Capital Market Efficiency

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1. CHARACTERIZATION OF EFFICIENCY

Capital markets exist because the transfer of funds that they make possible has a positive effect on welfare. The more efficient capital markets are in transfering funds from those who have them in excess to those who are short of them the more positive is their effect on welfare.

Perfect capital markets An idealized capital market that would achieve maximum welfare is known as "perfect capital market", and is usually defined as requiring the following characteristics (Copeland and Weston (1988)) : (a) perfect competition in all markets including the product market, what means that goods and services are produced at minimum average cost and all market participants are price takers ; (b) frictionlessness, that is, there are no transaction costs, taxes or regulations that restrict trading prices or volumes; the trading is instantaneous and all assets should be perfectly divisible; (c) perfect information, that is, information is complete, homogeneous (interpreted in the same way by all), free and received simultaneously by all market participants ; (d) utility maximization by all consumers and profit maximization by all firms ; and (e) rationality by all market participants in pursuing their objectives.

A perfect capital market is then a market that is allocationally,

* I am grateful to the advice given by professors T. Kitaoka, S. Komura and K. Maekawa. Needless to say that any mistakes are all of my making only.

operationally and informationally efficient and rational.

Allocative efficiency It can be shown that savers, after exhausting all their productive investment opportunities with expected returns greater than a certain lending rate, will be better off if they lend their excess funds at that rate than if they invest in productive assets with a lower rate of return. Investors, on the other hand, after exhausting all their funds, still have an excess of investment opportunities with expected returns greater than the borrowing rate. They will be better off if they borrow the necessary funds at the borrowing rate to undertake those investment opportunities. Savers, those with an amount of funds larger than investment opportunities, can become lenders with the existence of financial markets. Likewise, investors, those with a larger amount of investment opportunities than funds, can become borrowers. In this way, both savers and investors become better off with the existence of capital markets.

Operational efficiency and frictionlessness Operational efficiency of a market is related to the cost of transacting in that market. The more it costs to make a transaction the less operationally efficient is that market. In capital markets, that cost typically consists of a commission paid to a broker and a tax on the value of the transaction. Taxes that, for example, discriminate against short holding periods make the transaction of recently bought stocks more expensive and thus also add to the other transaction costs.

Frictionlessness implies not only operational efficiency (no transaction costs) but also that no restriction exists on the price, volume or timing of any possible transaction. In an ideal frictionless market any two parties would be able to transact at any price, for any number of securities, at any time they wished, at no transaction costs. This means that there would not exist regulations limiting the rate of change of prices (the amount a stock price is allowed to vary during a certain time period, usually one day), or the volume of stocks transactioned (minimum or maximum number of shares allowed per transaction) or the time or timing of a transaction (rules mandating that shares of company B must be traded after those of company A, or that all trades must occur only once or twice a day, etc.).

The more frictionless capital markets are, the faster can prices adjust to their true value and the faster can necessary adjustments to consumption and production take place. Thus frictionlessness enhances allocational efficiency and welfare.

Informational efficiency and perfect information Informational efficiency can be defined in several different ways. However, a fairly simple and standard definition requires that prices reflect completely and instantaneously all available relevant information.

Perfect information exists when information is complete (all relevant facts are made known), homogeneous (a piece of information means the same to everybody, that is to say, nobody has a better way of evaluating information), free (no cost in producing, no price to pay) and received at the same time by all market participants.

Capital markets can possibly be informationally efficient without information being perfect. As long as prices fully reflect all information, information does not need to be perfect: Cornell and Roll (1981), for example, show that an informationally efficient market can exist with costly information : in equilibrium, those who pay for more information achieve higher gross rates of return but everyone earns the same (zero) net rate of return.

Informational efficiency also does not require nor imply frictionlessness or even operational efficiency. Fama (1970), for example, argued that as long as "transactors take account of all available information, even large transactions costs that inhibit the flow of transactions do not in themselves imply that when transactions do take place, prices will not fully reflect available information" .

Efficient capital markets and perfect capital markets Perfect capital markets were defined above as requiring perfect competition, frictionlessness, perfect information and rationality and it can be shown that they are instrumental in achieving allocative efficiency.

Although the word "efficiency" was often used and several types of efficiency were defined, the concept of efficient capital markets (for simplicity, efficient markets) has not yet been touched. This concept will be presented in more detail later but a distiction should be made now. Efficient capital markets can have two different usages with different meanings. One more specialized usage considers efficient capital markets as informationally efficient : the question is whether prices fully and accurately reflect all available relevant information or not (Fama (1970)). This is the usage found in most of the finance literature. The other view of efficient capital markets is more comprehensive : the essential question is whether capital markets contribute positively to allocative efficiency or not, or to put it in another way, whether they have any role to play or any influence in the allocative process or not (Copeland and Weston (1988)); operational and informational efficiency are just instrumental requirements for that end. The two meanings are not incompatible : actually one is used as a proxy for the other in the "measures" of how efficient real markets actually are. However, although the extensive use of "market efficiency" as informational efficiency is justified by the especialized and focussed character of most finance literature, it is poorer in economic meaning : if informational efficiency were not instrumental to the achievement of allocative efficiency it would not be of much interest to economic theory.

Even taking the broader meaning of efficient markets it is obvious that perfect and efficient capital markets are two different concepts. Let's make the distinction between the two clear.

First, imperfect competition in product markets does not impede the existence of efficient capital markets: a firm can reap monopoly or oligopoly profits in the product market and still an efficient capital market determine the firm's stock price in a way that fully reflects the present value of the expected stream of monopoly profits. The allocative ineficiencies that arise in this situation are due to causes that have no direct relation with capital markets being efficient or not. As long as capital markets contribute positively to the general welfare by allowing the tranfer of resources (not by making the transfer of resources actually happen) from low to higher productive uses they can be considered efficient. Thus, allocative inefficiencies in product markets are compatible with efficient capital markets.

Then, even if capital markets are not frictionless they can still be efficient: prices will reflect all available information and capital markets will perform their function of transfering funds even if there are costs associated with those transfers. However, limits to the quantity of funds (shares) traded or to their prices (or their rate of change) will limit both the ability of prices to reflect information and the ability of capital markets to transfer funds.

Finally, it is not necessary to have perfect information in efficient capital markets. For example, costly information is compatible with efficient capital markets (Cornell and Ross (1981)).

From now on when refering to efficiency we shall take the narrower meaning of informational efficiency.

2. EVOLUTION OF THE CONCEPT OF EFFICIENT CAPITAL MARKETS

Random walks and fundamental values The emergence of the concepts related to the efficient capital markets hypothesis can be dated back to the 1930s. In 1933 Cowles reported that recomendations by brokerage houses did not outperform the market and, in 1934, Working suggested that random walks have patterns that look like those found in stock prices.

Against these sugestions that the analysis of brokers (or any analysis) is not usefull and that stock prices are random, in 1934 Graham and Dodd (in "Security Analysis") and in 1938 Williams (in "The Theory of Investment Value") popularized the concept, developed by Fisher, of fundamental or intinsic value. According to this concept an asset's price should equal the discounted value of the cash-flow arising from it.

Although Graham and Dodd's and Williams' arguments won the acceptance of many (especially in the securities industry), other studies found that stock prices were random. In 1953 Kendal in a statistical study found that stock prices follow a random walk and, in 1963, Granger and Morgenstern found the same using spectral analysis.

Until about this time the random walk model seemed to contradict the idea that stock prices have a fundamental (rational) value. How could a price that reflects a fundamental value behave in a random fashion? In 1959 Roberts gave a first step in solving the contradiction between the two views. He defended that an idealized market of rational individuals should show instantaneous adjustment of prices to the arrival of new information. Because the arrival of new information is random, prices in reflecting it should also behave randomly. The alternative, a systematic slow adjustment of prices to new information, would imply the existence of profitable trading opportunities that were not being exploited - something incompatible with the existence of profit maximizers.

Although backed by empirical evidence and by the above argument, the random walk hypothesis remained somewhat allien to mainstream economic theory. Several problems remained that needed harmonization. For example, how to make the relation between random walk prices and the framework of demand and supply (with preferences and technology) ? What allocative porpose serve random prices for?

Martingale models The contradiction between the random and the fundamentalist views was solved and the possibility of an economic interpretation was offered by Samuelson ((1965) and (1973)). Samuelson showed that if future dividends are random variables generated according a martingale process with respect to the information sequence $\{\phi_t\}$, then the expected present value of those dividends (that is, the stock's price) given information ϕ_t should also behave according to that process.

In this way the differences between the random walk and fundamentalist views was bridged. Stock prices can be determined according to their fundamental value of discounted future dividends and still present their observed random characteristics if dividends also follow a random process. And although prices behave randomly their formation can be explained by economic theory.

Fama's definitions The most widely used definition of market efficiency was presented by Fama (1970), following the definition given by Harry Roberts in an unpublished paper in 1967 : a capital market in which prices always fully reflect the available information in a given set ϕ is called efficient. Depending on what type of information is contained in set ϕ three types of efficiency can be distinguished : (a) weak-form efficiency when the information set contains only past prices and returns ; (b) semistrong-form efficiency when the information set contains any publicly available information; (c) strong-form efficiency when the information set contains all information, publicly available or not.

With this definition and the assumption that the conditions of market equilibrium can be stated in terms of expected returns, Fama drew out the implication that inovations (the difference between the observed value and the expected value that was projected a period before on the basis of the information then available) in stock prices and returns are fair games. A problem with this characterization of market efficiency is that it is tautological (LeRoy (1976), (1989)) : inovations are always fair games.

Later, Fama (1976) proposed a different definition of capital market efficiency. A capital market is efficient if : (a) it takes in account all information relevant to the determination of securities prices ; (b) it has rational expectations.

This definition implies that the market not only uses all relevant information to determine securities prices, but also that it uses it correctly. As pointed out by LeRoy (1989) if "the market's" information means that everybody in that market has the same information, then of course the market must be informationally efficient.

The Rubinstein-Latham definition According to the definitions given by Fama ((1970) and (1976)), if a market is efficient with respect to some information, then security prices should be unaffected by revealing that information to the market participants. Rubinstein (1975) and Latham (1985) proposed that the definition of market efficiency be made according to whether the revelation of information causes portfolio changes or not. For a market to be efficient in the Rubinstein-Latham sense prices and portfolio composition should reflect all relevant information. If, for example, a piece of information does not cause the price of a security to change but causes transactions to occur (because people disagree about the implications of that piece of information and adjust their portfolios accordingly) then the market, although efficient in Fama's sense, is not efficient in the Rubinstein-Latham sense.

LeRoy's insight LeRoy (1989) presents the theory of efficient capital markets as being just the theory of competitive equilibrium applied to financial markets. Its counterpart in international economics would be the principle of comparative advantage of David Ricardo. According to this view, what provides a rationale to profitable trading of securities is not information that is generally available but the existence of differences in information possessed by investors. As absolute advantage fails as a rationale for the existence of international trade, information widely held cannot explain the existence of trade (for profit reasons) in securities. But in the same way as comparative advantage can explain the existence of international trade, so can differences in information serve as a rationale for trade in securities.

According to this view of market efficiency, financial prices are determined in consonance to the conditions of equilibrium in competitive markets by the actions of rational agents.

3. EMPIRICAL TESTS OF THE EFFICIENT CAPITAL MARKETS HYPOTHESIS

Definition of random walks, martingales and fair games A sucession of stock prices P_t follows a random walk process if their probability distribution given a sucession of information sets ϕ_t is the same as their inconditional distribution. As for the first moment:

$$E[\ P_{t+s}\ ] = E[\ P_{t+s} \mid \phi_t\ ] \qquad (3-1)$$

for all $s > 0$. This requires that each sucessive change in the value of P_t (each sucessive return) is drawn independently from a probability distribution with zero mean and constant variance. Thus, P_t can be determined by the following process :

$$P_t = P_{t-1} + \varepsilon_t \tag{3-2}$$

with $E[\varepsilon_t]=0$ and $E[\varepsilon_t \ \varepsilon_{t-s}]=0$ for all $s \neq 0$. Assuming that the information set ϕ_t includes all past prices (and only that) forecasts of P_{t+s} ($s > 0$) (denoted by $\hat{}$) at time t are given by:

$$\hat{P}_{t+s} = E[\ P_{t+s} \mid P_t, P_{t-1}, \ldots, \ P_1 \ ] = P_t$$

with variance of forecast error equal to

$$E[\varepsilon_{t+s}{}^2] = s\ \sigma_\varepsilon^2$$

Thus, the standard error of forecast increases with the square root of s. Because stock prices have a long run tendency to increase (have an upward trend) a drift can be added in equation (3-2) :

$$P_t = P_{t-1} + d + \varepsilon_t \tag{3-3}$$

Now the s-period forecast is:

$$\hat{P}_{t+s} = E[\ P_{t+s} \mid P_t, P_{t-1}, \ldots ,P_1\ ] = P_t + s \cdot d$$

with standard error of forecast remainig the same as before.

Stock prices P_t follow a martingale process with respect to a sucession of information sets ϕ_t when:

$$E[\ P_{t+1}\ \mid\ \phi_t\ ]\ =\ P_t \qquad (3-4)$$

and a submartingale process when:

$$E[\ P_{t+1}\ \mid\ \phi_t\ ]\ \geqq\ P_t \qquad (3-5)$$

The price change $\Delta P_{t+1} = P_{t+1} - P_t$ is a fair game if

$$E[\ \Delta P_{t+1}\ \mid\ \phi_t\ ]\ =\ 0 \qquad (3-6)$$

If the stochastic process ΔP_{t+1} is a fair game then P_t is a martingale. Fair game and martingale models, contrary to random walks, make no restrictions on the variance of the distribution of stock prices and thus the nonstationarity of the variance of stock prices is not a problem. Random walks require the sequence of P_t's to be independent events from the same distribution, what implies that serial covariances between prices for any lag must be zero; fair games and martingales do not make that restriction.

The above definitions of martingales (3-4), submartingales (3-5) and fair games (4-6) could have been made for stock returns instead of stock prices.

The fundamental model and martingales Expected rate of return is defined as being equal to the expected rate of capital gain plus the dividend yield:

$$E[\, r_t \mid \phi_t \,] = \frac{E[\, P_{t+1} \mid \phi_t \,] - P_t}{P_t} + \frac{d_t}{P_t} \qquad (3-7)$$

where P_t is the price of a stock at the beginning of the time period t and d_t is the dividend paid at the end of time t.

If risk neutral individuals can arbitrage between stocks and a riskless asset that pays a rate of return ρ_t (that sometimes is assumed to be constant over time: $\rho_t = \rho$ for all t) then $E[r_t \mid \phi_t] = \rho_t$ and the above equation becomes:

$$\frac{E[\, P_{t+1} \mid \phi_t \,] - P_t}{P_t} + \frac{d_t}{P_t} = \rho_t \qquad (3-8)$$

Rearranging terms equation (3-8) becomes an expectational difference equation:

$$P_t = (\, 1 + \rho_t \,)^{-1} (\, E[\, P_{t+1} \mid \phi_t \,] + d_t) \qquad (3-9)$$

Equation (3-9) expresses that the stock price today equals the sum of the expected future price and dividends discounted back to the present at rate r_t. By writing equation (3-9) at time t+1, taking expectations of both sides conditional on the information available at time t, using the law of iterated expectations (which states that for any P: $E[\, E[P \mid \phi_{t+1}] \mid \phi_t] = E[P \mid \phi_t]$), substituting this result back in equation (3-9) and solving recursively up to infinity, results that stock prices equal the expected present value of future dividends:

$$P_t = \sum_{i=0}^{\infty} (\, E[\, d_{t+i} \mid \phi_t \,] \,/\, \prod_{j=0}^{i} (1 + \rho_{t+j})) \qquad (3-10)$$

provided that the following transversality condition is satisfied:

$$\lim_{i \to \infty} E[\ P_{t+i}\ |\ \phi_t\ ]\ /\ \prod_{j=0}^{i} (1 + \rho_{t+j}) = 0$$

Equation (3-10) is the result arrived at by Samuelson ((1965) and (1973)) and holds when agents have common and constant time preference, have common probabilities and are risk neutral. It implies that if the sequence $\{d_t, d_{t+1}, \ldots\}$ has the martingale property of equation (3-4) (applied to dividends) then stock prices will also follow a martingale process.

If agents have common and constant time preferences, have common probabilities and are risk neutral then they will prefer to hold the asset that has the highest expected return, ignoring differences in risk. Because in equilibrium all assets are held willingly any two assets must have the same expected rate of return. Thus, as implied in the above equation (3-8), holding stocks or holding a riskless asset is a fair game: no asset has higher expected return than the other. The difference between the rate of return of a stock r_t and the rate of return of the riskless asset ρ_t is then a fair game:

$$E[\ r_{r+1} - \rho_{t+1}\ |\ \phi_t\ ]\ = 0 \qquad (3-11)$$

This is equivalent to say that prices plus reinvested dividends follow a martingale (LeRoy (1989)). To see this let v_t be the discounted value at time zero of the value at time t of an initial share plus its reinvested dividends, and h_t the number of shares at time t whose value is equal to the value of the initial share plus its reinvested dividends. Then, the value of v_t is equal to:

$$v_t = P_t \, h_t \, / \prod_{i=0}^{t} (1 + \rho_i) \qquad (3-12)$$

and the value of h_{t+1} satisfies:

$$P_{t+1} \, h_{t+1} = (P_{t+1} + d_t) \, h_t \qquad (3-13)$$

Let's consider now the expected value at time t of v_{t+1}:

$$E[\, v_{t+1} \mid \phi_t \,] = E[\, P_{t+1} \, h_{t+1} \, / \prod_{i=0}^{t+1} (1 + \rho_i) \mid \phi_t \,]$$

$$= E[\, (P_{t+1} + d_t) \, h_t \, / \prod_{i=0}^{t+1} (1 + \rho_i) \mid \phi_t \,]$$

$$= P_t \, h_t \, / \prod_{i=0}^{t} (1 + \rho_i) = v_t \qquad (3-14)$$

In equation (3-14), after taking expectations, equations (3-13) and (3-9) were used successively to show that a series of prices plus reinvested divideds follows a martingale.

Risk neutrality implies that if returns are a fair game (equation (3-11)) then prices plus reinvested dividends are a martingale, but it does not imply the more restrictive random walk model. If, as risk neutrality implies, individuals do not pay attention to the higher moments of their return distributions they will not bid away any serial dependence in the higher conditional moments of returns that might exist. Therefore risk neutrality is compatible with nonzero serial correlation in conditional variances because no one cares about these variances.

Statistical tests (unadjusted for risk) of weak form efficiency Many tests, that did not take in consideration risk, were utilized in testing the weak form efficiency hypothesis. Some are here reviewed (for a more detailed review see Copeland and Weston (1988)).

(a) Linear relationships - The first tests performed examined whether price changes are linearly related over time. A possible specification of such test is:

$$P_t - P_{t-1} = \alpha + \beta (P_{t-T} - P_{t-1-T}) + \varepsilon_t \qquad (3-15)$$

where the term α, called drift, measures the expected change in price unrelated to the the previous price change. As long as stocks have a positive expected capital gain α should be positive. The term β measures the relationship between two price changes, between one occuring at time t and another at time t-T . If T=1 then it measures the relationship between two consecutive price changes; if T=2 it measures the relationship between a price change and the price change that occured two periods previously; and so on. ε_t is a random variable assumed to be normally independent and identically distributed with mean value of zero. It incorporates the variability of the current price change not related to the previous price change.

Another approach to test the linear relationship between stock prices is to use the natural logarithm of price relatives as in the next equation:

$$\ln(P_t/P_{t-1}) = \alpha + \beta \ln(P_{t-T}/P_{t-1-T}) + \varepsilon_t \qquad (3-16)$$

Using this later approach Fama (1965) showed that the serial correlations for T=1, 2, 3, 4, 5 were significantly different from zero for, respectively, 11, 9, 4, 4, 3 out of the 30 of the Dow Jones Industrials. Furthermore, 22 of the 30 estimated serial correlations were positive for T=1. This, together with other similar evidence collected by others (see Dos Santos

(1992)), shows that security returns are not random walks, but martingales or sub-martingales instead.

(b) Runs - The previous test has an important drawback: estimated β tends to be heavily influenced by extreme observations. An alternative test that eliminates the effect of very large observations consists of examinating the sign of prices changes. Let a price increase is designated by + , a price decrease by - and a no change by 0. A sequence of the same sign is called a run. Then, if price changes are positively related, it is more probable that a + be followed by a + than by a - , and a - by a - than by a + . In fact, if there is a positive correlation between price changes then there should exist more long sequences of + and - than could be attributed to chance; thus, there should also be fewer runs than if price changes were generated by chance. If there is a negative correlation, then there should be too many short sequences and too many runs. Because runs tests depend only on the sign of the change, it is irrelevant whether price differences, or logarithms of price relatives or rates of return are used.

Fama (1965) found that for one-day intervals there were somewhat fewer runs than it would be expected if prices were random, and that for longer intervals the actual number of runs was in every case almost exactly equal to the theoretically expected number. This is interpreted as evidence of a small positive relationship between the log of successive price relatives. Fama (1970) reviews the runs tests performed by Niederhoffer and Osborne.

(c) Spectral analysis - Using the Fourier transformation it tries to find cycles in stock prices. Such cycles, if found, would constitute evidence against the efficient market hypothesis. Granger and Morgenstern, who did the most work in this field, did find evidence of slight monthly and seasonal cycles.

(d) Filter rules - Filter rules, by assuming that there are systematic patterns in the movements of prices over time, specify buying and selling rules that are supposed to make profits to those who use them. A y % filter rule is: if the price of a stock rises y% buy and hold it until it falls y% and then sell and go short of it. Keep the short position until the price rises y% when the short position should be covered and a long position opened.

Fama (1970) reviews works by Alexander and Fama and Blume (1966). In general, the tests performed show that, even before subtracting transaction costs, filters greater than 1.5% do not do better than a simple buy-and-hold strategy; filters smaller than 1.5% make generally very small gross profits that are better than the market average because trading is very frequent; but net profits are null. Also, because all the securities tested had average positive returns, another inference from the results of filter tests is that stock prices seem to follow a submartingale.

Statistical tests (adjusted for risk) of weak form efficiency These statistical tests use some model (usually the CAPM) to remove the risk-premium component of asset returns. Several sophisticated empirical tests seem to give support to the joint hypothesis that capital markets are efficient and the CAPM is the "true" model.

Weak form efficiency anomalies Besides the ones mentioned above, seasonal patterns have recently been found in stock prices that are inconsistent with the weak form of the efficient markets hypothesis. Following are some examples of calendar-based anomalies.

(a) The January effect - Stock returns seem to be abnormally high during the first few days of January and especially so for small firms. This is a pattern that is inconsistent with the efficient markets hypothesis. Its non stationarity is also inconsistent with the martingale model (Thaler (1987)).

(b) The weekend effect - Average stock returns seem to be consistently negative from the close of trading on Friday to the close of trading on Monday (French (1980)).

(c) The Wednesday effect - In to order to facilitate the processing of orders at brokerage houses the New York Stock Exchange was closed on Wednesdays in 1968. It was found by French and Roll (1986) that the volatility of prices was lower from Tuesday to Thursday than over other two-day intervals. This suggests that stock prices fluctuate more when markets are open than when they are closed what is incompatible with the reasonable assumption that as much news about fundamentals is generated on Wednesdays as in any other weekday. Thus it seems that it is the trading process itself rather than the arrival of news about fundamentals that generates much of the prices changes.

(d) The turn of the month effect - It was found by Ariel (1987) that the returns are in average higher during the the last day and first days of each month.

Other anomalies are performance related:

(e) The P-E anomaly - Stocks with low price-earnings ratios appear to outperform systematically those with high price-earnings ratios.

(f) The losers anomaly - Stocks that suffer large drops in price appear to outperform systematically those who did not suffer drops in price.

(g) The price to book value anomaly - Stocks with low price to book value value ratio seem to outperform those with higher ratios.

(h) The small firm anomaly - Stocks of small firms appear to outperform systetematically those of larger firms. Evidence was found that links this anomaly to the the January anomaly.

These results may suffer from a selection bias problem: odd results are published because they are odd but confirmation of absence of an anomaly is not even submited to publication because it does not constitute "new" or "original" research. Consider, for example, the following anomaly: stock prices depend on the weather. If no correlation is found between stock prices and the weather no results will be published; but if a corelation is found then it will.

Other evidence that seems to contradict the weak form of the efficient markets hypothesis also exists. One of these is known as "winner's curse" (Thaler (1988)) : in an auction market, those with inflated opinions of an asset's value will be the ones that will get it but they will also tend to overpay. This anomality attacks the market efficiency hypothesis through the rationality side of the hypothesis. If market participants were rational, each bidder's strategy would make allowance for the possibility that his appraisal of the asset's value was biased.

Another fact also pointed as evidence against the efficient capital markets hypothesis is the high volume of trade in organized securities exchanges. Tirole (1982) showed that if rational agents with asymmetric information but common priors are risk averters then they will not trade securities based on a naive interpretation of their private information. This is because they are aware that someone else with different but perhaps equally accurate information is willing to take the other side of the trade. This kind of transactions is a zero-sum game for the typical individual and constitute pure risk uncompensated by positive expected gain.

Variance bounds tests Besides the anomalies presented above other more serious evidence against the weak form of the market efficiency hypothesis exists: the results of several variance bounds tests (also called excess volatility or Shiller tests). These tests were developed independently by Shiller (1981b) and LeRoy and Porter (1981).

We can start by noticing that the expectational difference equation (3-9) can be rewritten as (assuming that $\rho_t = \rho$ for all t):

$$P_t = (1+\rho)^{-1} (P_{t+1} + d_t) - (1+\rho)^{-1} \delta_{t+1} P_{t+1} \qquad (3-17)$$

where δ_t is an inovation operator defined as:

$$\delta_{t+1} P_{t+1} = E[P_{t+1} \mid \phi_{t+1}] - E[P_{t+1} \mid \phi_t]$$

The second term of the right-hand side of equation (3-17) is the unexpected component of the one-period return on stock.

Then, replacing t by t+i in equation (3-17) and multiplying both sides by $(1+\rho)^{-i}$ we get:

$$(1+\rho)^{-i} P_{t+i} = (1+\rho)^{-(i+1)} (P_{t+i+1} + d_{t+i}) - (1+\rho)^{-(i+1)} \delta_{t+i+1} P_{t+i+1} \qquad (3-18)$$

Summing equation (3-18) over i from zero to infinity and assuming convergence it results:

$$P^*_t = P_t + e_t \qquad (3-19)$$

where

$$P^*_t = \sum_{i=0}^{\infty} (1+\rho)^{-(i+1)} d_{t+i} \qquad \text{and} \qquad e_t = \sum_{i=1}^{\infty} (1+\rho)^{-i} \delta_{t+i} P_{t+i}$$

P_t^* is the perfect foresight (or, as Shiller calls it, the "ex-post rational") stock price, the price that would result if future dividends were perfectly forecastable. e_t, the difference between the ex-post rational and the actual price, is equal to the discounted sum of the unexpected component of future returns. Equation (3-19) expresses P_t^* as the sum of a forecast, P_t, and a forecast error, e_t.

Taking conditional expectations, equation (3-19) yelds:

$$P_t = E\ [P_t^* \mid \phi_t] \tag{3-20}$$

what means that P_t is a forecast of P_t^* given the information ϕ_t agents have available.

Optimal forecasting implies that forecasts and forecast errors are uncorrelated, what implies that:

$$Var(P_t^*) = Var(P_t) + Var(e_t) \tag{3-21}$$

Because variances are always nonnegative $Var(P_t^*)$ constitutes an upper bound for $Var(P_t)$:

$$Var(P_t^*) \geqq Var(P_t) \tag{3-22}$$

The above variance inequality (usually refered as the Shiller test) depends only on the dividends model and the discount factor, but not on the information sets ϕ_t of the agents. Thus, rejection of (3-22) unambiguously implies the rejection of the fundamental model irrespective of the specification of the information sets of the agents. Shiller (1981b) tested the above variance inequality for two annual series, the Standard and Poor Composite Stock Composite Index (1871-1979) and a modified Down Jones Industrial Average (1928-1979) , and found that it was reversed for the two data sets used. LeRoy and Porter (1981) using quarterly data (1955-1973) of the Standard & Poor's Composite Index and three large companies also found that (3-22) was violated when using earnings instead of dividends. Ueda et al. (1986) using annual data (1949-1985) and Hoshi (1987) using mensal data

(1952-1981) found that (3-22) was also violated for Japanese data (Topix).

Using mensal data for the Topix for the period from December 1973 to December 1992 inequality (3-22) was found again to be violated. First, the "Total Dividends Paid in the Tokyo Stock Exchange" time series was deseasonalized using a Fourier transformation (employing "RATS Ver 4.1"). The deseasonalized Total Dividends series was then multiplied by the mensal series consisting of the ratio of Topix to Market Capitalization to get a dividend index comparable to Topix. Both the dividend index and Topix were then deflated using the Consumer Price Index to obtain real dividends and real stock prices. The long-run exponential growth path of real stock prices was found by regressing their natural logarithm on a constant and time and then it was used to detrend

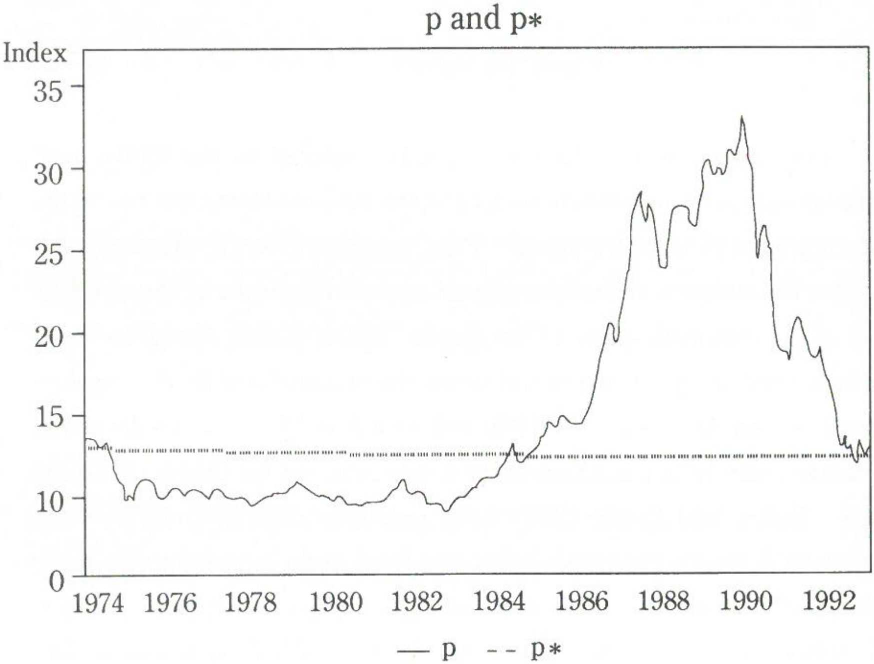

Figure 1

both real stock prices and dividends. A discount rate was estimated by dividing the average real dividend by the average real price ($r = 0.9\%$ in annual terms). The terminal value of the ex-post rational stock price P_t^* (December 1992) was assumed to equal the terminal detrended real stock price P_t. P_t^* was then calculated backwards from the terminal date using the relation $P_t^* = (1+r)^{-1}(P_{t+1}^* + d_t)$. The standard deviation was then computed to the P_t and P_t^* series yielding respectively 6.777 and 0.1259, resulting in the violation of inequality (3-22). The plot of P_t and P_t^* (presented in figure 1) shows clearly that P_t is more volatile than P_t^*. Notice that the short time span of this particular test (less than twenty years) as well the very low estimated discount rate both have some infuence in the result obtained for the standard deviation of P_t^* and its almost straight line representation in figure 1.

However, the above variance bounds test suffers from serious econometric problems. Flavin (1983) demonstrated that small sample distributions led to downward bias of the estimated variances of both P_t^* and P_t in Shiller (1981b), with the bias in the former exceeding that in the later. If the stock price time series is autorrelated the usual procedure of correcting the downward bias of the estimated variance due to the necessity of calculating the sample mean (reducing the number of degrees of freedom by one) is not enough. This problem leads to a high probability of occurrence of type I error: the Shiller test rejects the capital markets efficiency hypothesis with probability 0.999 even when the hypothesis is true.

Kleidon (1986), focusing on the statistical consequences of violation of the stationarity assumption showed that if dividends have unit roots, problems similar to those pointed by Flavin (1983) could remain even in very large samples. Marsh and Merton (1986) also attack Shiller's tests by focussing the assumption of stationarity of the dividend process and construct an example of an efficient market that violates equation (3-22).

Shiller (1981a) developed also other two variance bounds tests whose results, reported in Shiller (1981b), were also negative to the capital markets efficiency hypothesis. They are (for the derivation see Shiller (1981a)):

$$Var(\triangle P) \leqq Var(d)/\sqrt{2r} \tag{3-23}$$

and

$$Var(\triangle P) \leqq Var(d) \cdot \sqrt{(1+2r)/2r^3} \tag{3-24}$$

where $r_t = r$ for all r .

Another variance bounds test was developed by Mankiw, Romer and Shapiro (1985). This test, to avoid the small sample bias, tests the variance bounds inequality using variances around some other point than the sample mean. Suppose that P_t^0 is some "naive" forecast of P_t^*:

$$P_t^0 = \sum_{i=0}^{\infty} \gamma^{i+1} F_t d_{t+i} \tag{3-25}$$

where $\gamma = 1/(1+r)$ and $F_t d_{t+i}$ denotes a naive forecast made at time t. This naive forecast need not be a rational one. By subtracting and adding p_t we have the identity:

$$P_t^* - P_t^0 = (P_t^* - P_t) + (P_t - P_t^0) \tag{3-26}$$

Notice that $(P_t^* - P_t)$ equals e_t (equation (3-19)) and thus is uncorrelated with information available at time t. Squaring both sides of (3-26) and taking expectations at time t (denoted by E_t) we get:

$$E_t(P_t^* - P_t^0)^2 = E_t(P_t^* - P_t)^2 + E_t(P_t - P_t^0)^2 \qquad (3-26)$$

Equation (4-26) in turn implies that:

$$E_t(P_t^* - P_t^0)^2 \geqq E_t(P_t^* - P_t)^2 \qquad (3-27)$$

and

$$E_t(P_t^* - P_t^0)^2 \geqq E_t(P_t - P_t^0)^2 \qquad (3-28)$$

Mankiw, Romer and Shapiro using the same data as Shiler (1981a) performed excess volatility tests using the above inequalities, and found that they were reversed. They concluded then that "the stock market simply does not accurately reflect underlying fundamentals". Hoshi (1987), using Japanese data, found that (3-27) was accepted and (3-28) rejected (although the degree of violation seemed to be small); he interpreted those results (together with those from several other tests) as not rejecting the efficient market hypothesis.

Orthogonality tests Other tests also used to test volatility are the orthogonality tests. Assuming a constant discount factor ($\rho_t = \rho$, for all t) equation (3-10) can be rewritten as:

$$P_t = \sum_{i=1}^{\infty} (1 + \rho)^{-i} E[\, d_{t+i} \mid \phi_t]$$

Multipliplying the above equation by any variable Z_t observed at time t and then taking expectations, it results:

$$E[Z_t P_t] = E[\, Z_t \sum_{i=1}^{\infty} (1+\rho)^{-i}\, d_{t+i}] \qquad (3-29)$$

If $Z_t = P_t - E[P_t]$ equation (3-29) implies:

$$Var(P_t) = Cov\,(P_t, \sum_{i=1}^{\infty} (1+\rho)^{-i} d_{t+i}\,) \qquad (3-30)$$

As the Shiller tests seen above, the tests using equation (3-30) resulted in rejections of the efficient markets hypothesis. However they suffer from the same problems, notably, nonstationarity. This problem can be solved by dividing the constant discount factor version of equation (4-10) by dividends:

$$P_t/d_t = E[\, \sum_{i=1}^{\infty} (\prod_{k=1}^{i} (1+\rho)^{-1} \eta_{t+k}) \quad | \ \phi_t\,] \qquad (3-31)$$

with $\eta_t = d_t/d_{t-1}$.

Tests of equation (3-30) using the more stationary variables obtained with equation (3-31) still reject.

Another route was tried by allowing ρ_t to vary over time. A problem arises, however, because ρ_t is not directly observable and a proxy for it must be used. Campbell and Shiller (1988) added a constant risk premium to a real variable interest rate but still found a rejection (real interest rates do not vary much). Other approach used by Grossman and Shiller (1981) was to use measures of real investment opportunities in the real economy as proxy: their results were also negative for the efficient market hypothesis.

4. SUMMARY AND CONCLUSIONS

There are two two basic questions concerning stock markets. One, that can be solved theoretically, is whether stock markets can be instrumental in achieving allocative efficiency. It can be shown that they can.

The other question, whether capital markets are actually efficient (informationally and allocationally), must be solved empirically making use of sophisticated econometric models. It was pointed out that although most work in this area focuses on the informational efficiency question, this is made for simplicity reasons and because informational efficiency is thought to be a good proxy for allocative efficiency.

The results to this later question are, as we have seen, mixed and a resolution to the problem does not seem to be at hand. It is sad, but I think that this is due, at least in part, to the ideological character that this eminently empirical question has taken. There is on one side the church of efficiency that only sees evidence in favour of efficiency and seems to be able to explain away any anomaly found; and there is on the other side the cult of anomalies, always finding new anomalies and defending their discoveries with the zeal of proselytes. During the last twenty years, how many supporters of each camp changed sides?

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