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DO WE REALLY KNOW THAT FINANCIAL MARKETS ARE EFFICIENT?

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Abstract

This paper examines the power of statistical tests commonly used to examine the efficiency of speculative markets. It shows that for markets with "long horizons" such as the stock markets, or the market for long term bonds, these tests have very low power. Market valuations can differ substantially and persistently from the rational expectation of the present value of cash flows without leaving statistically discernible traces in the pattern of ex-post returns. This observation also suggests that speculation is unlikely to insure rational valuations, since similar problems of identification plague both financial economists and would-be speculators.

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The proposition that securities markets are efficient forms the basis for most research in financial economics. A voluminous literature has developed supporting this hypothesis. Jensen (1978) calls it the best established empirical fact in economics.[1] Indeed, apparent anomalies such as the discounts on closed end mutual funds and the success of trading rules based on earnings announcements are treated as indications of the failures of models specifying equilibrium returns, rather than as evidence against the hypothesis of market efficiency.[2] Recently the Efficient Markets Hypothesis and the notions connected with it, have provided the basis for a great deal of research in macro-economics. This research has typically assumed that asset prices are in some sense rationally related to economic realities.

Despite the widespread allegiance to the notion of market efficiency a number of authors have suggested that certain asset prices are not rationally related to economic realities. Modigliani and Cohn (1979) suggest that the stock market is very substantially undervalued because of inflation illusion. A similar claim regarding bond prices is put forward in Summers (1982). Brainard, Shoven and Weiss (1980) find that the currently low level of the stock market cannot be rationally related to economic realities. Shiller (1979, 81a) concludes that both bond and stock prices are far more volatile than can be justified on the

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[1]Similar assertions are very common in the finance literature. While doubts along the lines of the discussion here, appear to be part of an oral tradition, the only reference I could find is Shiller (1981b).

[2]For examples, see the recent issue of the Journal of Financial Economics devoted to anomalies in the Efficient Market Hypothesis.

basis of real economic events. Arrow (1982) has suggested that psychological models of "irrational decision making" of the type suggested by Tversky and Kahneman (1981) can help to explain behavior in speculative markets. These types of claims are frequently dismissed because they are premised on inefficiencies and hence imply the presence of exploitable excess profit opportunities.

This paper argues that the strength of existing evidence confirming the hypothesis of market efficiency has been vastly exaggerated. It demonstrates that the types of statistical tests which have been used to date have essentially no power against at least one interesting alternative hypothesis to market efficiency. Thus the inability of these tests to reject the hypothesis of market efficiency does not mean that they provide evidence in favor of its acceptance. In particular, the data in conjunction with current methods provide no evidence against the view that financial market prices deviate widely and frequently from rational valuations. The same considerations which make deviations from efficiency difficult to isolate statistically, make it unlikely that they will be arbitraged away, or eliminated by speculative trading. Thus the results here call into question the theoretical as well as empirical underpinnings of the Efficient Markets Hypothesis. While none of the analysis in this note demonstrates that securities markets are inefficient, it does imply that belief in the Efficient Markets Hypothesis is a shared act of faith, with little in the way of theoretical or empirical support.

The first section distinguishes alternative concepts of market efficiency and lays out the formulation used here. Tests of market efficiency in its weak and strong forms are considered in the second section. The implications of the results for our understanding of speculative markets are discussed in the third and final section.

I. Defining Market Efficiency

The notion of market efficiency has been defined in many ways. Fama (1976) presents a thorough discussion of both theoretical issues and empirical tests of this proposition. In the development below, I shall consider the evolution of the price of a single security. It can easily be taken to represent an entire portfolio. It is assumed that the required expected rate of return on the security is equal to a constant r, which is known with certainty. As has frequently been observed, standard tests of market efficiency are really joint tests of efficiency and a model specifying expected returns. The assumption made here that the ex-ante return is known and constant makes it possible to focus only on the test of market efficiency.[3]

Assume that the security in question yields a sequence of cash flows, D_t. These may be thought of as dividends if the security is a stock, or coupons if the security is a bond. If the security has a finite maturity T, then D_T may be taken to represent its liquidation value, and all subsequent values of D_t may be taken to equal zero. One statement of the hypothesis of market efficiency holds that:

$$P_t = P_t^* = E[(\sum_{s=t}^{\infty} \frac{D_s}{(1+r)^{s-t}})|\Omega_t] \tag{1}$$

where Ω_t represents the set of information available to market participants at time t. This is not the form in which the hypothesis is

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[3]Since the discussion here assumes that the model generating expected returns is known with certainty, it will overestimate the power of available statistical tests. Recent theoretical work such as that of Lucas (1978) suggests that the particular model of ex-ante returns considered here cannot be derived rigorously. This is immaterial for the points at issue here. What is crucial is that the discussion is carried on assuming full knowledge of the model characterizing ex-ante returns.

usually tested. Equation (1) is mathematically equivalent to the statement that, for all t:

$$P_t = E\left(\frac{P_{t+1}}{1+r}\right) + E(D_t) \tag{2}$$

or the equivalent statement that

$$E(R_t) = E\left(\frac{P_{t+1}}{P_t} - 1 + \frac{(1+r)_t}{P_t}\right) = r \tag{3}$$

where the information set in equations (2) and (3) is taken to be Ω_t. Note that once a transversality condition is imposd on the difference equation (3), it implies equation (1).[4]

Equation (3) also implies that:

$$R_t = r + e_t \tag{4}$$

where e_t is serially uncorrelated and orthogonal to any element of Ω_t. Market efficiency is normally tested by adding regressors drawn from Ω_t to (4) and testing the hypothesis that their coefficients equal zero, and/or by testing the hypothesis that e_t follows a white noise process.[5] The former represent tests of "semi-strong" efficiency while the latter are tests of "weak" efficiency. A vast literature, summarized in Fama (1976), has with few exceptions been unable to reject the hypothesis of market efficiency at least for common stocks. This has led to its widespread acceptance as a scientific fact.

[4]The transversality condition serves to rule at speculative bubbles.

[5]Abel and Mishkin (1980) and Jones and Roley (1982) show that other standard tests of efficiency are essentially equivalent to those described in this paragraph.

II. Tests of Market Efficiency

The inability of a body of data to reject a scientific theory does not mean that the tests prove, demonstrate or even support its validity. As students of elementary statistics are constantly reminded, failure to reject a hypothesis is not equivalent to its acceptance. This principle applies to all scientific theories, not just those that are stated statistically. Experiments can falsify a theory by contradicting one of its implications. But the verification of one of its predictions cannot be taken to prove or establish a theory.[6]

How then do we evaluate the strength of the evidence supporting a hypothesis? Clearly we do not simply count the number of implications of a hypothesis which are validated. We give more weight to the verification of some implications than to the verification of others. For example, almost everyone would agree that findings that excess returns cannot be predicted using past data on sunspots provides less support for the hypothesis of market efficiency than do demonstrations that excess returns are not serially correlated. This is because we find it much easier to imagine alternative models in which returns are serially correlated than we do alternative models in which sunspots can help predict returns. The point here is that the usefulness of any test of a hypothesis depends on its ability to discriminate between the hypothesis and other plausible formulations. The validity of evidence purporting to demonstrate or support a hypothesis cannot sensibly be evaluated in a vacuum. Below I examine the usefulness of standard tests of market efficiency according to this criterion.

[6] A discussion of what it means to establish evidence in favor of a scientific hypothesis may be found in Hempel (1965).

Evaluation of any test of a theory requires specification of an alternative hypothesis. A natural specification of an alternative hypothesis to market efficiency holds that:

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\begin{aligned}
P_t &= P_t^* + u_t \\
u_t &= \alpha u_{t-1} + v_t
\end{aligned}
\qquad (5)
$$

where lower-case letters indicate logarithms and u_t and v_t represent random shocks. This hypothesis implies that market valuations differ from the rational expectation of the present value of future cash flows by a multiplicative factor approximately equal to $(1+u_t)$. The deviations are assumed to follow a first-order autoregressive process. It seems reasonable to suppose that deviations tend to persist so that $0 \leq \alpha \leq 1$. The assumption that u_t follows an AR process is made for ease of exposition and does not affect any of the substantive points at issue. For simplicity, it is assumed that u_t and v_t are uncorrelated with e_t at all frequencies.

Many, though not all, of the plausible senses in which markets might be inefficient are captured by this specification. It clearly captures Keynes's (1936) notion that markets are sometimes driven by animal spirits unrelated to economic realities. It also is consistent with the experimental evidence of Tversky and Kahneman (1981) that subjects overreact to new information in making probabilistic judgements. The formulation considered here captures Robert Shiller's (1979; 1981a,b) suggestion that financial markets display excess volatility and overreact to new information. One deviation from standard notions of market efficiency which does not take this form is Blanchard and Watson's (1982) suggestion of intermittent rational speculative bubbles.[7]

Adopting the approximation that $\log(1+u_t) = u_t$, and that $\frac{Div_t}{P_t} \approx \frac{Div_t}{P^*_t}$, equations (3), (4) and (5) imply that excess returns $Z_t = (R_t - r)$ follow an ARMA (1,1) process.[8] That is:[9]

$$Z_t = \alpha Z_{t-1} - e_t - \alpha e_{t-1} + v_t - v_{t-1} \ . \tag{6}$$

Granger and Newbold (1978) show that since Z_t can be expressed as the sum of an ARMA (1,1) process and white noise, ARMA (0,0), it can be represented as an ARMA (1,1) process. Equation (6) can be used to calculate the variance and the autocorrelations of Z_t. These calculations yield:

$$\sigma_z^2 = 2(1-\alpha)\sigma_u^2 + \sigma_e^2 \tag{7a}$$

$$\rho_k = \frac{-\alpha^{k-1}(1-\alpha)^2\sigma_u^2}{2(1-\alpha)\sigma_u^2 + \sigma_e^2} \tag{7b}$$

where ρ_k denotes the kth-order autocorrelation. Note that the model predicts that the z should display negative serial correlation. When

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[7]Olivier Blanchard has pointed out to me that if $\alpha=1+r$ equation (5) will characterize a speculative bubble. In this case however, market valuations will come to diverge arbitrarily far from fundamental valuations.

[8]These approximations are necessary in order to obtain simple analytic expressions. I do not believe that they have a material impact on the conclusions since in most time periods dividends are not paid. Shiller (1981b) presents an example similar to the one here in his defense of volatility tests.

[9]This can be seen as follows. With the approximations assumed here, $R_t = \frac{Div_t}{P^*_t} + p_{t+1} - p_t = \frac{Div_t}{P^*_t} + P^*_{t+1} - p^*_t + u_{t+1} - u_t$, where the last equality is implied by equation (5). This can be written, using (3) and (4) as: $R_t = r + e_t + u_{t+1} - u_t$. Combining this last equation with equation (5) yields equation (6).

excess returns are positive, some part is on average spurious, due to a shock v_t. As prices revert to fundamental values, negative excess returns result.

Weak Form Tests of Market Efficiency

At this point the power of "weak form tests" of market efficiency can be evaluated. These tests involve evaluating the hypothesis that the $\rho_k = 0$. Table 1 presents the theoretical first order autocorrelation for various parameter combinations. In all cases, the parameters are chosen to accord with the observed variance in stock market returns. Note that (7b) implies that all subsequent autocorrelations are smaller in absolute value. In order to get a feeling for the magnitudes involved, it is useful to consider a concrete example. Suppose one is interested in testing market efficiency using aggregate data on monthly stock market returns over a 50-year period. With 600 observations, the estimated autocorrelations have a standard error of $1/\sqrt{597} \simeq .042$ on the null hypothesis of zero autocorrelation. This calculation leads to an overstatement of the power of tests because it counterfactually assumes a constant variance of excess returns and the normality of e_t. Suppose that $\sigma_u^2 = .08$ so that the standard deviation of the market's error in valuation is close to 30 percent, and that $\alpha = .98$. This implies that it takes about three years for the market to eliminate half of any valuation error u_t. These assumptions along with the observation that $\sigma_z^2 \simeq .004$ imply, using (7a), that $\sigma_e^2 \simeq .001$.[10] Equation (7b) implies that the theoretically expected value of ρ_1 is $-.008$. Thus, in this example, the data lack the power to reject the hypothesis of market efficiency even though market valuations frequently differ from the rational expectation of the present value of future cash flows by more

[10] This estimate for σ_z^2 is consistent with the 20 percent annual standard deviation of market returns reported by Ibbotsen and Sinquefield (1976,1979).

Table 1

Theoretical Autocorrelation of Excess Return Assuming Market Inefficiency

σ_e^2/σ_u^2	α: .75	.9	.95	.99	.995
1.0	-.042	-.008	-.003	.000	.000
.5	-.062	-.014	-.004	.000	.000
.25	-.083	-.022	-.007	.000	.000
.1	-.104	-.033	-.012	-.001	.000
.05	-.113	-.040	-.017	-.001	.000
.01	-.122	-.048	-.023	-.003	-.001

Note: Calculations are based on Equation (7b).

than 30 percent.[11] In order to have a 50 percent chance of rejecting the null hypothesis it would be necessary to have data for just over 5000 years. Note also that in this example three-fourths of variance in excess returns is due to valuation errors u_t, rather than genuine information e_t. Even if $\sigma_u^2 = .10$, so that all the variance in market returns is spurious, and $\sigma_e^2 = 0$, the theoretical value of ρ_1 is only -.01, so that deviations from efficiency could not be detected. If, as is plausible, the serial correlation in valuation errors is greater, the power of standard tests is even lower.

Note that these results have implications for testing efficiency in other markets. Take, for example, the proposition that long-term bond yields represent the rational expectation of average short-term yields. As is widely understood, this is equivalent to the proposition that no predictable excess returns can be earned in the long-term bond market.[12] This is frequently tested in a manner which parallels the tests described here. It is instructive to note that if interest rates average 10 percent, and long-term bonds are approximated as consols, a 30 percent valuation error implies a deviation of 300 basis points between the yield on long-term instruments and the rational expectation of average future short-term rates. Thus, the results in this paper also suggest that evidence purporting to demonstrate the validity of the "expectations" theory of the term structure of interest rates using long term bonds is not very powerful.

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[11] A more formal procedure would calculate the distribution of the test statistic $(\frac{P_k}{\sigma_k})$ under the alternative hypothesis. It should be obvious that carrying out this procedure would support the assertions in the text.

[12] See Jones and Roley (1982).

Two plausible objections might be lodged against this discussion. It might be that data at higher frequencies would yield more powerful tests. Further, the discussion so far has focused only on tests for first-order autocorrelation. Suppose one had daily rather than monthly data on excess returns over a 50-year period. It is true that one could then estimate daily autocorrelations much more accurately. In fact, the standard error would be approximately $1/\sqrt{50{:}250} \approx .009$. However, if α was .98 using monthly data, it would be approximately .9990 using daily data so that the theoretical autocorrelation under the assumptions made earlier would be $-.0005$. Thus, the power of the data to reject inefficiencies of the type considered here is not enhanced by obtaining more frequent observations. Given the nature of the inefficiency being considered - persistent miscalculations - this should not be surprising.

As has been noted, the model predicts that the first-order autocorrelation should exceed those at higher orders. Thus, the remarks above apply to tests of other individual autocorrelation coefficients. Sometimes, however, a joint test of the hypothesis of zero autocorrelations at all orders is performed. The Box-Pierce Q statistic is normally used for this purpose. This statistic is computed as

$$Q = n \sum_{k=1}^{m} \rho_k{}^2 \tag{9}$$

and is distributed as χ^2 with m degrees of freedom under the null hypothesis. In the example considered here, using monthly data, the theoretically expected value of Q is .29 for m=10, .49 for m=20, and .61

for m=30 compared to critical values at the five percent level of 18.3, 31.4, and 43.8, respectively. To state the conclusion more dramatically, in order to have a 50 percent chance of rejecting the hypothesis of market efficiency, assuming 30 autocorrelations are used to form the a-statistic, one would have to have approximately 1200 years worth of monthly data.

These results have implications for tests of market efficiency which go beyond the examination of serial correlation in excess returns. It has frequently been noted that one is unable to reject the hypothesis that excess returns follow a white noise process after a jump, following significant events such as stock splits and dividend announcements. The preceding discussion makes clear that this provides essentially no evidence against the hypothesis that the market either systematically over- or under-reacts to these announcements. In neither case would significant serial correlation be observed.

Tests of Semi-Strong Efficiency

In closing the last section on weak-form tests we considered one type of test for semi-strong efficiency - examining the profitability of strategies of buying or selling following certain types of announcements. Here we consider a different type of test. Equation (5) implies that expected excess returns should be negative when $p_t > p_t^*$ and positive when $p_t < p_t^*$. This reflects the assumed tendency of market prices to return towards the rational expectation of the present value of future cash flows. The key question is whether these expected excess returns are large enough to be detectable.

In practice any effort used to test efficiency in this way runs into the problems that p_t^* is unobservable. This problem is assumed away so that the hypothetical tests considered here have far more power than any test that could actually be devised. Under the assumptions that have been made so far, it is easy to see that:

$$E(z_t) = -(1-\alpha)u_{t-1} = (1-\alpha)(p_t^* - p_t) \qquad (10)$$

In the example considered above with $\alpha = .98$, and $\sigma_u = .28$, (10) implies that when the market was undervalued by one standard deviation, the expected excess monthly return would be $(.02)\cdot(.28) = .0056$. This contrasts with a standard deviation of monthly returns of .06.

How much data would it take for these excess returns to be discernible statistically? Suppose that the regression equation

$$Z_t = a + b(p_t^* - p_t) + n_t \qquad (11)$$

is estimated. Equation (10) implies that $E(\hat{b}) = (1-\alpha)$. The standard error of $\hat{b}$ can be calculated from the expression:

$$\sigma_{\hat{b}}^2 = \frac{\sigma_\eta^2}{n\sigma_u^2} \qquad (12)$$

In the example considered above one can calculate that $\sigma_b \simeq .01$. This implies that the hypothesis of market efficiency would not be rejected at the five percent level, with probability of one-half.[13] If $\alpha = .99$, the probability of rejecting the null hypothesis is less than one-sixth. Of course this discussion vastly overstates the power of any test that could actually be performed. In addition to the problem of measuring p_t^*, there are the problems of non-normality in the residuals, and the problem of measuring expected returns. These factors combine to suggest that tests of semi-strong efficiency do not have much more power against the type of

[13] There is one-half chance that $\hat{b} < E(\hat{b}) = .02$. In these cases the null hypothesis of efficiency will be accepted.

inefficiency considered here, than do tests on serial correlation properties of excess returns.

II . Implications and Conclusions

The preceding analysis suggests that certain types of inefficiency in market valuations are not likely to be detected using standard methods. This means the evidence found in many studies that the hypothesis of efficiency cannot be rejected, should not lead us to conclude that market prices represent rational valuations. Rather, we must face the fact that our tests have relatively little power against certain types of market inefficiency. In particular, the hypothesis that market valuations include large persistent errors is as consistent with the available empirical evidence as is the hypothesis of market efficiency. These are exactly the sort of errors in valuation one would expect to see if market valuations involved inflation illusion or were moved by fads as some have suggested.

The weakness of the empirical evidence verifying the hypothesis that securities markets are efficient would not be bothersome if the hypothesis rested on firm theoretical foundations, and if there were no contrary empirical evidence. Unfortunately, neither of these conditions is satisfied in practice.

The standard theoretical argument is that unless securities are priced efficiently, there will be opportunities to earn excess returns. Speculators will take advantage of these opportunities arbitraging away any inefficiencies in the pricing of securities. This argument does not explain how speculators become aware of profit opportunities. The same problems of identification described here, confronting financial economists also plague "would be" speculators. If the large persistent valuations errors considered here leave no statistically discernible trace in the historical patterns of returns, it is hard to see how speculators could become aware of them. Moreover, cautious speculators may be persuaded by the same arguments used by economists to suggest that apparent inefficiencies are not present. There is another logically separate point to be made here as well. Even if inefficiencies of the type considered here could be conclusively identified, the excess returns to trying to exploit them would be small and uncertain.

These inferences are supported by a cursory examination of the activities of actual speculators. A vast amount of speculative activity is directed at exploiting riskless arbitrage opportunities through triangular trades and the like. Traders engaged in this activity often are reluctant to hold naked positions for as long as ten minutes and typically admit to being completely oblivious to market fundamentals. Most risky speculation occurs in markets such as commodity futures, where the nature of traded securities insures that valuation errors cannot persist. In commodity markets for example, the futures price must ultimately draw close to the spot price as the contract date is approached. Very little professional speculation appears to take place in markets like the stock market which have an indefinite horizon. The principal exception to this assertion is the activities of risk arbitrageurs who trade takeover candidates. Here again, the major uncertainty has a short horizon.[14]

While tests of the type considered have little power to detect inefficiencies, other forms of evidence suggest that valuation errors are pervasive. In markets, where the horizon is short and so very persistent valuation errors

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[14] The argument here that the rational expectations assumption is untenable in settings where it is difficult to estimate structural parameters without extremely long time series is similar to that made in a macro-economic context by Benjamin Friedman (1979).

are impossible, inefficiencies are frequently detected. For example, almost every examination has concluded that forward prices are not efficient predictors of futures spot prices in the foreign exchange market. (See Meese and Rogoff (1982) for a recent example.) Other evidence comes from an examination of the relation between market valuations and fundamentals. A classic example is provided by the discounts on closed end funds. Corporations whose only assets are easily valued marketable securities sell at a substantial discount relative to the value of their assets. Observed patterns of takeover suggests that the same is true of many other corporations whose assets are less easily valued. A different kind of observation suggesting the incompleteness of current theories is the enormous trading volume observed on speculative markets. This is difficult to account for on the view that market valuations are rational expectations of rational calculations performed by market participants.

The foregoing discussion suggests that a more catholic approach should be taken to explaining the behavior of speculative markets. It may be possible to develop alternative models of pricing based on the observed experimental responses of persons to risky environments. These models may have testable implications differing from those of standard formulations. More modestly, it may be possible to explain how valuation errors once made can persist, by formalizing the notions of speculator learning discussed above. Finally, the analysis here suggests the importance of developing tests which have some power against the type of alternative hypotheses we considered. These might focus on the aftermath of apparently irrational market responses.[15]

[15] I am currently engaged in such a study of the market reaction following money supply announcements.

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