Journal of Accounting and Economics 4 (1982) 57–83. North-Holland Publishing Company

ANTICIPATION OF QUARTERLY EARNINGS ANNOUNCEMENTS

A Test of Option Market Efficiency*

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Received February 1982, final version received May 1982

This study tests Chicago Board Options Exchange efficiency by examining option price behavior in the weeks surrounding a firm's quarterly earnings announcement. The evidence presented here suggests that a first-order autoregressive seasonal process describes quarterly earnings behavior and demonstrates that the information content of an earnings announcement is fully incorporated in option prices by the end of the announcement week.

1. Introduction

In recent years much work has been devoted to testing the efficient market hypothesis.[1] Empiricists have focused on announcements of pending stock-splits, stock-dividends, mergers and acquisitions, secondary block offerings, and quarterly earnings and dividends, and have attempted to determine when the new information becomes fully incorporated in stock price.[2]

Of particular interest are the earnings announcement studies by Ball and Brown (1968), Jones and Litzenberger (1970), Litzenberger, Joy and Jones (1971), Brown and Kennelly (1972), Foster (1973), Joy, Litzenberger and McEnally (1977) and Watts (1978), among others. Since earnings expectations form the basis of security value, an unanticipated change in a firm's earnings level should be accompanied by a stock price movement.[3] Whether the stock price movement occurs after the earnings announcement date and, if it does, whether a trading strategy generates abnormal risk-adjusted returns are the issues that these studies investigate.

*Comments and suggestions by Kenneth M. Gaver, Ross L. Watts, Jerold L. Zimmerman and the referee are gratefully acknowledged. This research was supported by the Dean's Fund for Faculty Research at the Owen Graduate School of Management.

[1]For discussion on the 'efficient market hypothesis', see Fama (1976, ch. 5) or Jensen (1978).

[2]For a lucid review of some of the tests of market efficiency, see Fama (1976, ch. 5).

[3]This statement, of course, presumes that a positive relationship between accounting earnings and economic earnings exists.

The trading strategies employed in these investigations are usually based on univariate time series methods.[4] A model is fitted to the historical earnings of the firm, and then, using the estimated model parameters, a forecast of the next period's earnings is made. If, when the earnings figure for the next period is announced, the reported earnings exceed the forecast value, the common stock of the firm is purchased. If the reported earnings are below the forecast value, the stock is sold short. At the end of a predetermined holding period,[5] the positions are closed, and the gains or losses are realized.

Essentially these studies test the joint hypothesis that the time series model describes the quarterly earnings process and that the stock market is efficient. If abnormal returns from the trading strategies do not appear in the post-announcement period, the conclusion of stock market efficiency must be (and has not always been) tempered by the assumption that the time series model is valid.

Watts (1978) separates the hypothesis into parts by examining both pre-announcement and post-announcement stock price behavior. For the pre-announcement period Watts documents significantly positive abnormal returns. This evidence supports the structure of the earnings prediction model as well as the notion that the market anticipates the earnings release. The post-announcement returns, while significantly positive, are not large enough to offset transaction costs for individual traders, and, hence, New York Stock Exchange (NYSE) efficiency is supported.

The purpose of this study is to build upon the work of Watts by testing the efficiency of a relatively new market, the Chicago Board Options Exchange (CBOE). Previous studies of CBOE efficiency generally focus on identifying arbitrage opportunities, that is, option prices that deviate from the model values.[6] Only two studies, Patell and Wolfson (1979, 1981), investigate the effect of information releases by the underlying firm, but they concentrate on temporal movements in the implied standard deviation of stock return rather than profit opportunities in the option market. While they are able to support an information content hypothesis which posits that a firm's quarterly earnings announcement affects the standard deviation of the stock return distribution, they are unable to make a statement about the efficiency of the CBOE.

[4]Some studies use a model which specifies the earnings of the firm as a linear function of the earnings of some composite market index. This idea was first suggested by Ball and Brown (1968) and was later adopted by Magee (1974), Patell (1976), and Beaver, Clarke and Wright (1979), among others. Magee also examines a regression model that includes both a market and an industry factor.

[5]The length of the holding period ranges up to the 6 months used by Jones and Litzenberger (1970) and Litzenberger, Joy and Jones (1971).

[6]Examples of such studies include Black and Scholes (1972), Latane and Rendleman (1976), Galai (1977), Chiras and Manaster (1978), and Whaley (1982).

In an efficient capital market no one can earn abnormal risk-adjusted returns net of all transaction costs by trading on the basis of currently available information. The CBOE is essentially a redundant market since the income contingencies posed by an option can be duplicated by a continuously rebalanced portfolio consisting of a riskless asset and the underlying stock. The opportunity afforded by the option market is the savings in the transaction costs associated with rebalancing the riskless asset/stock portfolio. If small post-announcement returns before transaction costs appear for the stocks listed on NYSE, larger returns should appear for the call options written on those stocks, given the sensitivity of option price to movement in the stock price.[7] Whether the post-announcement option returns on a risk-adjusted basis are sufficient to offset the transaction costs a typical trader in the CBOE would face[8] is one issue that this research addresses. Whether a first-order autoregressive seasonal model describes the quarterly earnings process of the sample firms is another. In section 2 of the paper the sample data are described, and in section 3 the earnings forecast methodology is selected, discussed, and implemented. Section 4 contains the presentation of the option market efficiency test design and an examination of the test results. The paper concludes with a summary.

2. Data

The data employed in this study consisted of price, dividend, and earnings observations for 93 firms whose call options were traded on the CBOE during the 221-week period of September 28, 1973 through December 23, 1977. Ninety-two of the firms were listed on the NYSE, and one was listed on the AMEX. (A list of the firms is included in appendix A.) The weekly closing prices of the stocks, options, and Treasury Bills[9] were recorded from various issues of *Wall Street Journal*, and the quarterly dividend information was taken from *Standard and Poor's Stock Reports*. Quarterly earnings per share before extraordinary items and the earnings announcement date were compiled from *Wall Street Journal Index*, and the earnings figures were

[7]To see that a one percentage change in stock price wil induce at least a one percentage change in the call option price, consider the Black–Scholes (1973) option pricing equation as it is specified in appendix B. The elasticity of call price with respect to stock price is

$$\eta=(\partial C/\partial P)(P/C)=[1-Xe^{-rT}N_1(d_2)/PN_1(d_1)]^{-1}.$$

Since the call price is bounded from below by 0, the last term within the squared brackets has a maximum value equal to 1 and the elasticity has a minimum value equal to 1.

[8]In general, subsequent references to transaction costs in this study are to the costs incurred by a non-member individual trader. For a summary of these costs, see Phillips and Smith (1980, pp. 180–187).

[9]To compute the riskless rate appropriate to the time of expiration of each option, the effective yields of the two Treasury Bills whose terms most closely preceded and exceeded the option's expiration were interpolated.

verified with the information provided in *Moody's Common Stock Manuals*.[10] Wherever necessary, adjustments were made for stock-splits and stock-dividends. Weekly stock return data were generated from the *Center for Research in Security Price* (CRSP) daily return file, as were the weekly returns of the equal-weighted and the value-weighted NYSE-AMEX market indexes.

Three criteria were applied to determine if the call option would be included in the sample. First, the option's underlying stock had to have *no more* than one dividend paid during the option's remaining life. As part of the market efficiency test design, it was necessary to estimate the option's systematic risk. To do so, the stock's estimated systematic risk coefficient was multiplied by the elasticity of the option price with respect to the stock price, where the elasticity computation required an analytical valuation equation for the option. Since the solution to the American call option pricing problem where the underlying stock pays two or more dividends during the option's life is computationally expensive,[11] options with lives including more than one ex-dividend date were excluded. With the average sample option life about 3 months in duration, the average riskiness of the options is greater than it would have been if the long term options had been included.[12]

The second restriction disallowed every option whose price was less than $0.50 or more than $5 out-of-the-money. CBOE regulation generally prohibits traders from establishing new positions in options selling below these minimum prices. To presume trades could be initiated as the reported prices of these options would have introduced needless noise into the market efficiency test results.

The final restriction was imposed to accommodate the test methodology described in section 4. A 13-week period beginning 6 weeks before and ending 6 weeks after the quarterly earnings announcement week was defined as the interval during which option price movement would be investigated. Each of the weekly option prices were therefore earmarked by the number of weeks relative to the underlying firm's nearest earnings announcement week. Options traded during the sixth week before the firm's next earnings announcement were coded '−6', options traded during the fifth week before the announcement were coded '−5', and so on through the sixth week following the announcement. (The announcement week was coded '0'.)

[10]Where the *Wall Street Journal Index* earnings figure included extraordinary items, the *Moody's* figure was used.

[11]See Schwartz (1977) and Geske (1979b) for insights on how the American call option pricing problem may be solved when the stock pays multiple known dividends.

[12]The elasticity of call price with respect to stock price is specified in footnote 7. The change in the elasticity with respect to a change in the option's time to expiration is negative [see Galai and Masulis (1976, pp. 76–78)], hence, long-term options are less sensitive to stock price movements than short-term options.

Occasionally options on the stock were traded in weeks outside of this 13-week range because consecutive earnings announcement dates were more than 13 weeks apart.[13] These options were eliminated. Once all of the exclusion criteria were applied, 35,307 options remained in the 221-week sample period.

3. Earnings forecast methodology

Watts (1978) considers three univariate models to represent the quarterly earnings process: the Watts (1975) and Griffin (1977) first-order moving average, first-order seasonal moving average model, the Brown and Rozeff (1979) first-order autoregressive, first-order seasonal moving average model, and the Foster (1977) first-order autoregressive seasonal model. After a brief discussion concerning the past performance of the models, Watts examines the abilities of the models to generate abnormal returns in the periods before and after firms' earnings announcements. His evidence indicates that, of the three models, the more parsimonious Foster model provides the best description of the quarterly earnings process.[14] Consequently it was chosen to model earnings expectations in the present study.

The sample of earnings announcements for each firm was dictated by the availability of actively traded call options on the CBOE. At the beginning of the sample period, only 23 firms had options listed. For these firms the first quarterly earnings announcement recorded was that following September 28, 1973. For the remaining firms the first announcement recorded followed the date on which their options started trading on the Exchange.[15] The last recorded announcement for each firm was that preceding the end of the sample period, December 23, 1977, or the date on which the stock was delisted.[16] In all, 1,098 quarterly earnings announcements were compiled in this manner.

To develop the expectation of each earnings announcement by each firm, the Foster model was used. The quarterly earnings expectation using the first-order autoregressive seasonal model is

$$E(\tilde{z}_t) = z_{t-4} + \phi_1(z_{t-1} - z_{t-5}) + \delta, \tag{1}$$

[13] Conversely, there were occasions in which consecutive announcements were less than 13 weeks apart. In cases where a weekly option price was 6 weeks after the current earnings announcement week and 6 weeks before the next, the option price was earmarked only as -6. Thus, the number of options traded in the sixth week after the announcement is less than other weeks in the 13-week reaction interval.

[14] Watts (1978, p. 130) also cites evidence that, of the three models, the Foster model has the best predictive ability.

[15] Call options on the stock of Aluminum Company of America, for example, began trading in December 1974. Their first earnings announcement recorded in the sample was on January 18, 1975.

[16] In May 1976, Utah International, Inc. agreed to merge with General Electric Company. The last sample announcement date for UC was May 20, 1976.

where z_t represents the quarterly earnings process, ϕ_1 is the autoregressive parameter, and δ is a constant term. The values of ϕ_1 and δ were estimated using the 20 quarterly earnings observations prior to the firm's announcement, and, on the basis of each pair of parameter estimates, a forecast of the next quarter's earnings was developed.[17] The difference between the announced and the forecast values was defined as the unanticipated change in the firm's earnings.

4. Test of marked efficiency

4.1. Methodology

With the unanticipated quarterly earnings information recorded, the focus of the study turned to investigating the efficiency of the CBOE. Assuming quarterly earnings announcements contain information, the nature of the option price behavior in the weeks surrounding the announcement dates can support any of the following three hypotheses:[18]

H.1. The Foster model adequately describes the quarterly earnings process and the CBOE is an efficient market.

H.2. The Foster model adequately describes the quarterly earnings process and the CBOE is an inefficient market.

H.3. The Foster model does not adequately describe the quarterly earnings process.

If abnormal returns appear up to but not including the post-announcement period, the first hypothesis is supported, and, if abnormal returns appear in the post-announcement period also, the second hypothesis is supported. The last hypothesis is supported if abnormal returns do not appear in either the pre-announcement or the post-announcement periods.

Note the usage of 'adequately describes the quarterly earnings process' in the descriptions of the above hypotheses. The structure of the Foster model is supported if abnormal pre-announcement returns appear. That is not to say other expectation models will not generate abnormal pre-announcement returns. Many models will. Available empirical evidence, however, suggests

[17]The first earnings expectation developed for Alcoa (see footnote 15), for example, was based on the Foster model parameters estimated using the quarterly earnings number from the fourth quarter of 1969 through the third quarter of 1974.

[18]In the subsequent tests, the Black and Scholes (1973) and Roll (1977) and Whaley (1981) option pricing models are used to estimate the elasticity of the call option price with respect to the stock price, and the Sharpe (1964) and Lintner (1965) capital asset pricing model is used to perform risk adjustments on the arbitrage portfolio returns. The descriptions of the three joint hypotheses should therefore include references to the hypotheses: (a) that the option pricing models describe the observed structure of option prices and (b) that the two-parameter CAPM describes the observed structure of security returns.

that the Foster model does at least as well as any of the tested alternatives at explaining the quarterly earnings process. In the event a better expectation model can be found, a fourth hypothesis, observationally equivalent to H.1, should perhaps be entertained:

H.4. The Foster model adequately describes the quarterly earnings process, but it is not sufficiently adequate to detect CBOE market inefficiencies.

However, since a better expectation model has not been found,[19] a finding of abnormal returns in the pre-announcement but not the post-announcement period will be deemed to support H.1.

A 13-week reaction interval beginning 6 weeks before and ending 6 weeks[20] after the earnings announcement week was used in the investigation. Because the sample option prices were weekly closing prices, the 13 weeks were labeled by the integer values $i=-6,\dots,6$ with the announcement week labeled week 0.

Sixteen option trading strategies were considered. In the first 13 strategies (denoted by the integer values $i=-6,\dots,6$) the abnormal returns in the 13 weeks surrounding the announcement were examined. The investor was assumed to take his option position at the beginning of the ith week relative to the announcement and to hold it until the end of the week. With Trading Strategy -6, for example, the investor was assumed to have perfect knowledge of the impending announcement 6 weeks beforehand, to buy or sell the options according to whether the unanticipated earnings were positive or negative, and to hold his option position until the end of the week. With Trading Strategy -5 the investor was assumed to have perfect knowledge of the announcement 5 weeks beforehand, to take the appropriate position in the stock's options and to hold his position until the end of the week, and so on through Trading Strategy 6.

The fourteenth and fifteenth trading strategies (denoted by 'PRE' and 'POST', respectively) examined average pre-announcement and average post-announcement abnormal returns. With Trading Strategy PRE the option position was opened at the beginning of the sixth week before the announcement week and was closed at the end of the announcement week. With Trading Strategy POST the option position was opened at the beginning of the week following the announcement and was closed at the end of the sixth week following the announcement.

The sixteenth trading strategy (denoted by 'BOTH') examined the average

[19]Even if a better model is found, it will earn virtually the *same* abnormal profit as the Foster model since the two models will seldom differ as to the *sign* of the unanticipated change in earnings, and that is all the subsequent trading strategies depend on. For further discussion on this point, see Patell (1979).

[20]The methodology in this study assumes that the information content of the quarterly earnings announcement is incorporated in the option price by the end of the sixth week following the announcement.

abnormal return during the entire 13-week period surrounding the earnings announcement. The option position was opened at the beginning of the sixth week before the announcement week and was closed at the end of the sixth week following the announcement.

There are two problems posed by using options over the long investment horizons of Trading Strategies PRE, POST and BOTH. First, the risk of an option is not stationary through time. This makes effective option portfolio risk management difficult. Second, during the holding period, (a) some options may expire or (b) new options may be written. Since these options will also reflect the information content of the earnings announcement, they should also be included in the sample. To overcome these difficulties the option portfolio was rebalanced each week during the holding period. The rebalancing procedure explicitly adjusted for the temporal movement in the option's risk and allowed options to enter or leave the portfolio.

An arbitrage portfolio test methodology[21] was used to control the investment and the risk of the option position in each of the strategies. In Trading Strategy −6, for example, all options traded in the sixth week before a firm's earnings announcement were defined as 'eligible for investment'. At the beginning of each week during the 221-week sample period, 'favorable' options (i.e., eligible options whose underlying stocks had announced earnings above their predicted values) were ranked in descending order of systematic risk. An equal-weighted portfolio of 'high-risk' options and an equal-weighted portfolio of 'low-risk' options were then formed. Where the number of favorable options was odd, the low-risk portfolio contained an additional option. A single dollar was allocated between the high-risk and the low-risk portfolios such that the overall systematic risk of the combined portfolio position was equal to β^*, the arithmetic mean of the systematic risk coefficients of all options in the sample during the week.[22] The same procedure was then applied to the unfavorable options (i.e., eligible options whose underlying stocks had announced earnings below their predicted values), with the combined results being two option portfolios with similar wealth and risk characteristics. The favorable option portfolio was bought long, and the unfavorable option portfolio was sold short. Both positions were closed at the end of the week. If the Sharpe (1964) and Lintner (1965) capital asset pricing model (CAPM) describes the structure of security returns, the expected return of this costless arbitrage portfolio is

$$\begin{aligned} E(\tilde{r}_a) &= r + \beta_f[E(\tilde{r}_m) - r] - r - \beta_u[E(\tilde{r}_m) - r] \\ &= (\beta_f - \beta_u)[E(\tilde{r}_m) - r] = (\beta^* - \beta^*)[E(\tilde{r}_m) - r] = 0, \end{aligned} \tag{2}$$

[21]The costless arbitrage portfolio test methodology employed here was first used by Watts (1978) in his test of NYSE efficiency.

[22]While the selection of the value of β^* is somewhat arbitrary, the arithmetic mean of the options' systematic risk coefficients was chosen so that the weights on the high-risk and the low-risk option portfolios would be approximately equal and never negative.

where r_a denotes the costless arbitrage (a) portfolio return, β_f and β_u are the favorable (f) and unfavorable (u) option portfolio systematic risk coefficients, r_m is the return on the market portfolio, and r is the riskless rate of interest.

The mechanics underlying the weekly arbitrage portfolio selection warrants further description. A key element in forming the costless, riskless portfolio position is the call option's systematic risk. To estimate it, a four-step procedure was devised. First, the 100 weekly stock returns immediately preceding week t were regressed on the equal-weighted market index[23] in the market model form,

$$R_{Pt\tau}=\alpha_{Pt}+\beta_{Pt}R_{mt\tau}+\varepsilon_{Pt\tau}, \qquad \tau=t-100,\ldots,t-1, \tag{3}$$

to estimate the stock's systematic risk, β_{Pt}. Second, the implied standard deviation of the stock return, σ_{Pt}, was computed using all of the stock's options sharing a common maturity. (Appendix B contains a description of the option pricing models used, and appendix C contains the implied standard deviation computation procedure.) Third, the elasticity of the option price with respect to the stock price, η_t, was evaluated,[24] and, finally, the elasticity was multiplied by the stock's systematic risk to estimate the option's systematic risk,

$$\hat{\beta}_{Ct}=\eta_t\hat{\beta}_{Pt}.^{25} \tag{4}$$

Once the options' systematic risk estimates were computed, the weekly portfolio selection computations followed in a straightforward fashion. First, the high-risk (h) and the low-risk (l) favorable (f) and the high-risk and the low-risk unfavorable (u) option portfolio systematic risk estimates were made

[23]Brown and Warner (1980, pp. 239–243) argue that if the abnormal performance test methodology employs equal-weighted control portfolios an equal-weighted market index should be used. Consequently the results reported in this study are for the tests in which the equal-weighted NYSE-AMEX index was used. The test results using the value-weighted NYSE-AMEX index are essentially the same as those using the equal-weighted index, leaving the conclusions of the study unaltered. Copies of the value-weighted index test results are available from the authors.

[24]The elasticity of the option price with respect to the stock price is defined as

$$\eta_t=(\partial C_t/\partial P_t)(P_t/C_t),$$

where C_t is the option price at the beginning of week t and P_t is the stock price. Its value is estimated by evaluating the partial derivative of the American call option valuation equation with respect to the stock price and multiplying the result by the quotient, P_t/C_t.

[25]Eq. (4) holds only when the structure of capital asset prices is described by the Merton (1973a) intertemporal capital asset pricing model. By definition, $\beta_C\equiv\text{cov}(\tilde{r}_C,\tilde{r}_m)/\text{var}(\tilde{r}_m)$, where r_C and r_m are the instantaneous returns on the call option and the market portfolio. The Black and Scholes (1973) and Roll (1977) and Whaley (1981) call option pricing models assume that the returns of the option and the stock are perfectly correlated, that is, $\tilde{r}_C=\eta\tilde{r}_P$, where η is the elasticity of the option price with respect to stock price, so that $\beta_C=\text{cov}(\eta\tilde{r}_P,\tilde{r}_m)/\text{var}(\tilde{r}_m)=\eta\beta_P$.

using

$$\hat{\beta}_{hf}=\frac{1}{n_{hf}}\sum_{C=1}^{n_{hf}}\hat{\beta}_{Chf}, \tag{5a}$$

$$\hat{\beta}_{lf}=\frac{1}{n_{lf}}\sum_{C=1}^{n_{lf}}\hat{\beta}_{Clf}, \tag{5b}$$

$$\hat{\beta}_{hu}=\frac{1}{n_{hu}}\sum_{C=1}^{n_{hu}}\hat{\beta}_{Chu}, \tag{5c}$$

$$\hat{\beta}_{lu}=\frac{1}{n_{lu}}\sum_{C=1}^{n_{lu}}\hat{\beta}_{Clu}, \tag{5d}$$

respectively, where the subscript t has been dropped for notational convenience. Second, the mean systematic risk coefficient of all options was computed using

$$\beta^*=\frac{1}{n}\sum_{C=1}^{n}\hat{\beta}_{C}, \tag{6}$$

where, of course, $n=n_{hf}+n_{lf}+n_{hu}+n_{lu}$. Third, the portfolio weights (ω) attached to the high-risk and the low-risk favorable and unfavorable option portfolios were computed using

$$\omega_{hf}=(\beta^*-\hat{\beta}_{lf})/(\hat{\beta}_{hf}-\hat{\beta}_{lf}), \tag{7a}$$

$$\omega_{lf}=1-\omega_{hf}, \tag{7b}$$

$$\omega_{hu}=(\beta^*-\hat{\beta}_{lu})/(\hat{\beta}_{hu}-\hat{\beta}_{lu}), \tag{7c}$$

$$\omega_{lu}=1-\omega_{hu}. \tag{7d}$$

Finally, the favorable and the unfavorable option portfolios were combined to form the zero net investment (i.e., \$1 − 1 = \$0), zero systematic risk (i.e., $\beta^*-\beta^*=0$) arbitrage portfolio.

It is important to recognize that when the arbitrage portfolio systematic risk is estimated it may not be identically equal to zero. Certain biases may have been introduced in the formation of the riskless hedge. First, the elasticity computation used in estimating the option's systematic risk coefficient is based on an option pricing model that assumes the stock return follows a diffusion process which is stationary through time. However, since most of the sample options are on stocks of levered firms, the stock return process may not be stationary.[26] Furthermore, the way in which the model is used within the test methodology assumes that the stock price follows a jump process. Because the option pricing model employed may therefore be misspecified, the elasticities and hence the options' systematic risk estimates may be biased. Second, in the formation of the overall favorable and unfavorable option portfolios, options were classified into high-risk and low-risk portfolios. The high-risk portfolio therefore contains out-of-the-money options and the low-risk portfolio contains in-the-money options.[27]

The effects of these problems, however, should be minimized by the hedging of the favorable option portfolio against the unfavorable option portfolio. As long as the firms with favorable announcements do not differ systematically from the firms with unfavorable announcements and as long as the options in the favorable option portfolio do not differ systematically from the options in the unfavorable option portfolio, the errors in measurement introduced in forming the favorable option portfolio will be approximately offset by those in the unfavorable option portfolio.

In summary, 16 option trading strategies are considered. The abnormal returns of the 13 trading strategies denoted by the integer values will identify when option prices react to the information content of the earnings announcement. The pre-announcement Trading Strategy PRE will allow the evaluation of the earnings forecast model and of the market's anticipatory ability, and the post-announcement Trading Strategy POST in combination with PRE will enable the statement about market efficiency. Trading Strategy BOTH will examine whether options on stocks with favorable earnings announcements systematically outperform options on stocks with unfavorable announcements in the weeks surrounding the announcement.

4.2. Results

To illustrate how the portfolio selection methodology performed, the weekly composition of the arbitrage portfolio of Trading Strategy -6 is summarized in table 1. The procedure yielded well-balanced option positions during the 55 weeks in which the Strategy had open positions in options, with the weights on the high-risk and the low-risk portfolios averaging about 0.5 and never falling outside of the 0.3–0.7 range. It is interesting to note that the mean call option systematic risk is 7.584, reflecting the extreme sensitivity of option price to movement in the market.

[26]If the firm is levered and if the value of the firm is assumed to follow a lognormal diffusion process, the stock return process will be nonstationary. Geske (1979a) derives the valuation equation for a European call under these assumptions.

[27]The change in the elasticity (see footnote 7) with respect to a change in exercise price is positive [see Galai and Masulis (1976, pp. 76–78)]. Hence, options on a given stock will be more or less risky depending upon whether they are out-of- or in-the-money.

Table 1

Description of the high-risk and low-risk favorable and the high-risk and low-risk unfavorable option portfolio weights used in forming the costless arbitrage portfolio in each of the 55 weeks during which Trading Strategy −6 had open positions in the options. The sample period is September 28, 1975 through December 23, 1977.

		Favorable options			Unfavorable options		
	Portfolio[a] systematic risk	No. of options	High-risk[b] portfolio weight	Low-risk[b] portfolio weight	No. of options	High-risk[b] portfolio weight	Low-risk[b] portfolio weight
	β^*	n_f	ω_{hf}	ω_{lf}	n_u	ω_{hu}	ω_{lu}
Mean	7.584	18.4	0.476	0.524	16.9	0.430	0.570
Standard deviation	1.730	10.6	0.348	0.348	10.2	0.259	0.259
Mean absolute deviation	1.418	9.2	0.175	0.175	7.8	0.173	0.173
Deciles							
0.10	5.301	7.0	0.245	0.262	6.5	0.176	0.313
0.20	6.163	9.0	0.380	0.370	9.0	0.288	0.429
0.30	6.296	9.0	0.425	0.438	10.5	0.335	0.456
0.40	7.097	12.0	0.493	0.469	12.0	0.429	0.523
0.50	7.396	15.5	0.509	0.485	14.5	0.459	0.533
0.60	7.935	22.0	0.539	0.521	17.0	0.486	0.578
0.70	8.445	24.5	0.554	0.568	19.0	0.529	0.634
0.80	9.120	29.0	0.632	0.640	25.0	0.575	0.713
0.90	10.121	33.0	0.734	0.717	28.5	0.653	0.784

[a]The value of β^* is the arithmetic average of the systematic risk coefficients of all options contained in the sample in each week.

[b]To form the costless arbitrage portfolio each week, four portfolios are initially created by equal-weighted investments in high-risk and low-risk favorable and high-risk and low-risk unfavorable options. The four weights listed in these columns are the weights applied to the equal-weighted portfolios in order to match the systematic risk characteristics of the favorable and unfavorable options at β^*. By going long one dollar in the favorable option position and short one dollar in the unfavorable option position, a costless (i.e., $\$1-1=\$0$), riskless (i.e., $\beta^*-\beta^*=0$) arbitrage portfolio is formed.

Note that the arbitrage portfolio of Trading Strategy −6 had open option positions in only 55 of the 221 weeks during the sample period. If the trading strategy had fewer than 10 options eligible for investment in a given week, no arbitrage portfolio return observation was recorded for that week. The constraint requiring at least 10 options each week was imposed to ensure (a) that the portfolio weights attached to the high-risk portfolios (i.e., ω_{hf} and ω_{hu}) and to the low-risk portfolio (i.e., ω_{lf} and ω_{lu}) were positive and (b) that the arbitrage portfolios were at least modestly diversified. If the sample firms' fiscal year end dates and/or if the option expiration dates were randomly distributed throughout the calendar year the return series would likely not have had missing observations. However, such was not the case.

The timing of the earnings announcements and the option expirations had an effect on the number of options traded in each of the 13 weeks relative to announcement. These numbers were:

	Week relative to announcement	Total number of options traded
	−6	2,774
	−5	2,886
	−4	3,018
	−3	3,004
	−2	2,924
	−1	2,886
Announcement week	0	2,799
	1	2,700
	2	2,637
	3	2,532
	4	2,504
	5	2,418
	6	2,225[28]
	Total	35,307

Seventy-six percent of the firms in the sample had fiscal year end December 31, and another 11 percent had fiscal year end March 31, June 30 or September 30. (See appendix A.) Because the elapsed time between the quarter's end and the earnings announcement was about 4 weeks, the announcements of 87 percent of the sample firms fell approximately in the

[28]See footnote 13.

fourth week of January, April, July and October. Coincidentally, during the first 84 weeks of the sample period, the expiration dates of the call listed on the CBOE were in the fourth week of January, April, July and October.[29] Hence, one reason that the number of options decreased as the announcement week drew near is that the shortest term options became less actively traded and eventually expired. Moreover, during the last 137 weeks the CBOE listed options with four additional expiration months — February, May, August, and November. Hence, the number of options continued to decrease after the announcement week because more of the options expired about 4 weeks after disclosure.

Each of the 16 arbitrage portfolio return series was regressed on the equal-weighted market index,

$$R_{at} = \alpha_a + \beta_a R_{mt} + \varepsilon_{at}, \tag{8}$$

to check if any systematic risk effect remained. Indeed, this could have been the case because, in addition to the biases introduced when the option portfolio was formed, the option return process is not stationary through time.[30] Where the portfolio return series was discontinuous, the corresponding market return observations were dropped. The regression results are reported in table 2.

In table 2, the first column lists the trading strategies, the second, the number of time series observations used in the regression, and, the third, the number of eligible options. The remaining columns contain the market model regression statistics, where $p[t(\cdot)]$ is the p-value, that is, the probability that $t(\cdot)$ is exceeded in absolute magnitude by a random variable drawn from a Student t-distribution.

Note that the number of options used in each of the first 13 trading strategies in table 2 is less than the number of options in each week relative to the announcement week reported earlier. This is because of the constraint requiring at least 10 options in the option portfolio in a given week. With Trading Strategy −6, for example, 832 (i.e., 2,774 −1,942) options traded in the sixth week prior to the announcement were lost due to the constraint. On the other hand, with Trading Strategy BOTH the constraint had no effect and all of the sample options were included.

The regression results in table 2 show that there is no predictable systematic relationship between the arbitrage portfolio returns and the

[29]Prior to January 1976 the call option expiration date was the last Monday of the expiration month. Since January 1976 the expiration date has been the Saturday after the third Friday of the expiration month.

[30]Boyle and Emanuel (1980) examine the implications of using discretely adjusted hedge portfolios in tests of market efficiency.

Table 2

Summary results from the market model regressions of the 16 arbitrage portfolio time series on the equal-weighted market index for the 221-week period September 28, 1973 through December 23, 1977.

$$R_{at} = \alpha_a + \beta_a R_{mt} + \varepsilon_{at}.$$

Trading strategy[a]	No. of weeks[b]	No. of options[c]	$\hat{\alpha}_a$	$t(\hat{\alpha}_a)$	$p[t(\hat{\alpha}_a)]$	$\hat{\beta}_a$	$t(\hat{\beta}_a)]$	$p[t(\hat{\beta}_a)]$	R^2
−6	55	1,942	0.02278	0.86	0.393	2.43177	2.49	0.016	0.1048
−5	60	2,209	0.03554	1.33	0.187	0.62869	0.54	0.591	0.0050
−4	61	2,387	0.04145	1.72	0.091	−0.48172	−0.58	0.563	0.0057
−3	62	2,327	−0.01622	−0.78	0.439	0.52410	0.75	0.458	0.0092
−2	59	2,214	0.05328	1.36	0.179	−3.93695	−2.98	0.004	0.1349
−1	56	2,090	0.04496	1.14	0.260	1.32911	0.72	0.476	0.0094
0	56	1,954	0.10481	3.27	0.002	−1.57763	−0.99	0.324	0.0180
1	61	1,877	0.01933	0.70	0.484	−1.66986	−1.22	0.228	0.0245
2	65	1,829	−0.00227	−0.08	0.937	1.25329	0.89	0.374	0.0125
3	55	1,718	0.03964	1.31	0.195	1.05831	0.80	0.426	0.0120
4	49	1,577	−0.01126	−0.48	0.635	0.89112	0.91	0.366	0.0174
5	47	1,574	0.00489	0.15	0.878	−0.07707	−0.05	0.959	0.0001
6	47	1,544	−0.02705	−0.94	0.354	−0.28031	−0.26	0.796	0.0015
PRE	204	22,788	0.03692	3.66	0.000	0.36017	0.97	0.331	0.0047
POST	166	11,746	0.00603	0.53	0.598	−0.22268	−0.49	0.624	0.0015
BOTH	221	35,307	0.02718	4.16	0.000	0.29440	1.26	0.210	0.0072

[a]The numbers and labels in this column denote the trading strategy. The trading strategies with integer values $i = -6, \ldots, 6$ indicate the arbitrage portfolio is opened at the beginning and closed at the end of the ith week relative to the announcement week. With Trading Strategy PRE the arbitrage portfolio is formed using options traded between the beginning of the sixth week before the earning's announcement week and the end of the announcement week; with Trading Strategy POST the arbitrage portfolio is formed using options traded between the beginning of the week following the announcement and the end of the sixth week following the announcement; and, with Trading Strategy BOTH the arbitrage portfolio is formed using options traded between the beginning of the sixth week before and ending the sixth week after the announcement week.

[b]This column presents the number of weeks during which the trading strategy had open positions in the options.

[c]This column presents the number of options eligible for investment in all weeks given the trading strategy. For example, Trading Strategy 2 used 1,829 options in forming the arbitrage portfolio during the 65 weeks in which there were open positions, or, alternatively, there were an average of 28 options in the arbitrage portfolio each week during the 65 weeks.

market index for the first 13 trading strategies.[31] Although the systematic risk coefficients range from -3.937 to 2.432, the average risk coefficient across strategies is only about 0.006. The magnitude of some of the coefficients may seem to be a source of concern. However, it should be noted that the R-squared values are below 14 percent. This indicates that nearly all of the arbitrage portfolio return variability is unexplained by the market influence. Also, since the average systematic risk of the call options in the sample is 7.584, even a systematic risk coefficient of -3.937 is small in a relative sense.

The systematic risk coefficients of Trading Strategies PRE, POST and BOTH reflect the fact the average number of options in the arbitrage portfolio each week is greater than it is for the first 13 strategies. The coefficients are very close to their hypothesized value of zero. Furthermore, the R-squared values of less than 1 percent indicate virtually no correlation between the returns of the arbitrage portfolios and the market index remains.

Since the systematic risk coefficients reported in table 2 were generally not significantly different from zero, the tests of the hypothesis that the arbitrage portfolio returns were equal to zero were performed using the raw portfolio return series. The zero abnormal return hypothesis was tested under two distributional assumptions. First, the Student t-test,

$$t_S = \sqrt{n}\bar{R}_a / s_a,$$

where n denotes the number of return observations of the arbitrage portfolio, $\bar{R}_a$ denotes the mean realized return, and s_a denotes the sample standard deviation of return, was performed. It, of course, assumes that the return observations are drawn from a normal population. But, there was a possibility that the portfolio returns were asymmetric,[32] so a second test, the Johnson (1978) modified t-test,

$$t_J = \sqrt{n}[\bar{R}_a + \hat{\mu}_{3a}/6s_a^2 n + \hat{\mu}_{3a}\bar{R}_a/3s_a^4]/s_a,$$

[31] While it appears to have no bearing on the regression results, it is interesting to note that the 93 sample firms did not perform particularly well during the 221-week sample period. The means and standard deviations of the weekly returns for an equal-weighted portfolio of the sample stocks, the equal-weighted NYSE-AMEX market index and the value-weighted NYSE-AMEX market index were:

	Mean	Standard deviation
Equal-weighted stock portfolio	0.00031	0.03115
Equal-weighted market index	0.00400	0.02765
Value-weighted market index	0.00065	0.02548

[32] See footnote 30.

where $\hat{\mu}_{3a}$ denotes the third central sample moment of the portfolio returns, was also performed. The test results are reported in table 3.

The results in table 3 indicate that the information content of the earnings announcement is disseminating into the option market primarily during the announcement week. The abnormal return of Trading Strategy 0 is 9.91 percent, significant at the 5 percent level regardless of the choice of test statistic.[33] The abnormal returns during the remaining pre-announcement weeks (i.e., Trading Strategies -6 through -1) are generally positive, but insignificant. Those during the post-announcement weeks (i.e., Trading Strategies 1 through 6) are both positive and negative and insignificant.

It is interesting to note that the option market reaction appears at about the same time as the stock market reactions observed elsewhere. Foster (1977, p. 17), for example, finds that the information content of the earnings announcement has its largest effect on the stock price in the 2 trading days prior to the announcement.[34] In this study the frequency distribution of announcements during the announcement week is as follows:

Day	No. of announcements
Monday	96
Tuesday	204
Wednesday	230
Thursday	296
Friday	272
Total	1,098

On average the announcement occurs on the Wednesday of the announcement week, with the largest abnormal return, 9.91 percent, appearing in that week. The second largest abnormal return in the week before the announcement, probably as a result of the information content of Monday and Tuesday announcements.

The results in table 3 also indicate that the null hypothesis of a zero expected return can be rejected at the 5 percent level for Trading Strategy

[33]The similarity between the Johnson and the Student t-ratios indicates that the hedging activity managed to control the symmetry of the arbitrage portfolio return distribution.

[34]The announcement dates used in the Foster study, as well as in this study, are the dates on which the earnings reports were published in the *Wall Street Journal*. Patell and Wolfson (1981, pp. 445–446), however, point out that the earnings announcements generally appear on the *Dow Jones News Service* a day earlier. Hence, Foster's finding that the largest stock price movement occurs in the two trading days before the *WSJ* publication may actually be documentation of an information effect in the day before and the day of the earnings announcement.

Table 3
Mean weekly abnormal returns on the 16 arbitrage portfolio time series during the 221-week period September 28, 1973 through December 23, 1977.

Trading strategy[a]	No. of weeks[b]	No. of options[c]	Mean abnormal return $\bar{R}_a$	Student t-ratio t_S	$p(t_S)$	Johnson t-ratio t_J	$p(t_J)$
−6	55	1,942	0.04534	1.74	0.087	1.83	0.073
−5	60	2,209	0.04273	1.86	0.068	1.83	0.072
−4	61	2,387	0.03693	1.63	0.109	1.48	0.143
−3	62	2,327	−0.01117	−0.57	0.571	−0.59	0.558
−2	59	2,214	0.00694	0.18	0.857	0.12	0.902
−1	56	2,090	0.05442	1.47	0.148	1.35	0.183
0	56	1,954	0.09908	3.14	0.003	3.31	0.002
1	61	1,877	0.01468	0.54	0.593	0.53	0.598
2	65	1,829	−0.00107	−0.04	0.970	−0.06	0.951
3	55	1,718	0.03831	1.27	0.208	1.37	0.175
4	49	1,577	−0.01269	−0.54	0.591	−0.54	0.593
5	47	1,574	0.00489	0.16	0.876	0.14	0.890
6	47	1,544	−0.02684	−0.94	0.352	−0.92	0.364
PRE	204	22,788	0.03927	4.01	0.000	4.41	0.000
POST	166	11,746	0.00571	0.50	0.617	0.51	0.612
BOTH	221	35,307	0.02836	4.38	0.000	4.53	0.000

[a]The numbers and labels in this column denote the trading strategy. The trading strategies with integer values $i=-6,\ldots,6$ indicate the arbitrage portfolio is opened at the begining and closed at the end of the ith week relative to the announcement week. With Trading Strategy PRE the arbitrage portfolio is formed using options traded between the beginning of the sixth week before the earnings announcement week and the end of the announcement week; with Trading Strategy POST the arbitrage portfolio is formed using options traded between the beginning of the week following the announcement and the end of the sixth week following the announcement; and, with Trading Strategy BOTH the arbitrage portfolio is formed using options traded between the beginning of the sixth week before and ending the sixth week after the announcement week.

[b]This column presents the number of weeks during which the trading strategy had open positions in the options.

[c]This column presents the number of options eligible for investment in all weeks given the trading strategy. For example, Trading Strategy 2 used 1,829 options in forming the arbitrage portfolio during the 65 weeks in which there were open positions, or, alternatively, there were an average of 28 options in the arbitrage portfolio each week during the 65 weeks.

PRE and cannot be rejected at the 5 percent level for Trading Strategy POST. This evidence, on a before-transaction-cost basis, supports the joint hypothesis (H.1) that the Foster model describes the quarterly earnings process and the CBOE is an efficient market. The pre-announcement trading strategy allows a positive and significant abnormal return, while the post-announcement strategy allows a positive but insignificant one.

The mean abnormal return of the pre-announcement trading strategy in table 3 can be compared to returns documented in studies of stock market efficiency. For example, Foster (1977, p. 15), using a sample of 69 firms during the period 1963 through 1974, finds that a first-order autoregressive seasonal model generates a cumulative average residual of 0.0454 over the 60 trading days preceding and including the announcement date.[35] Since there are approximately 251 trading days in a calendar year, this figure translates to a mean abnormal weekly return of about 0.37 percent (i.e., 4.54% ×(251/60)/52). Watts (1978, p. 140), using a sample of 73 firms during the period 1962 through 1969 and the Foster earnings expectation model, reports an abnormal return of 5.3 percent for the 13 weeks preceding and including the announcement week. His figure, on a weekly basis, is 0.41 percent (i.e., 5.3%/13). These adjusted figures are dramatically below the 3.93 percent mean weekly abnormal return for the 7 weeks preceding and including the announcement week (i.e., the abnormal return of Trading Strategy PRE).

A similar comparison is possible with the abnormal return of Trading Strategy BOTH. Foster (1977, p. 17) reports that a seasonal earnings expectation model[36] is able to generate a cumulative average residual of about 0.0378 over the 41 trading days surrounding the announcement date.[37] This is roughly equivalent to a weekly abnormal return of 0.44 percent (i.e., 3.78% × (251/41)/52). The mean abnormal return of the arbitrage portfolio in the 13 weeks surrounding the earnings announcement was 2.84 percent, more than 6 times the stock return reported by Foster.

Such comparisons can be misleading given that the sample firms and time periods are different. Methodologically, however, this study is very much similar to that of Watts. The difference between the abnormal returns (3.93% versus 0.41%) is at least partially attributable to the fact that options are much more sensitive to information releases than stocks. That is not to say that the option market is more efficient, but merely that the elasticity of option price with respect to a change in stock price is greater than 1.

The Watts study also provides a benchmark with which the post-announcement results can be compared. For the 13 weeks after the earnings announcement Watts reports an abnormal return of 2.1 percent. On a weekly basis this figure is 0.16 percent (i.e., 2.1%/13). The mean weekly abnormal

[35]More precisely, Foster (1977, p. 15) reports that firms with favorable earnings announcements have a cumulative average residual (*CAR*) of 0.0202 and firms with unfavorable announcements have a *CAR* of −0.0252. Assuming the group of stocks with favorable announcements are bought long and the group of stocks with unfavorable announcements are sold short, the composite *CAR* (analogous to an arbitrage portfolio return) is 0.0454.

[36]The seasonal earnings expectation model used by Foster is $E(\tilde{z}_t) = z_{t-4} + \delta$.

[37]The figure Foster (1977, p. 17) reports as the composite cumulative average residual (CAR_c) is 0.0189. This value was computed as

$$CAR_c = (n_f CAR_f + n_u CAR_u)/(n_f + n_u),$$

where n_f and n_u are the number of firms with favorable and unfavorable earnings announcements, respectively, and CAR_f and CAR_u are the cumulative average residuals of the favorable and unfavorable announcement stock portfolios, respectively. Assuming n_f and n_u are approximately equal, his figure of 0.0189 must be multiplied by 2 to make it comparable to an arbitrage portfolio return.

return of the strategy which took an option position at the end of the announcement week and held it until 6 weeks after the announcement (i.e., the abnormal return of Trading Strategy POST) is 0.57 percent. These figures are close and small, reflecting that the information content of the quarterly earnings announcement is incorporated in stock and option prices by the end of the announcement week.

The joint hypothesis is that the Foster model describes the quarterly earnings process and the CBOE is an efficient market is also supported on an after-transaction-cost basis. Consider, for example, an investor who employs Trading Strategy POST. On the Friday of the earnings announcement week, he buys options whose underlying stocks have favorable announcements and sells options whose stocks have unfavorable announcements in proportions such that a zero systematic risk, zero net investment option portfolio is formed. Each week he rebalances his portfolio to maintain the riskless hedge and at the end of 6 weeks he closes his position, earning an average weekly return of 0.57 percent. To be eligible to earn this abnormal return of 3.42 percent (i.e., $0.57\% \times 6$) over the 6-week holding period, however, this investor would incur transaction costs both on the purchase and on the sale of the options both at the beginning and at the end of his 6-week holding period.[38] For a trading profit to be earned, therefore, the 'one-way' transaction cost rate would have to be less than 0.86 percent (i.e., $3.42\%/4$),[39] which is less than the Phillips and Smith (1980, p. 180) estimate of the option market maker's fee, 2.25 percent.[40] Thus, the CBOE appears to be an efficient market.[41]

In addition to the market maker's fee, an option trader faces a commission charge. Prior to May 1975 the CBOE set the minimum commission rate structure and since that time the rates have been negotiated. Under either regime, however, 1 percent of the money involved in the transaction is a low estimate of the commission cost. If the 1 percent figure is added to the relative spread estimate of 2.25 percent and is then applied to the return of Trading Strategy PRE in table 3, trading profit remains positive. This evidence supports the ability of the Foster model to describe the quarterly earnings process.

[38]It is assumed that no transaction costs are paid when the portfolio is rebalanced during the holding period.

[39]This figure is only an approximation, albeit a fairly accurate one. For an exact computation, see Whaley (1982, p. 55).

[40]Phillips and Smith (1980, p. 184) report that the average bid–ask spread for CBOE call options priced at more than $0.50 is 4.5 percent of the average of the bid and ask prices. Since the option prices used in this study are the prices recorded in the last transaction of the week, they are a mixture of bids and asks and are, on average, midway between the two. A plausible estimate of the market maker's fee in this analysis is, therefore, one-half of the relative spread or 2.25 percent.

[41]Given the magnitude of the post-announcement abnormal returns it is doubtful that an option market maker could react profitably to a firm's quarterly earnings announcement.

5. Summary and conclusions

This study investigates the efficiency of the Chicago Board Options Exchange during the period September 28, 1973 through December 23, 1978 by evaluating the information content of quarterly earnings announcements. A first-order autoregressive seasonal model (i.e., the Foster model) is used to forecast firms' quarterly earnings, and deviations from predictions are used to trigger purchases and sales of the firms' call options. An arbitrage portfolio selection technique is applied to govern the risk of and the investment in the option positions.

The evidence reported in this study indicates that the CBOE is an efficient market. No profits net of transaction costs can be earned in the option market by trading on the basis of firms' earnings announcements. Market prices appear to reflect fully the information content of the earnings disclosure by the end of the announcement week.

In fact, the information content of the earnings announcement has its most dramatic impact on option prices during the announcement week. While most of the returns in the pre-announcement weeks are positive, the return in the week of the announcement is dramatically larger and more significant.

Finally, the results of the study support the structure of the Foster earnings expectation model. Because the abnormal return of the pre-announcement trading strategy is positive and significant, it can be concluded that the model adequately describes the quarterly earnings process.

Appendix A: Sample firms

Ticker symbol	Firm name	Fiscal year end (month/day)
AA	Aluminum Company of America	12/31
AEP	American Electric Power, Inc.	12/31
T	American Telephone and Telegraph Company	12/31
AMP	AMP, Inc.	12/31
ARC	Atlantic Richfield Company	12/31
AVP	Avon Products, Inc.	12/31
BLY	Bally Manufacturing Corp.	12/31
BAX	Baxter Travenol Laboratories, Inc.	12/31
BS	Bethlehem Steel Corporation	12/31
BDK	Black & Decker Manufacturing Company	9/30
BA	Boeing Company	12/31
BCC	Boise Cascade Corporation	12/31

Ticker symbol	Firm name	Fiscal year end (month/day)
BC	Brunswick Corporation	12/31
BUR	Burlington Industries	9/30
BGH	Burroughs Corporation	12/31
CBS	CBS Incorporated	12/31
FNC	Citicorp	12/31
KO	Coca-Cola Company	12/31
CL	Colgate-Palmolive Company	12/31
CWE	Commonwealth Edison Company	12/31
CDA	Control Data Corporation	12/31
DAL	Delta Airlines, Inc.	6/30
DEC	Digital Equipment Corporation	6/30
DIS	Disney (Walt) Productions	9/30
DOW	Dow Chemical Company	12/31
DD	Du Pont (E.I.) De Nemours & Company	12/31
EK	Eastman Kodak Company	12/31
XON	Exxon Corporation	12/31
FNM	Federal National Mortgage Association	12/31
FLR	Fluor Corporation	10/31
F	Ford Motor Company	12/31
GD	General Dynamics Corporation	12/31
GE	General Electric Company	12/31
GF	General Foods Corporation	3/31
GM	General Motors Corporation	12/31
GWF	Great Western Financial Corporation	12/31
GW	Gulf & Western Industries, Inc.	7/31
HAL	Halliburton Company	12/31
HWP	Hewlett-Packard Company	10/31
HIA	Holiday Inns, Inc.	12/31
HM	Homestake Mining Company	12/31
HON	Honeywell, Inc.	12/31
HOI	Houston Oil & Minerals Corporation	12/31
INA	INA Corporation	12/31
IBM	International Business Machines Corporation	12/31
IFF	International Flavors & Fragrances, Inc.	12/31
HR	International Harvester Company	10/31
IGL	International Minerals & Chemicals Corporation	6/30
IP	International Paper Company	12/31
ITT	International Telephone & Telegraph Corporation	12/31
JM	Johns Manville Corporation	12/31
JNJ	Johnson & Johnson	12/31

Ticker symbol	Firm name	Fiscal year end (month/day)
KM	K Mart Corporation	1/31
KN	Kennecott Copper Corporation	12/31
KMG	Kerr-McGee Corporation	12/31
LTR	Loews Corporation	8/31
MGI	MGIC Investment Corporation	12/31
MCD	McDonald's Corporation	12/31
MRK	Merck & Company, Inc.	12/31
MER	Merrill Lynch & Co., Inc.	12/31
MMM	Minnesota Mining and Manufacturing Company	12/31
MOB	Mobil Corporation	12/31
MTC	Monsanto Company	12/31
NCR	NCR Corp.	12/31
NSM	National Semiconductor Corporation	5/31
NWA	Northwest Airlines, Inc.	12/31
OXY	Occidental Petroleums Corporation	12/31
PZL	Pennzoil Company	12/31
PEP	Pepsico, Inc.	12/31
PRD	Polaroid Corporation	12/31
RCA	RCA Corporation	12/31
RTN	Raytheon Company	12/31
RJR	Reynolds (R.J.) Industries, Inc.	12/31
SLB	Schlumberger, Ltd.	12/31
S	Sears Roebuck & Company	1/31
SKY	Skyline Corporation	5/31
SO	Southern Company	12/31
SY	Sperry Rand Corporation	3/31
SN	Standard Oil Company of Indiana	12/31
SYN	Syntex Corporation	7/31
TAN	Tandy Corporation	6/30
TDY	Teledyne, Inc.	12/31
TSO	Tesoro Petroleums Corp.	9/30
TXN	Texas Instruments, Inc.	12/31
TG	Texasgulf, Inc.	12/31
UAL	UAL, Inc.	12/31
UTX	United Technologies Corporation	12/31
UPJ	Upjohn Company	12/31
UC	Utah International, Inc.	10/31
JWC	Walter (Jim) Corporation	8/31
WY	Weyerhaeuser Company	12/31
WMB	Williams Companies	12/31
XRX	Xerox Corporation	12/31

Appendix B: Valuation equations for an American call option

Black and Scholes (1973) derive the first analytical solution to the European call option pricing problem. Its specification is

$$c(P,T,X)=PN_1(d_1)-X\mathrm{e}^{-rT}N_1(d_2), \tag{B.1}$$

where

$$d_1=[\ln(P/X)+(r+0.5\sigma^2)T]/\sigma\sqrt{T}, \qquad d_2=d_1-\sigma\sqrt{T},$$

and where P is the stock price, X is the exercise price, r is the riskless rate of interest, σ is the standard deviation of stock return, T is the time to expiration, and $N_1(d)$ is the univariate cumulative normal density function with upper integral limit d. Merton (1973b, p. 144) and Smith (1976, pp. 8–11) demonstrate that if the stock pays no cash dividends during the option's life the option will not be exercised before expiration and, hence, the value of an American call option on non-dividend-paying stock is equal to the value of the European call, that is,

$$C(P,T,X)=c(P,T,X). \tag{B.2}$$

If the stock pays a single known dividend during the option's life, eq. (B.2) no longer applies because: (a) the value of the underlying asset is reduced and (b) there is a non-zero probability that the option will be exercised before expiration. Whaley (1981), based upon the work of Roll (1977), provides the valuation equation for an American call option on a stock with a known dividend,

$$\begin{aligned} C(S,T,X)=&\,S[N_1(b_1)+N_2(a_1,-b_1;-\sqrt{t/T})]\\ &-X\mathrm{e}^{-rT}[N_1(b_2)\mathrm{e}^{r(T-t)}+N_2(a_2,-b_2;-\sqrt{t/T})]\\ &+\alpha D\mathrm{e}^{-rt}N_1(b_2), \end{aligned} \tag{B.3}$$

where

$$a_1=[\ln(S/X)+(r+0.5\sigma^2)T]/\sigma\sqrt{T}, \qquad a_2=a_1-\sigma\sqrt{T},$$

$$b_1=[\ln(S/S_t^*)+(r+0.5\sigma^2)t]/\sigma\sqrt{t}, \qquad b_2=b_1-\sigma\sqrt{t},$$

and where S is the stock price net of the escrowed dividend (i.e., $S_\tau=P_\tau-\alpha D\mathrm{e}^{-r(t-\tau)}$ for $\tau<t$ and $S_\tau=P_\tau$ for $t\leqq\tau\leqq T$), D is the amount of the dividend, t is the time to the ex-dividend date, and $N_2(a,b;\rho)$ is the bivariate cumulative normal density function with upper integral limits a and b and

correlation coefficient ρ. S_t^* is the ex-dividend stock price above which the option will be exercised just prior to the ex-dividend instant and is determined by solving

$$C(S_t^*, T-t, X) = S_t^* + \alpha D - X. \tag{B.4}$$

α is the proportion of the dividend that is reflected in the stock price decline at the ex-dividend instant and is usually assumed to be equal to one.

Appendix C: Computation of implied standard deviation

The computation of the implied standard deviation of stock return is based upon reported call option prices and their relationship to model values. With all of the parameters of the valuation equation known except σ, the stock's option prices may be represented as

$$C_j = C_j(\sigma) + \varepsilon_j, \qquad j = 1, \ldots, n, \tag{C.1}$$

where $C_j(\sigma)$ is the model's price, ε_j is a disturbance term, and n is the number of options of common maturity written on the stock. The estimate of the standard deviation of stock return, $\hat{\sigma}$, is obtained by solving the nonlinear programming problem,

$$\underset{\{\hat{\sigma}\}}{\text{Min}} \sum_{j=1}^{n} e_j^2, \tag{C.2}$$

where e_j is the observed residual.

Note that $\hat{\sigma}$ is accurate only insofar as the valuation equation is correctly specified. It may not be the 'best' estimate of the standard deviation of stock return.

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