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RATIONAL EXPECTATIONS IS NOT GENERALLY VALID FOR ECONOMETRIC MODELS: EVIDENCE FROM STOCK MARKET DATA

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Abstract. In applying the rational expectations hypothesis to generate expectations in an econometric model it is assumed that (1) the model itself is capable of generating reasonable forecasts of all required expectations variables included in the model, and that (2) the economic agents whose behavior is being modeled act as if they form their psychological expectations as conditional mathematical expectations generated by the model. Both assumptions can be invalid, as demonstrated by the historical data on Hong Kong stock prices and by the successful application of the adaptive expectations hypothesis to explain panel data of prices of individual stocks and aggregate time series data on stock price indices of the United States and of Hong Kong.

1. INTRODUCTION

Since the late 1970s the hypothesis of rational expectations has gained acceptance in the economics profession to generate expectations variables in econometric models. Before that time expectations variables had been usually generated by the assumption of adaptive expectations. The latter assumption has empirical support. Even the Cobweb theorem – which assumes that price expectation equals past price and is a special case of adaptive expectations when the adjustment coefficient equals unity – has been found to explain some agricultural output data. The adaptive expectations hypothesis as applied by Cagan (1956) to generate an expected rate of inflation to explain the demand for real money balance during hyperinflation, and by Friedman (1957) to generate an expected income variable to explain aggregate consumption, appears to be a good working hypothesis. From the late 1950s to the middle 1970s, this hypothesis was applied to form expectations variables in macroeconometric models. The oil crisis of 1973 shocked the world economy as well as the economics profession. Any plausible explanation for the failure of existing macroeconometric models became attractive to economists. One plausible explanation is that some of the large macroeconometric models were not specified with great care, with many equations selected by data mining rather than by strong theoretical support. The

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models did well when most time series moved forward without being affected by large variations of exogenous variables.

The assumption of rational expectations does have its theoretical appeal because economic agents are assumed to have complete knowledge in the static theory of consumer behavior and in other parts of static economics. To apply the assumption of complete knowledge to dynamic macroeconomic models in order to generate expectations variables as mathematical expectations implied by the models seemed reasonable to some, but was first resisted by the majority of macroeconometric model builders. Econometricians and economic agents may have knowledge to model certain economic time series, but not necessarily all time series the expectations of which are required to explain the endogenous variables. Not unexpectedly empirical evidence has accumulated since the late 1970s that econometric models of various types, when combined with the assumption of rational expectations, have more often than not been rejected by the data.

The time has come for the economics profession to accept a simple truth; namely, that it was a mistake to accept the assumption of rational expectations as applied to econometric models because it attributes too much knowledge to both the econometrician and the economic agents whose behavior the econometric model is intended to capture. To focus attention we have chosen the present-value model of stock prices to discuss the shortcoming of the rational expectations hypothesis and the validity of the adaptive expectations hypothesis. We first provide a simple explanation of Hong Kong stock prices since 1975 as resulting from the lack of knowledge on the part of most investors about the potential earnings of Hong Kong stocks. Two models built upon the assumption of adaptive expectations are then applied to explain the prices of stocks. The first is estimated using panel data of prices of stocks of individual firms and the second using data for a stock price index. In the latter case, the failure of the rational expectations hypothesis and the success of the adaptive expectations hypothesis are so clear that the conclusion to reject the former and accept the latter hypothesis is inevitable. This discussion also solves two puzzles in the finance literature. The first puzzle was why capital does not flow from low-yielding rich countries to high-yielding countries to equalize the rates of return. The second puzzle was why there is a home bias in investing. The simple and obvious answer to both questions is that investors in a developed economy are generally not well-informed about the earning abilities of assets in developing economies, and hence may overestimate the risks in investing in the stocks of the latter countries. This answer can be easily accepted if one gives up the incorrect paradigm that all investors possess the same valid knowledge about the earning abilities of all securities in the world.

2. CONTINUED INCREASE IN HONG KONG STOCK PRICES

Application of the rational expectations hypothesis of Muth (1961) to econometric models in general is based on two propositions. First, the econometric model itself can provide good forecasts of all relevant economic variables. Second, the economic agents whose behavior the model is intended to capture form their psychological expectations which are equal to the conditional mathematical expectations generated by the model. Both propositions can be incorrect, as illustrated by the application of the present-value model to explain stock prices. The present-value model states that the price of a stock $P(t)$ at the beginning of period t is the discounted value of its (psychologically) expected future dividends $D(t+k)$, $k=0,1,\ldots$. This model is reasonable. To estimate such a model statistically, one needs a hypothesis on how the psychological expectations are formed. The adaptive expectations hypothesis states that the psychological expectations of economic variables are formed adaptively according to equation (1) below. The rational expectations (RE) hypothesis states that the psychological expectations for dividends are the same as the conditional mathematical expectations of future dividends generated by the econometric model used by the econometrician. To apply RE, the econometrician is required to include dividends as an endogenous variable in the model. The history of Hong Kong stock prices from 1975 shows that no statistical model constructed in 1975 could have forecasted correctly the future economic development of Hong Kong/China and thus the earning abilities and the dividends of Hong Kong companies. Good forecasts of earnings and dividends from 1975 onward had to be based on "informed judgment" of the prospects of economic development in Hong Kong/China (Chow, 1994, chs 4, 5, 6, and 7) and could not be based on "time series" modeling which assumes that a given stochastic model generates the dividend data from 1970 to 2000. To estimate a time series model to be used in 1975, some observations before 1975 are needed. To forecast future dividends correctly for evaluating the sum of their discounted values, the model for dividend has to be valid for some future years. Given the historical circumstances of Hong Kong/China, no such time series model existed. The continued rise in the Hang Seng index of Hong Kong stock prices relative to the Standard and Poor index for US stock prices implies that investors and econometricians continued to fail in forecasting the future earning abilities of Hong Kong stocks relative to US stocks.

Some variables simply cannot be forecasted correctly by a statistical model which assumes certain time-invariant stochastic process generating the data. Econometricians have been wise to term these variables "exogenous" and do not claim to know how to use time series modeling to forecast them. The dividend series of Hong Kong stocks is a good illustration. To estimate the present-value model under adaptive expectations, the econometrician is more modest in not trying to forecast actual dividends into the distant future. The model requires only psychological expectations, which could be adequately approximated by adaptive expectations and which often turned out to be incorrect. The model so obtained (see equations (16) and (17) below) can successfully explain $P(t)$ by $P(t-1)$ and $D(t-1)$ but does not require a correct statistical model for $D(t)$ as under the assumption of rational expectations.

Researchers have found (Campbell et al., 1997, p. 283) that if psychological expectations of future dividends were equal to mathematical expectations generated by time series models of dividends fitted to historical data, stock prices derived as sums of expected discounted future dividends fluctuated too much relative to the fluctuations of the dividend series. One explanation is that the discount rate was not constant. Another explanation, possibly more important and more convincing, is that the psychological expectations of future dividends have changed more than the conditional expectations of future dividends calculated by a time series model fitted to past data. If people think that economic prospects are good, the psychological expectations of all future dividends are raised given the current data, more so than a VAR model for dividend or log dividend can allow for. The large fluctuations in stock prices are consistent with adaptive expectations formation which allows expected future dividends to change substantially after a change in the observed dividend of the preceding period.

We have plotted the Hang Seng Index together with the Standard and Poor 500 Composite Index. In figure 1, the Hang Seng Index has been deflated by the HK$/US$ exchange rate, so that it is effectively measured by US$. The S&P 500 Composite Index for the US Stock Market was taken from the CITIBASE. The data covers a period from 1975 to 1996. We have also provided in figure 2 the ratio between Hang Seng and S&P 500, normalized to equal unity in 1975:3. Here we clearly see that, starting from 1975:3, Hong Kong stock prices continued to rise as compared with US stock prices, until 1982 when the British government agreed to return sovereignty of Hong Kong to China on 1 July, 1997. Confidence in Hong Kong recovered from 1984 until 1989 when the Tiananmen tragic event occurred. Soon after in 1990 the ratio resumed its growth. The drop from the end of 1993 could be the result of 1997 approaching and/or the decrease in the annual growth rate of Hong Kong GDP

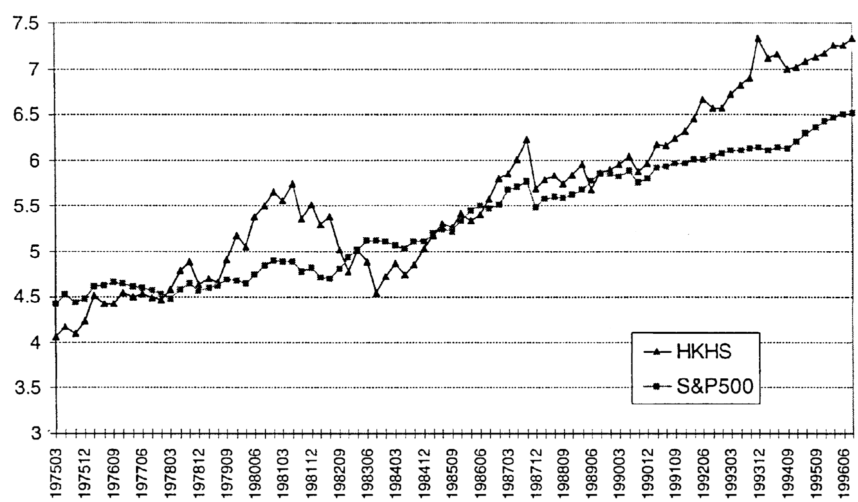

Figure 1. Standard and Poor 500 and HK Hang Seng indexes (log)

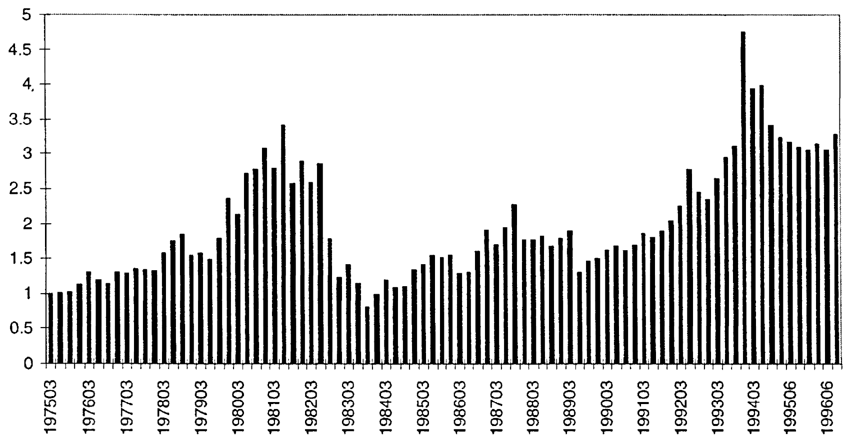

Figure 2. Ratio of Hang Seng index to S&P 500

from about 6 to 4.5 percent while the US economy was recovering. A more revealing analysis of the time effect is found in the next section after the effects of fundamentals on stock prices are eliminated.

This fact about Hong Kong stock prices which have continuously increased relative to the US stock prices is a convincing demonstration that the hypothesis of rational expectations is incorrect in assuming knowledge of all investors about future earning abilities. It also explains why capital does not flow from low-yielding rich countries to high-yielding countries to equalize the rates of returns immediately simply by the lack of knowledge on the part of world investors about the latter countries. A demonstration of the usefulness and superiority of the adaptive expectations hypothesis will be given in the remainder of this paper using two models based on the present-value model of stock prices.

3. PRESENT-VALUE MODEL OF STOCK PRICES

If the future dividends of a stock are known for certain, the value of the stock is the present value of all its future dividends. When the future dividends are uncertain it seems reasonable to assume that the value of the stock is related to the psychologically expected future dividends. In Chow (1958), it was assumed that the logarithm of the price of a stock is a linear function of the psychologically expected current log dividend and the expected rate of growth of dividends. Data on log stock prices were regressed on these two expected values using cross-sections of blue-chip stocks in the United States. The two expected values were obtained by the assumption of adaptive expectations. The results confirmed the hypothesis.

Let $P(t)$ denote the price of a stock at the beginning of a year and $D(t)$ denote the dividend issued during the year. Denote the natural logarithm of dividend D by d, and define the rate of growth g as $d(t) - d(t-1)$. The investors are assumed to form adaptive expectations:

$$g^*(t) = g^*(t-1) + b[g(t-1) - g^*(t-1)] = b[1 - (1-b)L]^{-1}g(t-1)$$
$$d^*(t) = d^*(t-1) + c[d(t-1) - d^*(t-1)] = c[1 - (1-c)L]^{-1}d(t-1) \qquad (1)$$

where L stands for the lag operator, with $Lg(t) = g(t-1)$. The logarithm of stock price is approximated by a linear function of $d^*(t)$ and $g^*(t)$:

$$p(t) \equiv \ln P(t) = d \cdot d^*(t) + a \cdot g^*(t). \qquad (2)$$

Multiplying equation (2) by $[1-(1-b)L][1-(1-c)L]$ and substituting equations (1) for $d^*(t)$ and $g^*(t)$, one obtains the following model for $p(t)$:

$$p(t) = \beta_1 p(t-1) + \beta_2 p(t-2) + \beta_3 d(t-1) + \beta_4 d(t-2) + \beta_5 d(t-3), \qquad (3)$$

where

$$\begin{aligned}
\beta_1 &= (1-c) + (1-b) \\
\beta_2 &= -(1-c)(1-b) \\
\beta_3 &= cd + ba \\
\beta_4 &= -cd(1-b) - ba(2-c) \\
\beta_5 &= ba(1-c).
\end{aligned} \qquad (4)$$

Equations (1) and (2) form a structural model which is motivated by the present-value model of stock price and the adaptive expectation hypothesis, with four structural parameters (b,c,d,a). Equation (3) is the implied reduced-form model with five parameters $(\beta_1,\ldots,\beta_5)$ subject to one implicit restriction, as they are nonlinear functions of the four structural parameters indicated in (4). Our behavioral model about stock price and expectation formation thus translates into one parametric restriction that can be statistically tested with stock market data.

We use a panel dataset of 17 Hong Kong blue-chip stocks from 1980 to 1993 taken from the Pacific Basin Capital Markets (PACAP) databases provided by the PACAP Research Center, College of Business Administration, University of Rhode Island, Kinston, RI, USA. Annual figures are constructed by summing up dividend payments in a year and using the stock price as of the end of year $t-1$ to approximate $p(t)$ for the beginning of year t. The empirical version of (3) is a two-factor fixed effect model of the form

$$\begin{aligned}
p(i,t) = \delta + \alpha(i) + \gamma(t) + \beta_1 p(i,t-1) + \beta_2 p(i,t-2) \\
+ \beta_3 d(i,t-1) + \beta_4 d(i,t-2) + \beta_5 d(i,t-3) + \varepsilon(i,t), \\
t = 1, 2, \ldots, 14;\ i = 1, 2, \ldots, 17
\end{aligned} \qquad (5)$$

where $\gamma(t)$ captures a time effect that affects all firms alike at year t, and $\alpha(i)$ represents a firm-specific effect. To ensure determinacy in the estimation, we impose two restrictions on the fixed effects by parameterizing them to be deviations from mean.

Using raw data on price and dividend per share as recorded can be highly misleading because the number of shares outstanding has not been constant owing to stock split, stock dividend, rights offering, and other capital distribution policies which generate abrupt changes in stock price. We therefore use total market value and total dividend payment constructed by multiplying per-share figures by the number of outstanding shares. This is equivalent to renormalizing the per-share data to a common basis that is constant over time. To handle rights offering, we impute the option value of the subscription rights and treat it as cash dividend.[1] All price and dividend data are divided by the GDP deflator (1990 = 100) under the assumption that investors do not have money illusion.

Assuming normally distributed disturbances in (5), maximum likelihood estimates (MLE) of the unrestricted reduced form can be calculated by applying least squares to (5), which gives a log likelihood value of 313.6060. MLE of the structural parameters is obtained by applying nonlinear least squares after substituting (4) into (5), which gives a log likelihood value of 313.0439. The numerical minimization iteration is facilitated by first eliminating the fixed effects in the usual way, by transforming all variables as deviations from cross-sectional and time series means:

$$x'_{it} = x_{it} - \bar{x}_{i.} - \bar{x}_{.t} + \bar{\bar{x}}.$$

To test the single structural restriction implied by theory, the likelihood ratio statistic is calculated to be $-2(313.0439 - 313.6060) = 1.1242$, giving a p-value of 0.2890 according to a chi-squared distribution with one degree of freedom. ($F(1,171) = 0.9450$ with significance level 0.3324.) Thus, the model for log stock price based on expected level of log dividend and the expected growth of log dividend formed by adaptive expectation is strongly supported by the data. We provide in tables 1 and 2 the results of estimating the unrestricted and the restricted versions of equation (5).

The adjustment coefficients b and c in the formation of expected g^* and d^* are respectively 0.8695 and 0.5708 (table 3). The coefficient d for d^* in the equation for log stock price is 0.5668, while the coefficient a for g^* is practically zero. The last result suggests that the expected rate of growth of log dividend as projected by adaptive expectations does not contribute to current price of Hong Kong stocks. This finding is consistent with the pessimistic view of investors in Hong Kong stocks who do not believe that recent growth rates can be extrapolated forward. Therefore stock price depends mainly on the expected current level of dividends. It is consistent with a low price-earnings ratio for Hong Kong stocks if the price is judged to be low by the observed growth of recent dividends. Related regressions using US data reported in Chow (1958), to be summarized below, show that by contrast US stock prices are affected by the expected growth of dividends as formed by adaptive expectations.

Investors familiar with the Hong Kong scene could comment on the firm effects as estimated, which appear reasonable to the authors. Note the time

[1] The value of a right can be calculated by using the equation $P - (RN + S) = R$, where P is the "rights-on" market price of the stock, R is the value of a right, N is the number of rights needed to buy one share, and S is the subscription price. See Sharpe and Alexander (1990, p. 414).

Table 1. Unrestricted model

Dependent variable PRICE
Estimation by least squares
Panel(14) of annual data from 1//1982:01 to 17//1993:01
Total observations: 204 Degrees of freedom: 171
Centered R**2: 0.7027 R Bar **2: 0.6957
Uncentered R**2: 0.7027 T × R**2: 143.350
Std Error of dependent variable: 0.425657
Standard error of estimate: 0.234792
Sum of squared residuals: 9.426749
Durbin–Watson statistic: 2.048

Variable	*Coeff*	*Std Error*	*T-Stat*
PRICE1	0.5694	0.0772	7.377
PRICE2	−0.1053	0.0694	−1.517
DIVIDEND1	0.3093	0.0431	7.176
DIVIDEND2	−0.0150	0.04591	−0.326
DIVIDEND3	0.0287	0.0394	0.729

Log likelihood: 313.60601

Constant term	Std Error
3.52	0.48987

FIRM EFFECTS (deviations from mean)

	Dev. from mean	*Std Error*
Bank of East Asia	−0.06783	0.04470
China Light	0.24967	0.03947
HSBC Holdings	0.24741	0.07497
Wharf (Holdings)	0.11694	0.02752
Amoy Properties	−0.37976	0.06618
Swire Pacific A	0.13851	0.01471
China Gas	0.15299	0.04363
Hang Seng Bank	0.25862	0.04684
Hopewell	−0.14039	0.03585
SHK Properties	0.08611	0.02862
Hang Lung	−0.21923	0.02273
Cheung Kong	0.19327	0.03002
Henderson Inv	−0.40817	0.06023
New World	0.02323	0.01127
Shun Tak	−0.49445	0.10389
HK Electric	0.03383	0.03918
Hutchison	0.20925	0.04439

TIME EFFECTS

Year	*Dev. from mean*	*Std Error*	*Incr.*	*Std Error*
1982	−1.21176	0.03052	NA	NA
1983	−0.27410	0.05783	0.56792	0.05138
1984	−0.09231	0.04243	0.18178	0.05573
1985	0.07897	0.03411	0.17128	0.02120
1986	0.17450	0.02779	0.09553	0.02040
1987	−0.15137	0.02651	−0.32586	0.02932
1988	0.06815	0.02143	0.21951	0.03450
1989	−0.15336	0.01978	−0.22150	0.03171
1990	−0.08108	0.02133	0.07228	0.01963
1991	0.24090	0.02227	0.32198	0.00928
1992	0.21376	0.03272	−0.02715	0.02480
1993	0.81795	0.03961	0.60419	0.01790

Table 2. The restricted model

Dependent variable PRICE
Estimation by nonlinear least squares
Panel(14) of annual data from 1//1982:01 to 17//1993:01
Total observations: 204 Degrees of freedom: 172
Centered R**2: 0.7011 R Bar **2: 0.7384
Uncentered R**2: 0.7011 T × R**2: 143.014
Std Error of dependent variable: 0.425657
Standard error of estimate: 0.217702
Sum of squared residuals: 9.478843
Durbin–Watson statistic: 2.033

Restricted Coefficients

0.5597
−0.0560
0.3135
−0.0279
−0.0043

Log likelihood: 313.04389
Constant term
3.42364

FIRM EFFECTS (deviations from mean)

	Dev. from mean
Bank of East Asia	−0.08632
China Light	0.24949
HSBC Holdings	0.25964
Wharf (Holdings)	0.11260
Amoy Properties	−0.35893
Swire Pacific A	0.13870
China Gas	0.13503
Hang Seng Bank	0.24466
Hopewell	−0.14848
SHK Properties	0.09727
Hang Lung	−0.21785
Cheung Kong	0.18101
Henderson Inv	−0.39666
New World	0.02450
Shun Tak	−0.49042
HK Electric	0.04694
Hutchison	0.20882

TIME EFFECTS

Year	*Dev. from mean*	*Incr.*
1982	−0.86418	NA
1983	−0.28918	0.57500
1984	−0.07398	0.21520
1985	0.09004	0.16403
1986	0.17587	0.08583
1987	−0.16239	−0.33826
1988	0.05618	0.21858
1989	−0.14270	−0.19888
1990	−0.08199	0.06071
1991	0.24732	0.32931
1992	0.22613	−0.02119
1993	0.81888	0.59275

Table 3. Estimates of the structural parameters from the restricted regression

Variable	*Coefficient*	*Std Error*	*T-Statistic*	*Significance*
a	−0.0115	0.05324	−0.21622	0.82903451
b	0.8695	0.12814	6.78573	0.00000000
c	0.5708	0.10812	5.27930	0.00000034
d	0.5668	0.06957	8.14724	0.00000000

effects which show a clearly positive trend. This trend summarizes the increase in confidence of investors in Hong Kong stocks as they learned about the continued growth of the Hong Kong/China economy. Note the monotone increase in the time effect from −0.86 in 1982 to 0.18 in 1986, a decline in 1987 during the world stock market decline, a recovery in 1988, and a fall in 1989 when the Tiananmen event occurred, and to rise again to 0.82 in 1993. To ease reading, the observation for 1987 refers to stock price at the end of the year 1987 or the beginning of 1988 as explained by equation (5).

If we multiply equation (3) by $(1-\beta_1 L-\beta_2 \mathrm{L}^2)^{-1}$ we can express $p(t)$ as a linear function of an infinite number of past $d(t-k)$, $k=1, 2, \ldots$. The coefficients of this linear function decrease, become negative, and then approach zero from below as we go back in time. The reason for some negative coefficients is the growth component of equation (2). To check the above pattern for the coefficients, two samples were used in Chow (1958). The preliminary sample consists of the 30 corporations used in the Dow Jones Industrial Average at the beginning of 1956. $\ln P(t)$ was regressed on 4 to 6 $d(t)$. It was assumed here that the earliest two $d(t-k)$ equal their expected values. The pattern of the coefficients was confirmed by this sample. A second sample consisting of Building, Automobile Parts, and Oil industries at the beginning of 1957 turned out also to be consistent with the hypothesis. The statistical analysis reveals that the implied pattern of the coefficients (which incorporates growth) is superior to the pattern of exponentially declining coefficients.

As another check, we have estimated equation (3) without the fixed effects using annual aggregate US Standard and Poor 500 stock price and dividend indices given in Shiller (1989) from 1874 to 1988, with 115 observations. The log likelihoods are 200.787 and 200.047, yielding a χ^2 (1) statistic of 1.479 and leading to accepting the restricted model with a significant level of 0.224. The coefficients of adjustment in adaptive expectation formation for the rate of growth g^* and log dividend d^* are 0.9995 (0.1149) and 0.0695 (0.0834), with standard errors in parentheses. The coefficients a and d in equation (2) for log price $p(t)$ are 0.169 (0.0995) and 0.5376 (0.9395). The coefficient a is significant at a 5% level using a one-tail test. The implied coefficients for $d(t-1)$, $d(t-2)$,…, $d(t-6)$ in the MA representation of (3) are 0.207, −0.134, 0.032, 0.030, 0.028 and 0.026 respectively, with a negative coefficient for $d(t-2)$, as pointed out earlier.

4. AGGREGATE TIME SERIES EVIDENCE ON RATIONAL VERSUS ADAPTIVE EXPECTATIONS

To summarize the strong evidence from aggregate time series data in favor of the adaptive expectations hypothesis as compared with the rational expectations hypothesis presented in Chow (1989), consider stock price $P(t)$ at the beginning of period t as determined by the expectation of future dividends $D(t+i)$ distributed during periods $t+i$:

$$P(t) = \sum_{i=0}^{\infty} \delta^{i+1} E_t D(t+i) \tag{6}$$

where E_t is expectation conditional on information available at the beginning of period t. Using this equation to evaluate $E_t P(t+1)$ and subtracting $\delta E_t P(t+1)$ from this equation for $P(t)$, we have

$$P(t) = \delta E_t[P(t+1) + D(t)]. \tag{7}$$

To estimate this equation under the assumption of rational expectations, we write

$$P(t+1) - E_t P(t+1) = u(t+1) \tag{8}$$

where $u(t+1)$ is serially independent. Replacing $E_t P(t+1)$ by $P(t+1) - u(t+1)$ in the above equation for $P(t)$ gives

$$P(t) = \delta P(t+1) + dE_t D(t) - u(t+1). \tag{9}$$

By the method of Chow (1983, ch. 11), we solve for $P(t+1)$ and reduce the time subscript of the equation by one to yield

$$P(t) = \delta^{-1} P(t-1) - E_{t-1} D(t-1) + u(t). \tag{10}$$

This equation for $P(t)$ can be estimated by assuming the following model for $D(t)$:

$$D(t) = \alpha_1 D(t-1) + \cdots + \alpha_p D(t-p) + \gamma_0 P(t) + \cdots + \gamma_p P(t-p) + b + v(t). \tag{11}$$

This enables us to replace $E_{t-1} D(t-1)$ in the equation for $P(t)$ by $D(t-1) - v(t-1)$ to yield

$$P(t) = \delta^{-1} P(t-1) - D(t-1) + u(t) + v(t-1). \tag{12}$$

Since $D(t-1)$ is correlated with the residual $u(t) + v(t-1)$, this equation is estimated by the method of instrumental variables using as instrument the least squares estimate $\hat{D}(t-1)$ of $E_{t-1} D(t-1)$. The result from using the deflated price index of Standard and Poor's 500 stocks from 1875 to 1987 is

$$\underset{(0.065)}{P(t) = 0.868}\; P(t-1) + \underset{(1.642)}{3.569}\; D(t-1) + \text{residual} \qquad s = 6.873 \quad DW = 1.685. \tag{13}$$

The model performs very poorly because the coefficient 0.868 of $P(t-1)$ should be $\delta^{-1} > 1$, but it is smaller by about two standard errors. The coefficient of $D(t-1)$ should be -1, but it is larger by over two and a half standard errors. The joint hypothesis of the two coefficients being respectively 1.02 and -1 is rejected at the 0.82 percent level.

To pursue the adaptive expectations hypothesis, denote $P(t+1)+D(t)$ by $X(t+1)$. The equation for $P(t)$ to be estimated implies $P(t)=\delta E_t X(t+1)$. Specify the adaptive expectations hypothesis as

$$E_t X(t+1) - E_{t-1}X(t) = \beta[X(t) - E_{t-1}X(t)] + \varepsilon(t) \tag{14}$$

where $\varepsilon(t)$ summarizes factors other than $X(t)-E_{t-1}X(t)$ which may affect the change in expectations; here the symbol E_t refer to psychological expectation based on information available at t. Multiplying this equation by δ and using this measure of expectation, one obtains

$$P(t) - P(t-1) = \delta\beta[P(t) + D(t-1)] - \beta P(t-1) + \delta\varepsilon(t) \tag{15}$$

or

$$P(t) = (1-\delta\beta)^{-1}(1\text{-}\beta)P(t-1) + (1-\delta\beta)^{-1}\delta\beta D(t-1) + (1-\delta\beta)^{-1}\delta\varepsilon(t). \tag{16}$$

This equation was estimated using annual data from 1875 to 1987 assuming the residual variance to be proportional to the square of the dependent variable. The result is (Chow, 1989, eq. 19):

$$\underset{}{P(t)} = \underset{(0.069)}{0.899}\ P(t-1) + \underset{(1.357)}{2.767}\ D(t-1) + \text{residual}. \tag{17}$$

Using these coefficients to solve for δ and β, one finds:

$$\hat{\delta} = \underset{(0.008)}{0.965} \qquad \hat{\beta} = \underset{(0.104)}{0.761}. \tag{18}$$

The adaptive expectations hypothesis is strongly supported by the data. The reader is referred to Chow (1989) for empirical analyses of the relation between long-term and short-term interest rates and of the mean reversion phenomenon for stock returns, supporting the adaptive expectations hypothesis and rejecting the rational expectations hypothesis. The evidence collaborates with the evidence in section 3 based on the adaptive expectation hypothesis. It is supported by the following analysis using Hong Kong data.

The Hong Kong data are obtained by aggregating the price and dividend data used in section 3 to form a value-weighted stock price index and a dividend index. We first regress the dividend index by two past dividends and current and two past prices, using up six degrees of freedom in a time series of 12 observations from 1982 to 1993. Because of heteroskadasticity, weighted least squares is used for the regression equation for dividends and the equations for stock prices under rational and adaptive expectations. The weights are constructed by assuming the residual variance to be proportional to $\exp[\alpha' w(t)]$, where $w(t)$ is a 3×1 vector consisting of 1, $y(t-1)$ and $y(t-2)$, y being the dependent variable in question. The weights are obtained by first regressing the logarithm of OLS residual squared on $w(t)$ and taking exponentials of the fitted values.

Under the assumption of rational expectations, the equation for the stock price index using 11 time series observations from 1983 to 1993 is

$$P(t) = \underset{(0.347)}{0.810}\, P(t-1) + \underset{(5.894)}{4.80}\hat{D}(t-1) + \text{residual} \qquad \begin{array}{l} s = 2.393 \\ DW = 1.430. \end{array} \tag{19}$$

According to theory, the coefficient of $P(t-1)$ should be larger than 1 and the coefficient for $\hat{D}(t-1)$ should be -1. The small number of observations makes the power of a test against such a null hypothesis small. Under the assumption of adaptive expectations, the result is

$$P(t) = \underset{(0.308)}{0.197}\, P(t-1) + \underset{(5.769)}{15.785}\, D(t-1) + \text{residual} \qquad \begin{array}{l} s = 2.343 \\ DW = 1.661 \end{array} \tag{20}$$

implying structural parameters

$$\hat{\delta} = \underset{(0.003)}{0.952} \qquad \hat{\beta} = \underset{(0.022)}{0.988} \tag{21}$$

which are consistent with the adaptive expectations hypothesis. The small standard errors in (21) given by the delta method are correct because of the large coefficient of $D(t-1)$ in (20) which appears in the denominator of the Jacobian to transform the coefficients in (20) to $\hat{\delta}$ and $\hat{\beta}$.

5. IMPLICATIONS FOR THE RATIONAL EXPECTATIONS HYPOTHESIS

The history of Hong Kong stock prices illustrates the possibility that the market can be affected by many uninformed investors. The existence of such investors explains the fact that capital does not flow from rich, low-yielding countries to high-yielding countries to equalize the rates of return in all countries immediately. US investors do not invest as much in Hong Kong stocks as warranted by their earning potential, simply because most US investors are not well-informed and do not understand the earning prospects of the Hong Kong stocks. This fact also explains the observed home bias in portfolio selection.

More generally, one should challenge the rational expectations hypothesis which assumes that economic agents know how to forecast expectations variables correctly. This hypothesis is contradicted by the reality of the current Hong Kong stock prices (*New York Times*, 1966). Section 4 has shown very conclusively by econometric analysis that the adaptive expectations hypothesis is much better than the rational expectations hypothesis in explaining the prices of stocks in terms of the prospects of future dividends. In Chow (1989), the adaptive expectations hypothesis is shown to be superior also in explaining the relations between long- and short-term interest rates, and is capable of explaining the phenomenon of mean revision in returns to stocks. Most learned economists reading Chow (1989) were convinced of the validity of the econometric analysis presented, but many did not abandon the rational expectations hypothesis which was considered a paradigm in the 1980s and 1990s.

Let it be emphasized that the evidence presented in this paper is not against the rational expectations hypothesis in general, but only the unquestioned application of the idea as originally conceived by Muth (1961) to all econometric models. The application assumes that economic agents whose behavior is captured in the model are always well-informed so that the mathematical expectations generated by the model are the same as the psychological expectations of the economic agents. When such an assumption is added to the present-value model of stock prices, the model fails, but when an adaptive expectations assumption is added, the resulting model succeeds. The failure of this model was also found by Campbell and Shiller (1987) and Campbell *et al* (1997, ch. 7) using other testing methods. The adaptive expectations assumption also works in the formation of the expected level of dividends and the expected change in dividends in explaining panel data on stock prices.

In the application of the rational expectations hypothesis to macroeconomic models, the expectations can be generated by solving the entire system of equations or only using a subset of instrumental variables (termed full-information and limited-information methods respectively). Fair (1994, ch. 5 and p. 320) found most of expectations variables so generated to be not significant for his model, except for three household expenditure equations. The evidence of this paper suggests that specification errors in an econometric model can result from the assumption of rational expectations. An argument supporting the rational expectations hypothesis for econometric models is that it follows from (1) the correctness of the model, and (2) the economic agents having at least as much information as the econometrician building the model. The problem in applying the hypothesis is that in estimating a model such as the present-value model (6), neither the econometrician nor the general investors have a very good model to forecast the important expectation variables (dividends in the example) far into the future, and thus the econometrician is forced to form some statistical time series model such as (11). The result is shown to be inferior to the adaptive expectations hypothesis. One area to which the rational expectations hypothesis can be fruitfully applied is perhaps general equilibrium theory dealing with the nature, existence and uniqueness of equilibrium.

Perhaps this paper will convince the economics profession to abandon the unquestioned application of rational expectations for the formation of psychological expectations in econometrics, because it is based on the frequently incorrect assumptions that all included economic variables are generated by a statistical model and that economic agents always form their psychological expectations which are equal to the mathematical expectations deduced from such a model. It is unreasonable to assume that all important economic events in history have been unbiasedly predicted, instant by instant, by the general public and by econometricians. If so, which econometricians?

Economists interpreting historical data by statistical models must admit that the movements of some variables, net of possible random effects, are known to them only by hindsight.

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