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**Abstract**

Market efficiency is one of the most fundamental research topics in both economics and finance. Since (Fama Journal of Finance 25(2): 383–417, 1970) formally introduced the concept of market efficiency, studies have been developed at length to examine issues regarding the efficiency of various financial markets. In this chapter, we review elements, which are at the heart of market efficiency literature: the statistical efficiency market models, joint hypothesis testing problem, and three categories of testing literature.

**Keywords**

Autocorrelation • Hypothesis testing • Information • Market efficiency • Price formation • Random walk model • Security returns • Serial correlation (tests) • (Speculative) profits • (Sub)martingale • Trading rules

**30.1 Definition**

The simplest but economically reasonable statement of market efficiency hypothesis is that security prices at any time fully reflect all available information to the level in which the profits made based on the information do not exceed the cost of acting on such information. The cost includes the price of acquiring the information and transaction fees. When the price formation in equity market satisfies the statement, market participants cannot earn unusual profits based on the available information. This classical market efficiency definition was formally introduced by Fama (1970), and developed at length by researchers in the field.

diversified expected return theories, they can in general be expressed as follows:

$$E(\hat{p}_{i,t+1}) = [1 + E(\hat{r}_{i,t+1}|I_t)] \times p_{i,t}, \tag{30.1}$$

where  $E$  is the expected value operator;  $p_{i,t}$  is the price of security  $i$  in period  $t$ ,  $r_{i,t+1}$  is the one-period rate of return on security  $i$  in the period ending at  $t + 1$ , and  $E(r_{i,t+1}|I_t)$  is the expected rate of return conditional on information ( $I$ ) available in period  $t$ . Also, variables with hats indicate that they are random variables in period  $t$ . The market is said to be efficient, if the actual security prices are identical to their equilibrium expected values expressed in Equation 30.1. In other words, if the actual security price formation follows the market efficiency hypothesis, there would be no expected returns/profits in excess of equilibrium expected returns. For a single security, this concept can be expressed as follows:

**30.2 The Efficient Market Model**

Much of work on this line of research is based on an assumption that the condition of market equilibrium can be stated in terms of expected returns. Although there exists

$$E(\hat{Z}_{i,t+1}|I_t) = 0, \text{ and} \tag{30.2}$$

$$Z_{i,t+1} = r_{i,t+1} - E(\hat{r}_{i,t+1}|I_t),$$

where  $Z_{i,t+1}$  is the return at  $t + 1$  in excess of the equilibrium expected returns anticipated at  $t$ . This concept can also apply to the entire security market. Suppose that market

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participants use information,  $I_t$ , to allocate the amount,  $\lambda_i(I_t)$ , of funds available to each of  $n$  security that makes up the entire security market. If the price formation of each of  $n$  security follows Equation 30.2, then the total excess market value at  $t + 1$  ( $\hat{V}_{t+1}$ ) equals to zero, i.e.

$$E(\hat{V}_{t+1}|I_t) = \sum_{i=1}^n \lambda_i(I_t)E(\hat{Z}_{i,t+1}|I_t) = 0. \quad (30.3)$$

The general efficient market models of Equations 30.2 and 30.3 are the foundations for empirical work in this area. Researchers in the field largely agree that security prices “fully reflect” all available information has a direct implication: successive returns (or price changes) are independent. Consequently, researchers tend to conclude market is efficient if there are evidences that demonstrate  $E(\hat{Z}_{i,t+1}|I_t) = 0$  and  $Z_{i,t}$  is uncorrelated with  $Z_{i,t+k}$  for any value of  $k$ . Similarly, if  $E(\hat{V}_{t+1}|I_t) = 0$  and  $V_{i,t}$  is uncorrelated with  $V_{i,t+k}$  for any value of  $k$ , market is evident to be efficient.

Based on efficiency models in Equations 30.2 and 30.3, two special statistical models, submartingale and random walk, are closely related to the efficiency empirical literature. The market is said to follow a submartingale when the following condition holds:

$$E(\hat{Z}_{i,t+1}|I_t) \geq 0 \text{ for all } t \text{ and } I_t. \quad (30.4)$$

The expected returns conditional on  $I_t$  is nonnegative and has an important implication on trading rule. This means investors should hold the security once it is bought during any future period, because selling it short cannot generate larger returns. More importantly, if Equation 30.4 holds as equality, the market is said to follow a martingale. Researchers usually conclude that security prices follow “patterns” and market is inefficient when the empirical evidences are toward rejection of a martingale model.

The security prices exhibit the random walk statistical property if not only that the successive returns are independent but also that they are identically distributed. Using  $f$  to denote the density function, the random walk model can be expressed as follows:

$$f(r_{i,t+1}|I_t) = f(r_{i,t+1}) \text{ for all } t \text{ and } I_t. \quad (30.5)$$

The random walk property indicates that the return distributions would repeat themselves. Evidences on random walk property are often considered to be a stronger supportive of market efficiency hypothesis than those on (sub)martingale property.

### 30.3 The Joint Hypothesis Problem

The continuing obstacle in this line of empirical literature is that the market efficiency hypothesis per se is not testable. This is because one cannot test market efficiency hypothesis

without imposing restrictions on the behavior of expected security returns. For example, the efficiency models of Equations 30.2 and 30.3 are derived based on a joint hypothesis: (1) the market equilibrium returns (or prices) are assumed to be some functions of the information set and (2) the available information is assumed to be fully utilized by the market participants to form equilibrium returns, and thereby current security prices. As all empirical tests of market efficiency are tests of a joint hypothesis, a rejection of the hypothesis would always lead to two possible inferences: either (1) the assumed market equilibrium model has little ability to capture the security price movements or (2) the market participants use available information inefficiently. Because the possibility that a bad equilibrium model is assumed to serve as the benchmark can never be ruled out, the precise inferences about the degree of market efficiency remains impossible to identify.

## 30.4 Three Categories of Testing Literature

The empirical work on market efficiency hypothesis can be categorized into three groups. First, weak-form tests are concerned with how well past security returns (and other explanatory variables) predict future returns. Second, semi-strong-form tests focus on the issue of how fast security price responds to publicly available information. Third, strong-form tests examine whether security prices fully reflect private information.

### 30.4.1 Weak-Form Tests

Controversy about market efficiency centers on the weak-form tests. Many results from earlier works on weak-form tests come directly from the submartingale expected return model or the random walk literature. In addition, much of the earlier works consider information set as just past historic returns (or prices). The most frequently used procedure to test the weak form of efficient markets is to examine whether there is statistically significant autocorrelation in security returns using serial correlation tests. A pattern of autocorrelation in security returns is interpreted as the possibility that market is inefficient and market participants are irrational, since they do not fully exploit speculative opportunities based on the price dependence. The serial correlation tests are tests of a linear relationship between current period's returns ( $R_t$ ) and past returns ( $R_{t-1}$ ):

$$R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t, \quad (30.6)$$

where  $R_t$  is the rate of return, usually calculated as the natural logarithm first differences of the trading price (i.e.  $R_t = \ln P_t - \ln P_{t-1}$ ;  $P_t$  and  $P_{t-1}$  are the trading prices

at the end of period  $t$  and of period  $t - 1$ , respectively.),  $\alpha_0$  is the expected return unrelated to previous returns, and  $\alpha_1$  is the size of first-order autocorrelation in the rate of returns. For market efficiency hypothesis to hold,  $\alpha_1$  needs to be statistically indifferent from 0.

After conducting serial correlation analysis, Kendall (1953) concluded that market is efficient because weekly changes in 19 indices of British industrial share prices and in spot prices for cotton and wheat exhibit the random walk property. Roberts (1959) notes that similar statistical results can be found when examining weekly changes in Dow Jones Index. (See also Moore, 1962; Godfrey et al., 1964; Fama, 1965.) Some researchers later argued that the size of serial correlation in returns offers no precise implications on the extent of speculative profits available in the market. They propose that examining the profitability of various trading rules can be a more straightforward methodology for efficiency tests. A representative study that adopted this methodology was done by Alexander (1961), where he examines the profitability of various trading rules (including the well-known  $y\%$  filter rule). Despite a positive serial correlation in return series, he also discovers that  $y\%$  filter rule cannot outperform buy-and-hold rule. He thus concludes that the market is still an efficient one. Similarly, Fama and Blume (1966) find positive dependence in very short-term individual stock price of the Dow Jones Industrial index. Yet, they also suggest that market is efficient because the overall trading costs from any trading rule, aiming to utilize the price dependence to profit, is sufficiently large to eliminate the possibility that it would outperform the buy-and-hold rule. In general, results from earlier work (conducted before the 1970s) provide no evidence against efficient market hypothesis since they all report that the autocorrelations in returns are very close to 0.

As more security data becomes available, the post-1970 studies always claim that there is significant (and substantial) autocorrelation in returns. Lo and MacKinlay (1988) report that there is positive autocorrelation in weekly returns on portfolios of NYSE stocks grouped according to size. In particular, the autocorrelation appears to be stronger for portfolios of small stocks. According to Fisher's (1966) suggestion, this result could be due to the nonsynchronous trading effect. Conrad and Kaul (1988) investigate weekly returns of size-based portfolios of stocks that trade on both Wednesdays to somehow alleviate the nonsynchronous trading effect. However, as in Lo and MacKinlay (1988), they find positive autocorrelation in returns and that this pattern is stronger for portfolios of small stocks.

On another note, the post-1970 weak-form test studies focus on whether variables other than past returns can improve return predictability. Fama and French (1988) use dividend yield to forecast returns on the portfolios of NYSE stock. They find that dividend yield is helpful for return

predictability. On the other hand, Campbell and Shiller (1988) report that earnings/price ratio increases the return predictability. In summary, recent studies suggest that returns are predictable when variables other than past returns are used and the evidences seem to be against the market efficiency hypothesis that was well supported before the 1970s.

### 30.4.2 Semi-Strong-Form Tests

Each of the semi-strong-form tests is concerned with the speed of price adjustment to a particular public information event. The event can be macro-economic announcement, companies' financial reports, or announcement on stock split. The initial work in this line of research was by Fama et al. (1969), in which they studied the speed of price adjustment to the stock-split announcement. Their results show that the informational implications of a stock split are fully reflected in the price of a share at least by the end of the month, or most probably almost immediately after the day of the stock-split announcement. They therefore conclude that the stock market is efficient because the prices respond quite speedily to new public information. Waud (1970) uses residual analysis to study how fast market reacts to the Federal Reserve Bank's announcement on discount rate changes. The result suggests that market responds rapidly to the interest-rate announcement even when the Federal Reserve Board is merely trying to bring the discount rate in line with other market rates. Ball and Brown (1968) investigate the price reactions to the annual-earnings announcement. They conclude that market participants seem to have anticipated most information by the month's end, after the annual-earnings announcement. These earlier studies (prior to the 1970s), focusing on different events of public announcement, all find supportive evidences of market efficiency hypothesis. Since the 1970s, the semi-strong-form test studies have been developed at length. The usual result is that stock price adjusts within a day of the announcement being made public. Nowadays, the notation that security markets are semi-strong-form efficient is widely accepted among researchers.

### 30.4.3 Strong-Form Tests

The strong-form tests are concerned with whether prices fully reflect all available information so that no particular group of investors have monopolistic access to some information that can lead to higher expected returns than others. It is understandable that as long as some groups of investors in reality do have monopolistic access to the information, the strong-form market efficiency hypothesis

is impossible to hold. In fact, both groups of specialists, NYSE (see Niederhoffer and Osborne, 1966) and corporate insiders (see Scholes, 1969), have monopolistic access to information, and which has been documented. Since the strong-form efficiency model is impossible to satisfy, the main focus in this line of work is to assess if private information leads to abnormal expected returns, and if some investors (with private information) perform better than others because they possess more private information. The most influential work before the 1970s was by Jensen (1968, 1969) where he assessed the performance of 115 mutual funds. Jensen (1968) finds that those mutual funds under examination on average were not able to predict security prices well enough to outperform the buy-and-hold trading rule. Further, there appears no evidence suggesting that individual mutual fund performs significantly better than what we expect from random chances. Using Sharpe–Lintner theory (see Sharpe, 1964; Lintner, 1965), Jensen (1969) developed a model to evaluate the performance of portfolios of risk assets. Most importantly, he manages to derive a measure of portfolio’s “efficiency”. The empirical results show that on average the resources spent by the funds managers to better forecast security prices do not generate larger portfolio returns than what could have been earned by equivalent risk portfolios selected either by random selection trading rule or by combined investments in market portfolios and government bonds. Jensen further interprets his results that probably mutual fund managers do not have access to private information. These results are clear in line with strong-form market efficiency models because evidence suggests that current security prices have fully reflected the effects of all available information. After the 1970s, there is less of new research examining investors’ access to private information that is not reflected in security prices. Representative studies were done by Henriksson (1984) and Chang and Lewellen (1984). In tests of 116 mutual funds, Henriksson (1984) reports that there is difference between mutual fund returns and Sharpe–Lintner market line. Similarly, Chang and Lewellen (1984) note that examination of mutual fund returns show no supportive evidence of fund managers’ superior selection abilities. In short, recent studies largely agree to prior literature’s view that investors with private information are unable to outperform a passive investment strategy. Evidences are still in favor of the existence of market efficiency hypothesis.

### Conclusion

This review has been brief and so various issues related to market efficient model have not been considered. Volatility tests of market efficiency, and cross-sectional return predictability based on various asset pricing models are

just some of the omitted issues. For more details, readers are referred to two excellent market efficiency survey papers by Fama (1970, 1991).

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