of Financial Reporting*, 2(1), pp. 69–93.
- Lee, C.M.C. (2001) 'Market efficiency and accounting research: a discussion of "capital market research in accounting" by S.P. Kothari', *Journal of Accounting and Economics*, 31(1–3), pp. 233–253.
- Lee, C.M.C., Myers, J. and Swaminathan, B. (1999) 'What is the Intrinsic Value of the Dow?', *The Journal of Finance*, 54(5), pp. 1693–1741.
- Lee, C.M.C. and So, E.C. (2014) 'Alphanomics: The Informational Underpinnings of Market Efficiency', *Foundations and Trends® in Accounting*, 9(2–3), pp. 59–258.
- Lehmann, E.L. and Casella, G. (1998) *Theory of Point Estimation*. Second edition. New York, USA: Springer.
- Lewellen, J. and Shanken, J. (2002) 'Learning, Asset-Pricing Tests, and Market Efficiency', *The Journal of Finance*, 57(3), pp. 1113–1145.

- Li, K. and Mohanram, P. (2019) 'Fundamental Analysis: Combining the Search for Quality with the Search for Value', *Contemporary Accounting Research*, 36(3), pp. 1263–1298.
- Li, K.K. and Mohanram, P. (2014) 'Evaluating cross-sectional forecasting models for implied cost of capital', *Review of Accounting Studies*, 19(3), pp. 1152–1185.
- Lyle, M.R., Callen, J.L. and Elliott, R.J. (2013) 'Dynamic risk, accounting-based valuation and firm fundamentals', *Review of Accounting Studies*, 18(4), pp. 899–929.
- McLean, R.D. and Pontiff, J. (2016) 'Does Academic Research Destroy Stock Return Predictability?', *The Journal of Finance*, 71(1), pp. 5–32.
- Mohanram, P.S. (2005) 'Separating winners from losers among lowbook-to-market stocks using financial statement analysis', *Review of Accounting Studies*, 10(2–3), pp. 133–170.
- Muth, J.F. (1961) 'Rational Expectations and the Theory of Price Movements', *Econometrica*, 29(3), pp. 315–335.
- Nekrasov, A. and Shroff, P.K. (2009) 'Fundamentals-Based Risk Measurement in Valuation', *The Accounting Review*, 84(6), pp. 1983–2011.
- Ohlson, J.A. (1995) 'Earnings, Book Values, and Dividends in Equity Valuation', *Contemporary Accounting Research*, 11(2), pp. 661–687.
- Ohlson, J.A. (1999) 'On Transitory Earnings', *Review of Accounting Studies*, 4(3–4), pp. 145–162.
- Ohlson, J.A. and Juettner-Nauroth, B.E. (2005) 'Expected EPS and EPS Growth as Determinants of Value', *Review of Accounting Studies*, 10(2–3), pp. 349–365.
- Pástor, L. and Veronesi, P. (2003) 'Stock Valuation and Learning about Profitability', *The Journal of Finance*, 58(5), pp. 1749–1789.
- Pástor, L. and Veronesi, P. (2006) 'Was there a Nasdaq bubble in the late 1990s?', *Journal of Financial Economics*, 81(1), pp. 61–100.
- Pastor, L. and Veronesi, P. (2009) 'Learning in Financial Markets', *Annual Review of Financial Economics*, 1(1), pp. 361–381.
- Piotroski, J.D. (2000) 'Value Investing: The Use of Historical Financial Statement Information to Separate Winners from Losers', *Journal of Accounting Research*, 38, pp. 1–41.
- Piotroski, J.D. and So, E.C. (2012) 'Identifying Expectation Errors in Value/Glamour Strategies: A Fundamental Analysis Approach', *Review of Financial Studies*, 25(9), pp. 2841–2875.
- Quine, W.V. (1951) 'Main Trends in Recent Philosophy: Two Dogmas of Empiricism', *The Philosophical Review*, 60(1), p. 20.
- Rubinstein, M. (1976) 'The valuation of uncertain income streams and the pricing of options', *The Bell Journal of Economics*, 7(2), pp. 407–425.
- Samuelson, P.A. (1965) 'Proof That Properly Anticipated Prices Fluctuate Randomly', *Management Review*, 6(2), pp. 41–49.
- Samuelson, P.A. (1973) 'Proof That Properly Discounted Present Values of Assets Vibrate Randomly', *The Bell Journal of Economics and Management Science*, 4(2), pp. 369–374.
- Shleifer, A. (2000) *Inefficient Markets: An Introduction to Behavioral Finance*. New York: Oxford University Press.
- Shleifer, A. and Vishny, R.W. (1997) 'The Limits of Arbitrage', *The Journal of Finance*, 52(1), pp. 35–55.
- Sloan, R.G. (2019) 'Fundamental Analysis Redux', *The Accounting Review*, 94(2), pp. 363–377.
- Timmermann, A. and Granger, C.W.J. (2004) 'Efficient market hypothesis and forecasting', *International Journal of Forecasting*, 20(1), pp. 15–27.

Timmermann, A.G. (1993) 'How Learning in Financial Markets Generates Excess Volatility and Predictability in Stock Prices', *The Quarterly Journal of Economics*, 108(4), pp. 1135–1145.

