S&P 500 Trading Strategies and Stock Betas

Anand M. Vijh
University of Southern California

This paper shows that S&P 500 stock betas are overstated and the non-S&P 500 stock betas are understated because of liquidity price effects caused by the S&P 500 trading strategies. The daily and weekly betas of stocks added to the S&P 500 index during 1985-1989 increase, on average, by 0.211 and 0.130. The difference between monthly betas of otherwise similar S&P 500 and non-S&P 500 stocks also equals 0.125 during this period. Some of these increases can be explained by the reduced nonsynchroneity of S&P 500 stock prices, but the remaining increases are explained by the price pressure or excess volatility caused by the S&P 500 trading strategies. I estimate that the price pressures accountfor 8.5 percent of the total variance of daily returns of a value-weighted portfolio of NYSE/AMEX stocks. The negative own autocorrelations in S&P 500 index returns and the negative cross autocorrelations between S&P500 stock returns provide further evidence consistent with the price pressure hypothesis.

I have benefited from helpful comments by the seminar participants at the American Finance Association meetings, the University of California at Berkeley, the University of California at Los Angeles, the Case Western Reserve University, the Financial Management Association meetings, the Georgetown University, the University of Pittsburgh, the University of Southern California, the Virginia Polytechnic Institute, and the Western Finance Association meetings. I wish to thank Mukesh Bajaj. Peter Bossaerts, Marshall Blume, Michael Brennan, Harry DeAngelo, Eugene Fama, Steve Figlewski, Bruno Gerard, Larry Harris, Francis Longstaff, Vikram Nanda, Mark Rubinstein, Jim Shapiro, G. Sharathchandra, A. Subrahmanyam, and Randy Westerfield for useful comments. I am deeply obliged to Andrew Lo and Chester Spatt (the editors) and especially Bruce Grundy (the referee) for many insightful suggestions that improved this paper substantially. All errors are entirely my own responsibility. Address correspondence to Anand M. Vijh, School of Business Administration, Department of Finance and Business Economics, University of Southern California. Los Angeles, California 91X89-1421.

The Review of Financial Studies Spring 1994 Vol. 7, No. 1, pp. 215-251

We examine the changes in betas of 329 stocks added to the S&P 500 index during 1975-1989. On average, the daily and weekly betas measured by using the CRSP value-weighted index returns as a proxy for market returns decrease by 0.072 and 0.045 during 1975-1979, but increase by 0.211 and 0.130 during 1985-1989. In another sample of 79 matched pairs of S&P 500 and non-S&P 500 stocks, the differences between daily, weekly, and monthly betas average 0.077, 0.067, and 0.028 during 1975-1979, but increase to 0.380, 0.279, and 0.125 during 1985-1989. The widening gap between S&P 500 and non-S&P 500 stock betas coincides with the growing popularity of S&P 500 trading strategies (strategies that involve simultaneous trading of the S&P 500 stocks, such as buying or selling the futures and options, portfolio insurance, and program trading).

Further analysis shows that the differences in betas are related to the microstructure price effects caused by the S&P 500 trading strategies. Recent growth in trading volume associated with these strategies has put forth two different viewpoints concerning the likely nature of price effects. Critics claim that heavy trading in the basket of S&P 500 stocks causes price pressure or excess volatility and threatens the orderly working of capital markets. (Henceforth, this is called the price pressure hypothesis.) Proponents, however, suggest that these strategies simply enable investors to trade the market portfolio more efficiently. As a side benefit of increased trading volume, prices of individual S&P 500 stocks are rarely stale and reflect the market information accurately at all times. (This is called the nonsynchronous trading hypothesis.)

Both hypotheses predict that measured betas of S&P 500 stocks will increase and the measured betas of non-S&P 500 stocks will decrease. Their cross-sectional implications concerning stocks added to the index, however, are quite different. The price pressure affects measured returns of all S&P 500 stocks and, therefore, the market returns. As a result, the covariances between S&P 500 stock returns and the market returns are overstated while the covariances between non-S&P 500 stock returns and market returns remain unchanged. The addition of a stock to the S&P 500 index always increases the covariance with market returns and hence the beta.

The nonsynchronous trading hypothesis predicts that the increase in a stock's beta following its addition to the S&P 500 index will depend on the before and after trading volumes. During 1985-1989, the average trading volume increases by 34 percent after inclusion, but individually many cases experience a decrease. Scholes and Williams (1977) predict that for stocks trading less frequently than market average, an increase in trading volume should lead to higher stock beta and a decrease in trading volume should lead to lower stock beta. For a few stocks trading more actively than the market average, the converse should be true.

Empirically, the daily betas of stocks added to the S&P 500 index during 1985-1989 increase by an average of 0.211. For the subset of stocks for which both hypotheses predict an increase, the betas increase by an average of 0.241. But even for the subset of stocks for which the price pressure hypothesis predicts an increase and the nonsynchronous trading hypothesis predicts a decrease, the betas increase by a significant 0.113. Increases in the latter case are consistent with the critics' claim that S&P 500 trading strategies lead to price pressure that creates a deviation between observed prices and the underlying values. Based on a simple model, I infer that if the increase in the latter case were to be attributed to price pressure, then the price pressure would explain 8.5 percent of the daily variance of a value-weighted portfolio of all NYSE/AMEX stocks. As a proportion of the daily variance of S&P 500 index returns, the price pressure would explain 11.5 percent.

Evidence on index autocorrelations and cross autocorrelations further supports the price pressure hypothesis. Positive autocorrelations in S&P 500 returns consistent with nonsynchronous trading have gradually disappeared with increasing popularity of index trading strategies, and negative autocorrelations consistent with price pressure have shown up during 1985-1989. The cross autocorrelations between stock and index returns decrease substantially after inclusion in the index and become negative from lag 2 to 5. The evidence on betas and cross autocorrelations is confirmed with the sample of 79 matched pairs of seasoned S&P 500 and non-S&P 500 stocks (i.e., stocks that were included in or excluded from the index during the entire period from 1975 to 1989).

Because most asset pricing models investigate returns over periods longer than a week, I also examine the weekly and monthly betas. During 1985-1989, the weekly betas of stocks added to the index increase by 0.130 and the monthly betas of seasoned S&P 500 stocks exceed the monthly betas of non-S&P 500 stocks by 0.125. This raises the question of whether some of the increases in measured betas are caused by increases in true betas rather than microstructure price effects. To examine this possibility, I measure betas in many short windows surrounding the inclusion date. The betas increase soon after the inclusion, in a manner consistent with the existence of microstructure price effects. The microstructure biases in weekly and monthly betas may arise due to the persistence of price pressure for several days as indicated by the negative autocorrelations.

This study is related to studies of market frictions and stock betas, such as by Scholes and Williams (1977), Dimson (1979), and Cohen et al. (1983). It is also related to studies of the price effects of program trading, such as by Harris, Sofianos, and Shapiro (1990) and Neal (1991). While related in objectives, however, the study differs in some respects from the studies of program trading. First, daily data rather than transactions data is examined. Cohen et al. (1983) argue that some market frictions persist for several days. Lo and MacKinlay (1990a) document large positive autocorrelations in weekly index returns. It is possible, therefore, that the liquidity price effects resulting from concentrated buying or selling by institutions persist for several days. Second, S&P 500 trading is a broader term than program trading and includes trading in index futures, options, and other derivative products that far exceeds the program trading volume.

Grossman (1988a) and Brennan and Schwartz (1989) provide theoretical models of why portfolio insurance strategies may increase volatility.[1] However, this study is most closely related to Harris (1989), who also examines the excess-volatility implications of S&P 500 trading. Harris concludes that trading in S&P 500 index futures and/or S&P 100 index options increases cash index volatility measured over 1-day, 5-day, 10-day, and 20-day differencing intervals during 1982-1987, but leaves open the question of whether increased volatility is caused by a reduction in nonsynchronous trading or by trading-induced and temporary price effects.

1. S&P 500 Trading Strategies, Price Pressure, and Stock Betas

Financial theory suggests that liquidity traders with no special information should purchase the market portfolio or market-contingent claims (such as portfolio insurance). The true market portfolio, consisting of every asset in the economy, cannot be traded. As a result, the S&P 500 portfolio, consisting of the largest stocks representing all sectors of the economy, has emerged as a feasible alternative. Investments in the portfolio of S&P 500 stocks began with index funds in 1970s. S&P 500 futures were introduced in 1982 and S&P 100 and S&P 500 index options started trading in 1983. (The S&P 100 index includes the 100 largest stocks accounting for two-thirds of the market value of S&P 500 stocks.) These remain the most popular S&P 500 trading strategies, although many other derivative products have been

[1] A contrary opinion is expressed in a recent paper by Basak (1993). In his general equilibrium model, the portfolio insurers behave as more risk averse than normal agents. With the portfolio insurers present, to clear the market the risky securities must become more favorable relative to the riskless security. This favorableness is achieved by decreased volatility of risky securities in his model. However, the volatility in Basak's model arises only from the valuation of dividends paid by risky securities and not from the transfer of funds between risky and riskless securities.

introduced in recent years. In addition, the program trading of S&P 500 stocks has become very popular.[2]

Table 1 presents the historic trading volume in S&P 500 products. The program trading data were unavailable for all except the last year and could not be included. The trading volume in futures and options exceeds the trading volume in stocks during every year since 1983. One may reasonably ask whether such large trading volume causes price effects.

1.1 The price pressure hypothesis

Temporary price effects resulting from short-term imbalances in demand and supply for individual securities are well documented [see, for example, Scholes (1972), Kraus and Stoll (1972), and Holthausen, Leftwich, and Mayers (1987)) The price pressure hypothesis says that the large S&P 500 trading volume causes similar and ongoing price pressures in the 500 stocks, resulting from short-term imbalances in demand and supply.

The large trading volume in S&P 500 products may affect prices because simply by chance the buy orders will dominate sell orders on certain days while the sell orders will dominate buy orders on other days. The order imbalances will be more severe if the trading is dominated by large traders and if those traders follow investment strategies that prescribe similar actions based on changes in the market level. Casual observation suggests that institutions have become a dominant force in recent years; for example, Lakonishok, Shleifer, and Vishny (1991) document that institutional investors held 50 percent of the equity and accounted for 70 percent of the NYSE trading volume in 1989. The 1980s also witnessed increased popularity of portfolio insurance strategies. As many as $100 billion in stock market funds during 1986-1987 were managed by portfolio insurance strategies that typically involve purchasing a synthetic put option by continually shifting funds between S&P 500 futures and cash.[3] (Although theory does not assign any special role to the S&P 500 stocks in portfolio insurance, the lower transaction costs make such trading concentrated in the S&P 500 futures contract.) This amounted to between 4 and 5 percent of the then market value of S&P 500 stocks. Brennan and Schwartz (1989) estimate that with 5 percent of the funds under portfolio insurance, a 1 percent change in market price

[2] Program trading is a general term that refers to a simultaneous order for any 15 or more stocks with a portfolio value of at least $1 million. But Neal (1991) reports that index arbitrage accounts for nearly half of the program trading volume. Index arbitrage involves buying the S&P 500 stocks and selling futures, or vice versa.

[3] I am obliged to Mark Rubinstein for this estimate. Precise estimates of portfolio insurance are unavailable.

Table 1
Trading volume in S&P 500 stocks and derivative products from 1982 to 1989

	S&P 500 trading volume[1,2]							S&P 100 trading[1,2] volume		NYSE trading[3,4] volume	
	Index futures		Index options		Futures options			Index options		Stocks	
Year	Contracts	Dollars	Contracts	Dollars	Contracts	Dollars	Total Dollars	Contracts	Dollars	Round lots	Dollars
1982	2,935	161	—	—	—	—	**161**	—	—	16,670	**495**
1983	8,069	678	14	1	281	24	**703**	10,595	**177**	21,845	**775**
1984	12,364	947	12	1	673	52	**1000**	64,288	**977**	23,309	**773**
1985	15,056	1444	8	1	1090	105	**1550**	90,805	**1686**	27,774	**981**
1986	19,505	2446	1683	42	1886	237	**2725**	113,151	**2684**	36,010	**1389**
1987	19,045	2895	6205	187	1877	285	**3367**	101,827	**3044**	48,143	**1889**
1988	11,354	1553	4817	132	735	101	**1786**	57,433	**1503**	41,118	**1366**
1989	10,560	1679	6274	199	1162	185	**2063**	58,371	**1721**	42,022	**1556**

The trading volume in S&P 500 stocks is not available and therefore is substituted by the aggregate volume in all NYSE stocks obtained from the NYSE Fact Book (1991). The S&P 500 index futures and options on futures trading volumes are obtained from the Chicago Mercantile Exchange. The S&P 500 and S&P 100 index option trading volumes *are* obtained from a publication of the Chicago Board Options Exchange.

[1] Number of contracts is in thousands. A contract of S&P 500 index futures or futures options represents the obligation or the right to trade a dollar amount of 500 times the underlying cash index, but a contract of S&P 500 and S&P 100 index options represents the right to trade only 100 times the underlying cash index.

[2] Dollar volume is in billions and is calculated by multiplying the contract volume by 500 times the midyear cash index value in the case of index futures and futures options and by 100 times the midyear cash index value in the case of S&P 500 and S&P 100 index options.

[3] Number of round lots in millions. Each round lot represents 100 shares.

[4] Dollar volume in billions is obtained directly from the NYSE Fact Book (1991).

leads to 0.1 percent trading volume. That increase represents one-third of the daily NYSE trading volume, and all of it is in the form of buy orders when prices have risen and sell orders when prices have fallen. Besides, a sudden increase (decrease) in price can also trigger margin calls and force many holders for short (long) positions in options and future accounts not following any particular strategy to initiate buy (sell) orders to close their positions. Both reasons suggest frequent and potentially large imbalances between the demand and supply of S&P 500 securities.

Even if market makers could ascertain that the sudden increase in buy orders at certain times and sell orders at other times is liquidity related, models of market making, such as by Ho and Macris (1984), suggest that the market makers will charge a premium to compensate them for the risk of carrying a large inventory. The trade prices will be higher than some fundamental value in response to buy orders and lower in response to sell orders. These deviations are called price pressures. Uncertainty concerning whether the orders are initiated by liquidity or information motivated traders will exacerbate the price pressures. The price pressures will persist until dealers are able to locate investors willing to take the other side of trades.

For reasons of transaction costs, a large part of the S&P 500 trading occurs in the futures market rather than the stock market. Grossman (1988b) argues that institutional investors can increase or decrease their holdings of the S&P 500 with a single transaction in the futures market, whereas an alternate strategy in the stock market involves 500 separate transactions. Besides the lower monitoring and settlement costs of a single trade, the futures contract also lowers the bid-ask spread by eliminating firm-specific risk and the associated adverse-selection spread component in each stock [Harris (1990)]. This raises the natural question of whether the futures trading volume affects the individual S&P 500 stock prices.

Grossman (1988a and 1988b) argues that the futures and stock markets are linked by index arbitrage. If the futures market comes under selling pressure and prices fall, index arbitrageurs buy futures and sell stocks. This activity continues until the futures and stock prices are correct relative to each other. Index arbitrage thus distributes the price pressure across exchanges. Duffie, Kupiec, and White (1990) argue that index arbitrage may also cause additional price pressure as the heavy trading volume exhausts the liquidity in the stock market and causes stock prices to be driven beyond their correct relative prices.[4]

Any liquidity-related and temporary price effects must revert over a sufficiently long time period. Table 2 shows that S&P 500 daily returns over 1985-1989 (but excluding October 1987) had the first five autocorrelations of 0.024, -0.041, -0.031, -0.033, and -0.026. In comparison, an equally weighted portfolio of all NYSE and AMEX stocks had autocorrelations of 0.237, 0.038, 0.019, -0.005, and 0.025. Because of nonsynchronous trading, price pressures may not have been able to induce negative first-order autocorrelation in S&P 500 returns, but they perhaps decreased the positive autocorrelation. Further evidence that this may have been the case is provided by S&P 100 returns, which have negative autocorrelations up to five lags of -0.045, -0.041, -0.030, -0.023, and -0.023. Each autocorrelation is estimated with a standard error of 0.028, and the cumulative evidence suggests that S&P 500 trading may lead to price pressure.

[4] Index arbitrage can cause real price pressures, but it can also give the mere appearance of price pressures. Because of index arbitrage, the day-end prices of the 500 stocks may not be randomly distributed between the bid and the ask prices. Suppose, in an extreme case, the day-end prices of all S&P 500 stocks are at the ask price, in response to a program (buy) trade executed just before the end of trading in every stock. Then the observed S&P 500 index will be overstated by half of the average bid-ask spread. Some of the price pressures measured in this article may be attributed to this tendency, but it cannot explain negative autocorrelations beyond the first lag [see Roll (1984) and Lo and MacKinlay (1990a) for details].

Table 2
Autocorrelations in index daily returns from 1975 to 1989

			Autocorrelations at lags 1 to 5				
Period	Index	vations	1	2	3	4	5
1975–1979	S&P 100	1004[1]	0.066	0.009	0.004	−0.015	0.003
	S&P 500	1263	0.189	−0.019	0.015	0.009	0.018
	EWRETD	1263	0.451	0.119	0.121	0.137	0.154
1980–1984	S&P 100	1265	0.004	0.015	−0.024	−0.056	0.002
	S&P 500	1265	0.095	0.035	−0.019	−0.041	0.006
	EWRETD	1265	0.269	0.114	0.083	0.029	0.082
1985–1989	S&P 100	1236[2]	−0.045	−0.041	−0.030	−0.023	−0.023
	S&P 500	1236	0.024	−0.041	−0.031	−0.033	−0.026
	EWRETD	1236	0.237	0.038	0.019	−0.005	0.025

The data on the S&P 100 daily returns are obtained from the Chicago Board Options Exchange *and* are available only from 1976 onwards. The data on the S&P 500 daily returns are obtained from the CRSP 1989 daily index files. EWRETD stands for equally weighted returns with dividends on a portfolio of all NYSE and AMEX stocks. also obtained from the CRSP daily index files. Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987.

[1] In this row. each estimated autocorrelation has a standard error of $(1004)^{-0.5} = 0.032$. All other autocorrelations have standard errors of 0.028.

[2] During 1985-1989, the *p*-value of none of the 10 autocorrelations for the S&P 100 or the S&P 500, by itself, is less than 0.05. However, 9 of the 10 autocorrelations are negative, and 6 are at least one standard error below zero. The cumulative evidence against the null hypothesis of zero or positive autocorrelations should therefore be quite significant. (The *p* value of five negative autocorrelations in S&P 100 index alone equals $0.5^5 – 0.03$.) The first five autocorrelations for the two indices sum to -0.162 and -0.107.

Price pressures will cause S&P 500 stock betas to be overstated and non-S&P 500 stock betas to be understated. Assume that there are $j = 1, 2, 3, \ldots, J$ traded stocks in the market. Assume also that returns on these stocks are distributed as joint lognormal random variables. The log stock returns are denoted by r_{jt} and are measured over time periods $t = 1, 2, 3, \ldots, T$. Let r_{mt} represent the log market returns, measured by averaging across the J traded stocks, as follows:[5]

[5] If the log stock returns are normally distributed, then r_{mt} in the market model should be a weighted average of the log stock returns. The average of log returns has no economic interpretation, however, as it is not realizable. The log of average (or market) returns has an economic interpretation, but it is not theoretically correct to use it in the market model. Fortunately, evidence with both real and simulated daily stock returns shows that the correlation between the log of average daily returns and the average of log daily returns in diversified portfolios exceeds 0.999 (details available from the author on request). This permits the use of log market returns in the market model in place of the average of log returns. The specification of the log returns model and log market returns is also identical to the specification used by Scholes and Williams (1977). Alternatively, the results in this article can be derived by assuming that stock returns are joint normally distributed, in which case the market model will be specified with simple returns. Simple returns present an alternative problem, that they cannot be added over time. If daily returns were normally distributed, then weekly and monthly returns could not be normally distributed. Furthermore, tests of autocorrelations and instrumental-variable betas are more accurately specified with log returns that can be added over time. As a practical matter, the results are quite unaffected by whether betas are calculated using log returns or simple returns. For example, the average daily betas before and after inclusion of 124 stocks in the S&P 500 index during 1985-1989 equal 0.858 and 1.069 with log returns, and 0.860 and 1.069 with simple returns. The differences between average monthly betas calculated with the log returns or simple returns are also around 0.010.

$$r_{mt} = \sum_{j=1}^{J} w_j r_{jt}, \tag{1}$$

where w_j is the weight of the jth stock. Joint lognormality leads to the market-model specification:

$$r_{jt} = \alpha_j + \beta_j r_{mt} + \epsilon_{jt} \qquad \text{for all } j = 1, 2, 3, \ldots, J. \tag{2}$$

For expositional convenience, assume that there are no other market frictions so that market-model betas estimated from Equation (2) are unbiased estimates of true betas. Now assume that the first J_1 stocks belong to a basket; that is, many investors trade these J_1 stocks simultaneously within short intervals, for similar reasons, and on an ongoing basis. (The S&P 500 and non-S&P 500 stocks are also called the basket and nonbasket stocks.) Their trades lead to price pressures that increase the measured return $\hat{r}_{jt}$, for each basket stock by η_t on day t:

$$\hat{r}_{jt} = r_{jt} + \eta_t \qquad \text{for all } j = 1, 2, 3, \ldots, J_1. \tag{3}$$

All variables with a hat denote measured values as distinct from true or fundamental values.

The term η_t denotes the net basketwide price pressure on day t. If price pressures last up to a maximum of n days, η_t will include not only the effects of basket trading on day t, but also the corrections of price pressure caused by basket trading during the preceding n days. It follows that η_t will show negative autocorrelations. I assume, however, that the trading activity and hence η_t are uncorrelated with the contemporaneous, leading, or lagged true stock returns.

Based on Equation (3), the measured market returns will also be biased:

$$\hat{r}_{mt} = \sum_{j=1}^{J} w_j \hat{r}_{jt} = \sum_{j=1}^{J} w_j r_{jt} + \sum_{j=1}^{J_1} w_j \eta_t = r_{mt} + W\eta_t, \tag{4}$$

where $W = \Sigma_{j=1}^{J_1} w_j$ is the cumulative weight of the basket stocks. Appendix A.1 shows that in the presence of basket trading as modeled by Equations (1) to (4), the measured betas of all nonbasket stocks will be understated as

$$\hat{\beta}_{j,nb,ols} = (1 - R)\beta_j \qquad \text{for all } j = J_1 + 1, \ldots, J. \tag{5}$$

R is the proportion of market volatility accounted for by trading-induced price effects

$$R = \frac{\mathrm{Var}(\hat{r}_{mt}) - \mathrm{Var}(r_{mt})}{\mathrm{Var}(\hat{r}_{mt})}, \tag{6}$$

and subscripts *nb* and *ols* denote that the measured beta is for a

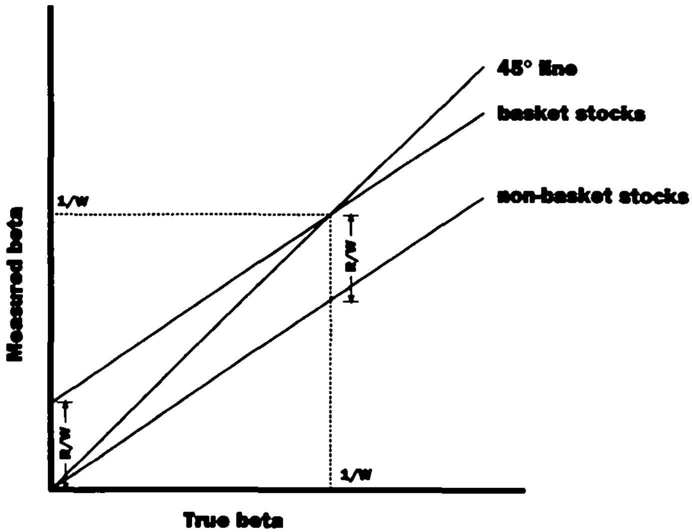

Figure 1
Price pressure and biases in S&P 500 and non-S&P 500 stock betas (also called basket and nonbasket stocks).
The measured betas of nonbasket and basket stocks in the presence of S&P 500 trading-induced price pressures are given by $\hat{\beta}_{j,nb,ols} = (1 - R)\beta_j$ and $\hat{\beta}_{j,b,ols} = (1 - R)\beta_j + R/W$, where R is the proportion of noise variance in total market portfolio variance, W is the cumulative weight of basket stocks, β_j is the true beta, and $\hat{\beta}_{j,b,ols}$ and $\hat{\beta}_{j,nb,ols}$ are the measured betas if the stock were included or excluded from the basket. The figure also illustrates that price pressures caused by S&P 500 trading reduce the cross-sectional spreads of betas within the S&P 500 and non-S&P 500 stock groups.

nonbasket stock and is measured using the ordinary-least-squares (OLS) technique. The measured betas of basket stocks will be biased as

$$\hat{\beta}_{j,b,ols} = (1 - R)\beta_j + R/W \qquad \text{for all } j = 1, 2, 3, \ldots, J_1. \qquad (7)$$

The subscript b denotes a basket stock. Equation (7) shows that the measured betas of all basket stocks with true betas less than $1/W$ will be overstated. The measured betas of basket stocks with true betas greater than $1/W$ will be understated, but by less than if they were not included in the basket. Inclusion in or exclusion from the index will change the estimated betas by R/W.

Figure 1 plots the biases in basket and nonbasket stock betas. The addition of a stock to the S&P 500 index always increases that stocks's covariance with the market returns, and hence the beta. Price pressure also decreases the cross-sectional spreads of betas within both the S&P 500 and the non-S&P 500 groups of stocks by a factor of $1 - R$.

From Equation (3), it follows that the price pressures will also induce negative cross autocorrelations between S&P 500 stocks:

$$\mathrm{Cov}(\hat{r}_{jt}, \hat{r}_{kt-l}) = \mathrm{Cov}(r_{jt}, r_{kt-l}) + \mathrm{Cov}(\eta_t, \eta_{t-l}) \leq \mathrm{Cov}(r_{jt}, r_{kt-l}), \qquad (8)$$

for all basket stocks j and k, and at lags l less than the duration of price effects. If r_{jt} and r_{kt-l} are uncorrelated, then $\hat{r}_{jt}$ and $\hat{r}_{kt-l}$ will be negatively correlated. However, Lo and MacKinlay (1990a) document positive cross autocorrelations between stock returns over 1962-1987, which could mitigate some of the negative cross autocorrelations induced by price pressure.

The biases in estimated betas and the cross autocorrelations given by Equations (5), (7), and (8) are based on a specification of price pressure given by Equation (3). This specification makes two important assumptions. First, the price pressure is assumed to be identical for all basket stocks. However, the price pressure could vary cross-sectionally with some measure of stock liquidity, such as the (inverse of) turnover ratio. S&P 500 trading strategies include stocks in proportion to their market weights, so the extra trading volume on account of basket trading could be a greater strain for low-turnover stocks. Appendix A.2 shows that inclusion in the index will make a greater difference to betas of low-turnover stocks in this case. Second, the specification assumes that Cov(r_{mt}, n_t) = 0. This is inconsistent with trading strategies on account of portfolio insurance and forced margin calls described before; negative true return r_{mt} induces selling of index futures, which causes downward price pressure n_t. Appendix A.3 shows that the biases in this case will be smaller, but the basic intuition that betas of non-S&P 500 stocks will be understated and betas of S&P 500 stocks will be overstated remains unchanged.

1.2 The nonsynchronous-trading hypothesis

Ever since Fama (1965) and Fisher (1966), it has been known that discrete or nonsynchronous trading causes positive autocorrelations in index returns based on (last) observed prices of individual stocks. Scholes and Williams (1977) show that nonsynchronous trading also biases the estimated betas. The nonsynchronous trading hypothesis says that S&P 500 trading strategies increase the trading frequency of S&P 500 stocks and derivative products. As a result, the basket stock prices reflect market information accurately whereas nonbasket stock prices are often stale. Table 2 provides some evidence in favor of this hypothesis: The positive autocorrelations in S&P 500 daily returns declined substantially from 1975-1979 to 1980-1984 and disappeared during 1985-1989.

Scholes and Williams demonstrate that the relationship between trading frequency and estimated stock betas is nonmonotonic; OLS betas of stocks trading either infrequently or very frequently are understated whereas betas of more average-trading stocks are overstated. Due to nonsynchronous trading, the measured market return on day t includes part of the true market return on day $t-1$ and part of the true market return on day t. The measured market return is therefore most strongly correlated with stocks whose measured returns on day t include their true returns on days t – 1 and tin proportions similar to the market as a whole. The covariance between measured market returns and measured stock returns is lower if the stock trades much more frequently (in which case its measured return on day *t* includes very little of its true return on day t – 1) or much less frequently (in which case its measured return on day t includes very little of its true return on day *t)*. In practice, the distribution of market values of stocks is considerably skewed to the right. The value-weighted average trading frequency is substantially exceeded by very few stocks, so the betas of most large stocks are overstated.[6]

The Scholes and Williams nonsynchronous trading model implies that, on average, betas of stocks added to the S&P 500 index will increase as their trading frequencies move closer to the market average. (The market average is largely determined by S&P 500 stocks, since they account for 75 percent of the market value of all NYSE and AMEX stocks.) Increases in individual cases will depend on the prior and posterior trading frequencies. Four different cases can be considered. In case 1, the stock trades more frequently after inclusion in the index than before, but both before and after frequencies are smaller than market average. Betas in this case should increase. In case 2, the stock trades less frequently after inclusion, and both before and after trading frequencies are smaller than market average. Betas in this case should decrease. In case 3, the stock trades more frequently after inclusion, and both before and after trading frequencies are greater than market average. Betas in this case should also decrease. In case 4, stock trades less frequently after inclusion, but both before and after trading frequencies are greater than market average. Betas in this case should increase. The two cases in which the before trading frequency is greater than market average and the after frequency is smaller, or vice versa, lead to ambiguous predictions and are not considered in analyzing the source of biases.

The nonsynchronous trading hypothesis predicts that betas of stocks added to the S&P 500 index will increase in cases 1 and 4 and decrease in cases 2 and 3. The price pressure hypothesis predicts that betas will increase in every case. If both hypotheses are simultaneously true and the price pressure is sufficiently strong relative to the nonsynchronous trading effect, one may expect that increases in cases 2 and 3 will be positive, but smaller than in cases 1 and 4.

[6] During 1988, only 8.5 percent of the NYSE and AMEX stocks exceeded the value-weighted average trading frequency (based on midyear market values). Only 2.4 percent were at least twice as active.

2. Data Sources and Institutional Details

Stock price, return, and trading volume data are obtained from the CRSP 1989 daily and monthly stock files. A list of stocks included in and excluded from the index at various times is obtained from the Standard & Poor's Corporation and the S&P 500 Directory (1989). Other hard-copy data include S&P 500 futures and options on futures volume data obtained from the Chicago Mercantile Exchange (CME), C&P 100 daily returns and trading volumes from the Chicago Board Options Exchange (CBOE), and trade size data from the NYSE Fact Book.

The available data span the 1975-1989 period, which is divided into three segments of five years. S&P 500 trading started in a substantial way only with the introduction of the futures contract in 1982, but the earlier years provide a useful benchmark. Prices and returns for the month of October 1987 are excluded from all calculations of betas, autocorrelations, and trading volumes to remove the effects of the market crash of 1987.[7] Market returns are proxied by returns on the CRSP value-weighted portfolio of NYSE and AMEX stocks.

It is necessary to understand whether inclusion in the S&P 500 index has any impact on a stock's "true" beta. From time to time, companies in the index cease to exist, because of merger, bankruptcy, or reorganization. When a company disappears, Standard & Poor's Corporation adds the next largest company, usually from the same industry. No company is ever replaced because its stock has been doing poorly, nor is addition to the index a reflection of Standard & Poor's beliefs concerning a company's future prospects. It appears unlikely that inclusion of a stock in the S&P 500 index will immediately increase its true beta, which should depend on how well the firm's projects do in market upturns and downturns.

3. Daily and Weekly Betas of Stocks Added to the S&P 500 Index

The first test is an "event study" that examines measured betas of 329 stocks added to the S&P 500 index between 1975 and 1989. A total of 360 companies were added between 1975 and 1989. However, eight of these were the result of the AT&T divestiture in 1983 and were excluded because no previous data on the divested companies existed. Two companies were included immediately after a merger, so pre-

[7] The market declined by 18.05 percent on October 19, 1987. Just this one return may double the daily variance of stock returns estimated over 250 trading days. Including the month of October 1987 increases standard errors of betas and, using a 250-day estimation period, the daily betas of 124 stocks added to the S&P 500 index during 1985-1989 increase by 0.166 instead of 0.211 as reported in Table 3. Increases outnumber decreases by 86 to 38 instead of 90 to 34. Of course, increasing the estimation period to 500 trading days decreases the influence of October 1987. I dropped October 1987 so that my results reflect "normal" times.

Table 3
Daily betas before and after addition of stocks to the S&P 500 index from 1975 to 1989

Period	Number of additions to index	Average beta before inclusion	Average beta after inclusion	Increase in beta (t-statistic)	Number of decreases and increases in beta (z-statistic)	
1975–1989	329	1.014	1.094	**0.080** (4.30)***	142	187 (2.48)**
1975–1979	107	1.139	1.067	**−0.072** (−2.75)***	68	39 (−2.80)***
1980–1984	98	1.075	1.157	**0.082** (2.32)**	40	58 (1.82)*
1985–1989	124	0.858	1.069	**0.211** (7.08)***	34	90 (5.03)***
1982	27	0.931	0.962	**0.030** (0.56)	11	16 (0.96)
1983	10	1.027	1.072	**0.044** (0.38)	5	5 (0.00)
1984	29	1.209	1.380	**0.172** (2.22)**	9	20 (2.04)**
1985	27	1.013	1.004	**−0.009** (−0.15)	13	14 (0.19)
1986	27	0.858	1.213	**0.355** (5.96)***	4	23 (3.66)***
1987	24	0.907	1.075	**0.168** (2.80)***	8	16 (1.63)
1988	22	0.773	1.062	**0.288** (4.47)***	3	19 (3.84)***
1989	24	0.712	0.981	**0.269** (3.78)***	6	18 (2.45)**

The sample of 329 stocks added to the S&P 500 index consists of all inclusions that satisfy the following criteria. (1) The company was newly added to the index and not the result of reorganization of an existing S&P 500 company. (2) Daily returns data are available from CRSP 1989 files for at least the 62 days preceding the following the inclusion date. (3) Inclusion is not accompanied by delisting from NASDAQ and listing on the NYSE during the 62 days preceding or following the inclusion date. Betas before (after) the listing date are calculated over 250 trading days ending (starting) three days before (after) the inclusion date, using the market model with log daily returns and the OLS regression technique. The market returns are proxied by returns on a value-weighted portfolio of all NYSE and AMEX stocks. If 250 days of data are not available, the estimation interval is suitably shortened, but not to less than 60 trading days. Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987. The t-statistics are calculated cross sectionally using the distribution of increases in beta.

The following notation is used to denote significance levels in every table:

* Significantly different from zero at the 10 percent level.

** Significantly different from zero at the 5 percent level.

*** Significantly different from zero at the 1 percent level.

vious data on the merged companies did not exist. Five companies were included after September 1989, so there were insufficient data in the 1989 CRSP files to determine their post-inclusion betas. Fifteen companies were excluded because their addition to the index was preceded or followed shortly by their delisting from NASDAQ/OTC and listing on the NYSE.[8] Finally, one company was excluded because it could not be unambiguously identified. The remaining sample contains 286 NYSE and 43 NASDAQ stocks.

During the period of this study, the Standard & Poor's Corporation simultaneously announced and implemented the composition changes after the close of trading on Wednesdays. The inclusion dates were evenly spread over the 15-year period, so the associated changes in beta do not reflect some common calendar effect. The postinclusion betas are calculated over a 250-day period starting three days after

[8] McConnell and Sanger (1987) show that listing on the NYSE is an economically significant event.

Table 4
Weekly betas before and after addition of stocks to the S&P 500 index from 1975 to 1989

Period	Number of additions to index	Average beta before inclusion	Average beta after inclusion	Increase in beta (t-statistic)	Number of decreases and increases in beta (z-statistic)	
1975–1989	329	1.149	1.186	**0.037** (1.34)	152	177 (1.38)
1975–1979	107	1.205	1.160	**−0.045** (−1.11)	57	50 (−0.68)
1980–1984	98	1.222	1.228	**0.007** (0.12)	45	53 (0.81)
1985–1989	124	1.044	1.174	**0.130** (2.84)***	50	74 (2.16)**

The sample of 329 stocks added to the S&P 500 index satisfies the criteria listed in Table 3. Weekly returns are calculated by aggregating the daily returns suitably. Betas before (after) the listing date are calculated over the 50 weeks ending (starting) the week before (after) the inclusion week, using the market model with log weekly returns and the OLS regression technique. If 50 weeks of data are not available, the estimation interval is suitably shortened, but not to less than 12 weeks. The market returns are proxied by returns in a value-weighted portfolio of all NYSE and AMEX stocks. Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987. The t-statistics are calculated cross sectionally using the distribution of increases in beta.

the inclusion date. The first two days are excluded because there is typically a sharp increase in trading volume immediately after inclusion, perhaps resulting from initial purchases by index funds. (During 1985-1989, the average trading volume on the first and second trading day after inclusion equals 5.96 and 1.89 times the average trading volume over the subsequent 250 days. The volume tends to stabilize from the third day onwards.) Because I intend to study the price effects of ongoing trading in S&P 500 stocks as part of a basket (and not the one-time surge resulting from initial purchases by index funds after inclusion), I exclude the first two days. To maintain symmetry, I calculate the pre-inclusion betas over a 250-day period ending three days before the inclusion date. When data for all 250 days are not available, I shorten the estimation period to the number of days of available data, but not fewer than 60 trading days.

Table 3 shows that the daily betas of all 124 stocks increase by an average of 0.080 after inclusion. However, the picture differs considerably from subperiod to subperiod. Betas decrease by a significant 0.072 during 1975-1979, but increase by a significant 0.082 during 1980-1984 and a much larger 0.211 during 1985-1989. Decreases outnumber increases by 68 to 39 during 1975-1979, whereas increases outnumber decreases by 90 to 34 during 1985-1989. The evidence from 1986 onwards is so strong that any one year's data can reject the null hypothesis of no change in daily betas.

S&P 500 trading also affects betas estimated over longer periods, although the magnitude of bias is reduced. Table 4 shows weekly betas before and after addition to the index. Weekly betas increase by an insignificant 0.037 over the entire period, but by a significant 0.130 for the 124 stocks added during 1985-1989. The large increase

Table 5
Daily betas in monthly and quarterly windows before and after addition of stocks to the S&P 500 index from 1985 to 1989

Month relative to event month	Average beta (std error)	Quarter relative to event quarter	Average beta (std error)
Event −12	0.955 (0.075)		
−11	0.849 (0.066)	Event −4	0.930 (0.049)
−10	0.946 (0.081)		
−9	0.916 (0.073)		
−8	0.859 (0.078)	−3	0.911 (0.053)
−7	0.931 (0.075)		
−6	0.872 (0.069)		
−5	0.950 (0.068)	−2	0.903 (0.048)
−4	0.901 (0.063)		
−3	0.759 (0.073)		
−2	0.875 (0.069)	−1	0.880 (0.047)
−1	0.867 (0.079)		
+1	1.005 (0.060)		
+2	1.030 (0.066)	+1	1.043 (0.041)
+3	1.035 (0.084)		
+4	1.112 (0.058)		
+5	1.145 (0.065)	+2	1.144 (0.043)
+6	1.081 (0.063)		
+7	1.276 (0.071)		
+8	1.207 (0.059)	+3	1.169 (0.038)
+9	1.060 (0.057)		
+10	1.084 (0.604)		
+11	1.092 (0.078)	Event +4	1.107 (0.040)
Event +12	1.107 (0.060)		

The sample of 90 stocks added to the S&P 500 index consists of all inclusions that satisfy the following criteria. (1) The company was newly added to the index and not the result of reorganization of an existing S&P 500 company. (2) Daily returns data are available from CRSP 1989 files for at least the 254 days preceding and following the inclusion date. (3) inclusion is not accompanied by delisting from NASDAQ and listing on the NYSE during the 254 days preceding or following the inclusion date. The first two columns report daily betas calculated over monthly windows (21 trading days) from 12 month before to 12 month after the inclusion date (but excluding a period of two days before to two days after the inclusion day). The market returns are proxied by returns on a value-weighted portfolio of all NYSE and AMEX stocks. The next two columns report daily betas calculated over quarterly windows (63 trading days). Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987. This sometimes results in a missing beta for a month overlapping October 1987 (minimum 10 days data are required to calculate any beta in this table), in which case beta for the previous month is assigned to that month (in order to keep the sample size at a constant 90 for every observation). The standard errors of mean are calculated cross sectionally using the distribution of betas. Daily betas over the entire 12-month period before and after the inclusion averaged 0.901 and 1.107, representing an increase of 0.206 (r-statistic 6.00).

in weekly betas during 1985-1989 suggests that some of the market-wide liquidity price effects may persist for several days.

For stocks with true betas less than 1/W, Figure 1 shows that the increases of 0.211 and 0.130 in daily and weekly betas during 1985-

1989 equal the sum of downward bias when the stock is excluded from the index and the upward bias when the stock is included in the index. For stocks with true betas greater than 1/W, both betas are downward biased. The figure shows that even though betas increase by the same magnitude for this group of stocks, the sum of biases is greater than the increase.

3.1 Confounding influences: Microstructure effects versus true betas

Increases in betas may reflect microstructure price effects or changes in true betas. I investigate this issue by examining measured betas in several short windows around the inclusion date. True betas should depend on the riskiness of the firm's cash flows. Whereas microstructure effects should begin soon after a stock is included in the index and starts trading as part of a basket, it is unlikely that cash flows from projects will suddenly become much riskier.

Table 5 shows daily betas for each month during the year before and the year after inclusion of stocks in the S&P 500 index. The sample includes the 90 stocks added during 1985-1989 for which at least 12 months of data before and after inclusion are available. Daily betas average 0.901 during the full year before inclusion and 1.107 during the full year after inclusion. Overall, the betas increase by an average of 0.206 (t-statistic 6.00). Half of this increase occurs in the first month after inclusion [calculated as (1.005 – 0.901)/0.206 = 0.501. The process is complete by the end of the fourth month. The almost immediate increase in measured betas after inclusion of stocks in the S&P 500 index suggests microstructure price effects rather than changes in true betas.

3.2 Trading activity and betas: a resolution of the microstructure hypotheses

I examine the relationship between trading activity and betas to understand whether my results support the price pressure hypothesis, the nonsynchronous trading hypothesis, or both. I examine two measures of trading activity. The first measure is simply the daily trading volume and is obtained by averaging the number of shares traded each day during the same estimation period as described before in the context of daily betas. The second measure is the annualized turnover ratio and is obtained by annualizing the total dollar volume during this estimation period and dividing by the end-of-period market value. The process yields volume data for 311 of the total 329 stocks. (The remaining 18 stocks are excluded because the volume

Table 6
Daily trading volumes and annualized turnover ratios before and after addition of stocks to the S&P 500 index from 1975 to 1989

Period	Sample size	Daily trading volume[1] Before inclusion mean (median)	After inclusion mean (median)	Percentage increase 1	Percentage increase 2[2]	Annualized turnover ratio Before inclusion mean (median)	After inclusion mean (median)	Percentage increase 1	Percentage increase 2[2]
1975–1989	311	797 (465)	1068 (647)	34	20	0.61 (0.44)	0.84 (0.50)	37	33
1975–1979	95	244 (166)	275 (208)	13	−4	0.36 (0.24)	0.34 (0.26)	−5	−13
1980–1984	92	827 (469)	1163 (590)	41	16	0.70 (0.49)	1.05 (0.55)	51	46
1985–1989	124	1198 (837)	1604 (1150)	34	25	0.75 (0.62)	1.06 (0.66)	43	40

The sample of 311 stocks added to the S&P 500 index consists of all inclusions that satisfy the following criteria. (1) The company was newly added to the index and not the result of reorganization of an existing S&P 500 company. (2) Daily returns data are available from CRSP 1989 files for at least the 62 days preceding and following the inclusion date. (3) Inclusion is not accompanied by delisting from NASDAQ and listing on the NYSE during the 62 days preceding or following the inclusion date. (4) Trading volume data before and after the inclusion is available for at least 62 trading days. (Volume data is available for NYSE/AMEX stocks from July 1962 onwards, but for NASDAQ stocks from November 1982 onwards.) Before (after) trading volume is obtained by averaging the number of shares traded each day during the same estimation interval as daily betas reported in Table 3. The annualized turnover ratio is obtained by annualizing the total dollar volume during this estimation period and dividing by the end-of-period market value.

[1] In hundreds of shares.

[2] Two measure of percentage increase in trading volume and turnover ratio are reported. The first measure equals the ratio of average trading volume (turnover ratio) after inclusion to the average trading volume (turnover ratio) before inclusion. The second measure adjusts the after-trading volume (turnover ratio) for changes in the average trading volume (turnover ratio) of all NYSE/AMEX stocks (see Section 3.2 and note 9 for details).

data for NASDAQ stocks before November 1982 are not available.) The October 1987 data remain excluded.[9]

Table 6 shows that changes in both measures of trading activity during 1975-1979 are small and negative after adjusting for the contemporaneous changes in trading activity of all NYSE/AMEX stocks.[10] This may not be surprising; S&P 500 stocks during this period were of special interest only to index funds that follow buy-and-hold strategies. The picture changes during the 1980s. The before and after trading volumes average 82,700 and 116,300 shares a day during 1980-

[9] This detailed examination was made possible by the availability of machine-readable data on trading volumes just before a final revision of the article. The CRSP 1991 tapes contain daily volumes for all NYSE/AMEX stocks since July 1962 and for NASDAQ stocks since November 1982.

[10] Using the CRSP volume data, I first estimate the average daily trading volume of all current NYSE/AMEX stocks by calendar month during 197551989. To understand the procedure of adjusting for contemporaneous changes in market volume, consider Fleet Norstar Financial Group, which was added to the S&P 500 index on 881109. The before and after trading volumes for this stock average 107,800 and 146,400 shares a day. (All volume figures are rounded off to the nearest 100 shares.) The before volume is estimated over 871110 to 881104. Trading volume for an avenge NYSE/AMEX stock over this period is estimated as 80,100 shares a day by suitably adding the monthly averages. The after volume is estimated over 881114 to 891109. Trading volume for an average NYSE/AMEX stock over this period is estimated as 79,200 shares a day. From this, the market-adjusted trading volume after inclusion for Fleet Norstar is calculated as 146,400 × 79,200/80,100 = 144,800. A similar procedure is used to adjust for contemporaneous changes in market turnover.

Table 7
Daily betas as a function of daily trading volume from 1985 to 1989

Quintile of trading volume	Sample size	Daily trading volume[1]: Before inclusion mean (median)	After inclusion mean (median)	Percentage increase 1	Percentage increase 2[2]	Increase in beta (t-statistic)	Number of decreases and increases in beta (z-statistic)	
All stocks	124	1198 (837)	1604 (1150)	34	25	**0.211** (7.08)***	34	90 (5.03)***
Lowest	24	398 (372)	710 (673)	78	53	**0.366** (5.64)***	4	20 (3.27)**
2	25	622 (524)	1237 (779)	99	77	**0.180** (2.92)***	7	18 (2.20)**
3	25	901 (822)	1488 (1078)	65	47	**0.165** (2.19)**	7	18 (2.20)**
4	25	1201 (1206)	1514 (1542)	26	22	**0.230** (3.53)***	7	18 (2.20)**
Highest	25	2835 (2484)	3036 (2627)	7	5	**0.121** (2.03)*	9	16 (1.40)

The sample of 124 stocks added to the S&P 500 index satisfies the criteria listed in Table 6. Betas before (after) the listing date are calculated over 250 trading days ending (starting) three days before (after) the inclusion date, using the market model with log daily returns and OLS regression technique. The market returns are proxied by returns on a value-weighted portfolio of all NYSE and AMEX stocks. When data for all 250 days are not available, the computation period is shortened to the number of days of available data. but not fewer than 60 trading days. Before (after) trading volume is obtained by averaging the number of shares traded each day during the same estimation interval as betas. The quintile ranking uses trading volume during the year before the immediate last year in order to avoid a selection bias discussed in note 10. The October 1987 data are excluded from all computations.

[1,2] **See notes to Table 6.**

1984 and 119,800 and 160,400 shares a day during 1985-1989. The before and after annualized turnover ratios average 0.70 and 1.05 during 1980-1984 and 0.75 and 1.06 during 1985-1989. The market-adjusted trading volume and turnover ratio increase by 25 and 40 percent during 1985-1989. The increases are positive in 84 and 79 cases out of 124 (with z-statistics of 3.95 and 3.05).

The higher trading volume and turnover ratios of S&P 500 stocks during 1980s both suggest that S&P 500 trading may cause micro-structure price effects. The two measures suggest different types of price effect, however. The nonsynchronous trading effects should depend on the trading frequency, which may be better proxied by the trading volume. The price pressure effects should depend on the stock liquidity, which may be better proxied by the turnover ratio.

Table 7 shows the before and after trading volumes and increases in betas of 124 stocks added to the S&P 500 index during 1985-1989. The stocks are also arranged into five quintiles based on the average daily volume during the year preceding the last year before inclusion.[11] The average trading volume increases in every case, but the percentage increase is higher for low-volume quintiles. Looking down

[11] Arranging stocks into quintiles based simply on the immediate last year's trading volume would have introduced a selection bias: Stocks with temporarily low (high) trading volume would tend to be included in the lower (higher) quintiles. As a result, the percentage growth in trading volume over the following year would be overstated for lower quintiles and understated for higher quintiles. Only in rare cases when a stock is listed on a different exchange or volume data are otherwise not available during the year before the last year before inclusion, the last year's data are used. A similar procedure is used to rank turnover ratios in Table 8.

Table 8
Daily betas as a function of annualized turnover ratio from 1985 to 1989

Quintile of turnover ratio	Sample size	Annualized turnover ratio: Before inclusion mean (median)	After inclusion mean (median)	Percentage increase 1	Percentage increase 2[1]	Increase in beta (t-statistic)	Number of decreases and increases in beta (z-statistic)	
All stocks	124	0.75 (0.62)	1.06 (0.66)	43	40	**0.211** (7.08)***	34	90 (5.03)***
Lowest	24	0.30 (0.26)	0.50 (0.47)	65	62	**0.374** (6.17)***	3	21 (3.67)***
2	25	0.49 (0.44)	1.22 (0.53)	148	137	**0.284** (4.81)***	4	21 (3.40)***
3	25	0.68 (0.63)	0.98 (0.69)	45	46	**0.209** (3.10)***	7	18 (2.20)**
4	25	0.85 (0.82)	1.06 (0.84)	25	22	**0.104** (1.59)	9	16 (1.40)
Highest	25	1.39 (1.14)	1.53 (1.18)	10	10	**0.091** (1.35)	11	14 (0.60)

The sample of 124 stocks added to the S&P 500 index satisfies the criteria listed in Table 6. Betas before (after) the listing date are calculated over 250 trading days ending (starting) three days before (after) the inclusion date, using the market model with log daily returns and OLS regression technique. The market returns are proxied by returns on a value-weighted portfolio of all NYSE and AMEX stocks. When data for all 250 days are not available, the computation period is shortened to the number of days of available data, but not fewer than 60 trading days. Before (after) trading volume is obtained by annualizing the total dollar volume during the same estimation interval as betas and dividing by the end-of-period market value. The quintile ranking uses turnover ratio during the year before the immediate last year in order to avoid a selection bias discussed in note 10. The October 1987 data are excluded from all computations.

[1] See notes to Table 6.

from the lowest to the highest-volume quintile, the daily betas increase by an average of 0.366, 0.180, 0.165, 0.230, and 0.121, significant in every case. The largest increase in betas of the lowest-volume quintile and the smallest increase in betas of the highest-volume quintile provide some evidence in support of a nonsynchronous trading effect.

Table 8 shows the corresponding results for stocks arranged into turnover quintiles. Once again, the average turnover ratio increases in every case, but the percentage increase is greater for low-turnover quintiles. This may not be surprising; S&P 500 trading strategies are proportional strategies (1 percent of Boeing's outstanding equity for 1 percent of Citicorp's), so the increased turnover from basket trading is a greater percentage of prior turnover for low-turnover stocks. The relationship between turnover ratios and increases in betas is quite monotonic. The daily betas of five turnover quintiles increase by an average of 0.374, 0.284, 0.209, 0.104, and 0.091. This evidence supports the price-pressure hypothesis.[12]

The univariate analysis of Tables 7 and 8 suffers from a potential problem that the correlation between volume and turnover ranks is 0.71. The trading volume effect may be confounded by the turnover ratio effect, and vice versa. The following regression addresses this problem:

[12] The average daily trading volume and annualized turnover ratio for all NYSE/MIEX stocks during 198551989 average 77,200 shares and 0.60. The third, fourth, and fifth quintiles in Tables 7 and 8 thus contain stocks more actively traded than the simple market average.

$$\text{Increase in daily beta} = 0.419 + 0.020 \times \text{volume rank} - 0.088 \times \text{turnover rank}.$$

The regression has an adjusted-R^2 of 0.090 and the intercept and the regression coefficients of volume and turnover ranks have t-statistics of 5.84, 0.68, and -3.08. It appears that the volume rank has no significant effect on betas by itself.[13] But this regression also suffers from a potential limitation that it assumes a linear relationship between changes in betas and the prior trading volume. The assumption is somewhat inconsistent with the discussion of nonsynchronous trading hypothesis in Section 1.2, which suggests that changes in betas depend on both the before and after trading volumes and their relationship with the weighted-average market trading volume.

To address this limitation, I examine the four cases outlined in Section 1.2. I calculate the weighted-average market volume for each calendar month during 1984-1989 by using CRSP volume data for all NYSE/AMEX stocks listed on the last trading day of the month and taking month-end market values as weights. (The figures range from 207,600 shares a day in December 1988 to 513,600 shares a day in January 1987.) Then I calculate the contemporaneous weighted-average market volume relevant for each stock by averaging monthly figures over the combined computation period of before and after betas. By comparing before and after stock trading volume with this market average, I classify 116 of the 124 stocks into one of the four cases shown in Table 9. The nonsynchronous trading hypothesis predicts that as trading frequency of a stock moves closer to market average in cases 1 and 4, the stock beta will increase. Conversely, as trading frequency moves farther away from market average in cases 2 and 3, the betas will decrease. The price pressure hypothesis predicts that the betas will increase in every case.

Table 9 shows that the betas of 86 stocks belonging to case 1 increase the most, by an average of 0.250 (f-statistic 6.56). The after volume for these stocks is always greater than before volume, and both volumes are smaller than market average. The 24 stocks belonging to case 2 are more interesting. Their after volume is smaller than before volume, and both volumes are smaller than market average. Yet their betas increase by an average of 0.148 (f-statistic 2.76). This increase cannot be explained by the nonsynchronous trading hypothesis. Despite the reduced overall trading volume in these stocks, there is evidence of price pressure caused by the basket trading volume

[13] **This may not be surprising. The NYSE Fact Book reports an average trade size of around 2050 shares during 1985-1989. Thus the average time between trades for the 124 stocks should equal 390 × 2050/119,800 or 6.7 minutes before inclusion and 380 × 2050/160,400 or 5.0 minutes after inclusion (assuming 6.5 trading hours a day). Lo and MacKinlay (1990b) show that such trading frequencies imply very small index autocorrelations.**

Table 9
Testing the price pressures versus the nonsynchronous-trading hypotheses from 1985 to 1989

Trading volumes	Before and after volumes were smaller than market average	Before and after volumes were greater than market average	All cases
After volume was greater than before volume	**Case 1:** 86 stocks[1] 730 1257 **0.250** (6.56)***	**Case 3:** 3 stocks 4287 5787 **−0.168** (−1.03)	89 stocks 850 1409 **0.236** (6.21)***
After volume was smaller than before volume	**Case 2:** 24 stocks 1399 1196 **0.148** (2.76)**	**Case 4:** 3 stocks 5024 4038 **0.006** (0.03)	27 stocks 1801 1511 **0.132** (2.55)**
All cases	110 stocks 876 1243 **0.227** (7.08)***	6 stocks 4655 4912 **−0.080** (−0.65)	116 stocks 1071 1433 **0.211** (6.68)***

Sample description	Predictions of the price pressures hypothesis	Predictions of the nonsynchronous-trading hypothesis	Results
Diagonal terms cases 1 and 4	Increase	Increase	89 stocks 875 1350 **0.241** (6.44)***
Off-diagonal terms cases 2 and 3	Increase	Decrease	27 stocks 1719 1706 **0.113** (2.11)**

The sample of 116 stocks added to the S&P 500 index satisfies the criteria listed In Table 6, plus the additional criterion that either the before and after trading volumes are both greater than weighted-average market volume, or both are smaller. Betas before (after) the listing date are calculated over 250 trading days ending (starting) three days be-fore (after) the inclusion date, using the market model with log daily returns and OLS regression technique. The market returns are proxied by returns on a value-weighted portfolio of all NYSE and AMEX stocks. When data for all 250 days are not available, the computation period is shortened to the number of days of available data, but not fewer than 60 trading days. Before (after) trading volume is obtained by averaging the number of shares traded each day during the same estimation interval as betas. The weighted-average market volume is calculated as described in Section 3.2. The October 1987 data are excluded from all computations. The &statistics are calculated cross sectionally using the distribution of increases in beta.

[1] The second row in each cell reports the before and after trading volumes in hundreds of shares a day. The third row gives the increase in daily beta and the corresponding t-statistic.

common to all S&P 500 stocks. Betas of stocks belonging to case 3 decrease by 0.168 and betas of stocks belonging to case 4 increase by 0.006, but due to sample size of only three stocks in either case, both changes are insignificant. For cases 1 and 4 combined, the betas increase by 0.241 (t-statistic 6.44). Both hypotheses predict an increase here. For cases 2 and 3 combined, the betas still increase, but by a smaller 0.113 (t-statistic 2.11). The price pressure hypothesis predicts an increase here, but the nonsynchronous-trading hypothesis predicts a decrease. Overall, the evidence is consistent with both hypotheses.[14]

[14] This statement is subject to a caveat: the turnover ratio of diagonal cases is smaller than the turnover ratio of off-diagonal cases. (Average quintile ranks equal 2.70 and 3.78). Some of the differences between these two cases may, therefore, reflect different intensities of price pressure.

More importantly, the evidence is consistent with the price pressure hypothesis.

3.3 Estimated excess volatility from price pressure

The simple model specification of Section 1.1 shows that the betas of stocks added to the index should increase by *R/W*. *W* was around 0.75 during mid-1980s. Assuming that the average increase of 0.113 in daily betas of the 21 stocks belonging to cases 2 and 3 is explained by price pressure, *R* should equal 0.75 × 0.113 = 0.085. In other words, 8.5 percent of the daily variance of value-weighted market returns can be attributed to price pressure caused by the S&P 500 trading strategies. As a proportion of the daily variance of S&P 500 stock returns, however, the price pressure will account for 11.5 percent. To understand this, first note that, consistent with the microstructure hypotheses, the S&P 500 daily return variance during 1985-1989 is 27 percent higher than the CRSP value-weighted return variance. Now, it was just shown that for the CRSP value-weighted returns

$$R = \frac{\mathrm{Var}(W\eta_t)}{\mathrm{Var}(r_{vwt}) + \mathrm{Var}(W\eta_t)} = 0.085 \qquad \text{and} \qquad W = 0.75, \quad (9)$$

from which it follows that if the S&P 500 daily returns were used as a market proxy, then

$$W = 1.00 \qquad \text{and} \qquad R = \frac{\mathrm{Var}(W\eta_t)}{\mathrm{Var}(r_{spt}) + \mathrm{Var}(W\eta_t)} = 0.115. \quad (10)$$

Note that even with this alternate proxy of market returns, the betas should increase by *R/W*= 0.115 on account of price pressure, nearly identical to the case of value-weighted returns. It is interesting to note that the actual before and after betas of all 124 stocks added to the index during 1985-1989 with respect to the S&P 500 proxy average 0.733 and 0.939. Both the before and after betas are smaller than with the original proxy due to the higher S&P 500 return variance, but the increase of 0.206 is quite similar to the increase of 0.211 in the original case.

4. Further Evidence on Biases in Estimated Betas

Differences in before and after betas of stocks added to the index suggest that S&P 500 trading affects stock betas. This section provides more evidence of the estimation biases using seasoned S&P 500 and non-S&P 500 stocks. These additional tests help in further understanding of biases in many ways. First, because of data limitations, changes in monthly betas could not be estimated with the sample of stocks added to the index during 1985-1989. Monthly betas are important in tests of asset pricing models and capital budgeting applications and are investigated later. Second, changes in cross-sectional dispersion of stock betas predicted by the price pressure hypothesis can only be tested with a sample of seasoned stocks (because the inclusion dates of new S&P 500 stocks are spread out in calendar time). Third, there may be some remote possibility that previous results concerning increases in betas following inclusion of stocks in the index were driven by some other economic event associated with the inclusion. Examining betas of seasoned rather than recently included stocks removes this possibility.

A total of 239 stocks were included continuously in the S&P 500 index from 1975 to 1989. All of these stocks were traded on the NYSE; the first AMEX and NASDAQ stocks were added to the S&P 500 index on 30 June 1976. I matched each of these S&P 500 stocks with another stock belonging to the same industry (having the same two-digit industry code) that had also traded continuously on the NYSE from 1975 to 1989, was comparable in size (not more than twice or less than half the market value in July 1982, the midpoint in time), and had never been included in the index. This procedure yields 79 matched pairs of basket and nonbasket stocks. Matching by industry type and size suggests that the true betas of basket and nonbasket stocks should be comparable. Matching by the NYSE listing suggests that differences in betas over time do not capture improved liquidity of one exchange versus another.

Table 10 shows that even the monthly betas are not unchanged. Monthly betas of S&P 500 stocks exceed corresponding non-S&P 500 stock betas by an average of 0.028 during 1975-1979, by 0.038 during 1980-1984, and by 0.125 during 1985-1989. The difference is statistically insignificant during the earlier subperiods but significant during the last subperiod. Monthly betas of basket stocks during 1985-1989 are bigger in 49 cases and smaller in 30 cases (z-statistic 2.14).

Weekly and daily betas of seasoned S&P 500 and non-S&P 500 stocks show bigger effects. Daily betas of basket stocks are larger than daily betas of nonbasket stocks in all but seven cases during 1985-1989. The average difference of 0.380 during 1985-1989 is also much greater than the average difference of 0.077 during 1975-1979 and 0.112 during 1980-1984.

Table 10 also shows that the cross-sectional dispersion of betas within both the S&P 500 and the non-S&P 500 stock groups has decreased in recent years (as predicted by the price pressure hypothesis). For example, the measured cross-sectional variance of measured S&P 500 daily betas equals $0.391^2 = 0.1529$ during 1975-1979 and $0.240^2 = 0.0576$ during 1985-1989. S&P 500 trading was practically nonexistent during 1975-1979, but quite heavy during 1985-1989. Because predictions of the price pressure hypothesis are based on

Table 10
Matched-pairs tests of seasonal S&P 500 non-S&P 500 stock betas from 1975 to 1989

Estimation interval	Average value of S&P 500 stock betas (cross-sectional) std deviation)	Average value of non–S&P 500 stock betas (cross-sectional std deviation)	Difference in S&P 500 and non–S&P 500 stock betas (t-statistic)	Nonparametric tests: number of times S&P 500 beta is smaller or greater than non–S&P 500 beta (z-statistic)	
		Monthly betas			
1975–1979	1.146 (0.404)	1.118 (0.408)	**0.028** (0.56)	39	40 (0.11)
1980–1984	0.965 (0.416)	0.927 (0.458)	**0.038** (0.70)	35	44 (1.01)
1985–1989	1.063 (0.348)	0.938 (0.319)	**0.125** (2.83)***	30	49 (2.14)**
		Weekly betas			
1975–1979	1.023 (0.353)	0.956 (0.419)	**0.067** (1.32)	32	47 (1.69)
1980–1984	0.873 (0.320)	0.830 (0.347)	**0.043** (1.03)	34	45 (1.24)
1985–1989	1.026 (0.304)	0.747 (0.250)	**0.279** (6.53)***	16	63 (5.29)***
		Daily betas			
1975–1979	0.906 (0.391)	0.829 (0.463)	**0.077** (1.39)	28	51 (2.59)***
1980–1984	0.802 (0.323)	0.690 (0.332)	**0.112** (2.50)**	30	49 (2.14)**
1985–1989	1.011 (0.240)	0.631 (0.190)	**0.380** (10.67)***	7	72 (7.31)***

The sample of 79 pairs of S&P 500 and non-S&P 500 stocks satisfies the following criteria. (1) Both stocks were listed on the NYSE continuously from 1975 to 1989. (2) The first stock was included in the S&P 500 before 1975, and the second was never included. (3) Both stocks have the same two-digit industry code. (4) The market value of the non-S&P 500 stock is no more than twice and no less than half of the market value of the S&P 500 stock on July 1, 1982 (the midpoint in time). Betas are calculated using the market model with log returns and the OLS technique. The market returns are proxied by the returns on a value-weighted portfolio of NYSE and AMEX stocks. Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987. The r-statistics are calculated cross sectionally using the distribution of differences in estimated betas.

the cross-sectional variance of asymptotic (or large-sample) betas given by (5) and (7), the following transformation is carried out before testing for changes in variance:[15]

Estimated cross-sectional variance of asymptotic betas

= measured corss-sectional variance of measured (small-sample) betas

– average squared error of measured (small-sample) betas.

[15] From Equation (7). it follows that in finite samples the cross-sectional variance of betas within the S&P 500 group will equal

$$\widehat{\mathrm{Var}}(\hat{\beta}_{j,b,ols}) = \frac{1}{n-1}\sum_{j=1}^{n}\left\{\left[(1-R)\beta_j + \frac{R}{W} + \xi_j\right] - \left[(1-R)\bar{\beta} + \frac{R}{W} + \bar{\xi}\right]\right\}^2$$

$$= \frac{(1-R)^2}{n-1}\sum_{j=1}^{n}(\beta_j - \bar{\beta})^2 + \bar{\xi}^2,$$

where ξ_j^2 is the squared error of measured beta for the jth stock, and other notations are the same as in Section 1. Here ξ_j is assumed to be uncorrelated with β_j, and $\bar{\xi} = 0$. The term on the left side represents the measured cross-sectional variance of measured betas, and the two terms on the right side represent the estimated variance of asymptotic betas and the average squared error of measured betas.

The average squared errors of measured betas of S&P 500 stocks equal 0.0045 and 0.0036 during 1973-1979 and 1985-1989. The estimated cross-sectional variance of asymptotic betas during these two subperiods is therefore given by 0.1529 – 0.0045 = 0.1484 and 0.0576 – 0.0036 = 0.0540. Equality of these two variances can be rejected by Hartley's F-test [see Sachs (1984) for details]. Hartley's F-statistic equals the ratio of sample variances, or 1.1484/0.0540 = 2.75, which is greater than the cutoff value of 1.90 corresponding to the 1 percent significance level with 79 observations. The equality of cross-sectional variance of non-S&P 500 daily betas during 1975-1979 and 1985-1989 can be similarly rejected with an F-statistic of 7.04.[16]

Figure 2 plots the distributions of estimated S&P 500 and non-S&P 500 stock betas. This figure shows how the recent trading innovations have divided the exchange-traded stocks into two distinct and compact groups based on their estimated betas. Using unadjusted betas in empirical tests of asset pricing models will induce an "S&P 500 bias."

5. Price Pressure and the Cross Autocorrelations between Stock Returns

I now examine common reversion of prices over time for additional evidence on price pressure. Equation (8) predicts that price pressure will cause negative cross autocorrelations between S&P 500 stock returns. This prediction contrasts with results documented by Lo and MacKinlay (1990a), who find positive cross autocorrelations between S&P 500 stock returns. This prediction contrasts with results documented by Lo and MacKinlay (1990a), who find positive cross autocorrelations between stock returns over the aggregate time period from 1962 to 1987. They explain that nonsynchronous trading can induce positive cross autocorrelations, although the measured autocorrelations are greater than implied by the usual level of trading.

Measurement of cross autocorrelations between individual stock returns is subject to some limitations. First, the large unsystematic return makes the estimated correlations very imprecise. Second, the number of pairwise interactions of individual stocks becomes very large. To reduce the noise and the number of computations, I examine cross autocorrelations between stock returns and the S&P 500 index returns, instead of between individual stock returns. Security j in Equation (8) thus remains a stock, but security k becomes the S&P 500 index. If S&P 500 trading strategies cause price pressure, then

[16] The equality of weekly and monthly betas of non-S&P 500 stocks during 1975-1979 versus 1985-1989 can also be rejected with F-statistics of 4.16 and 2.18. However, the corresponding F-statistics for S&P 500 stocks both equal 1.43 (coincidentally) and are insignificant.

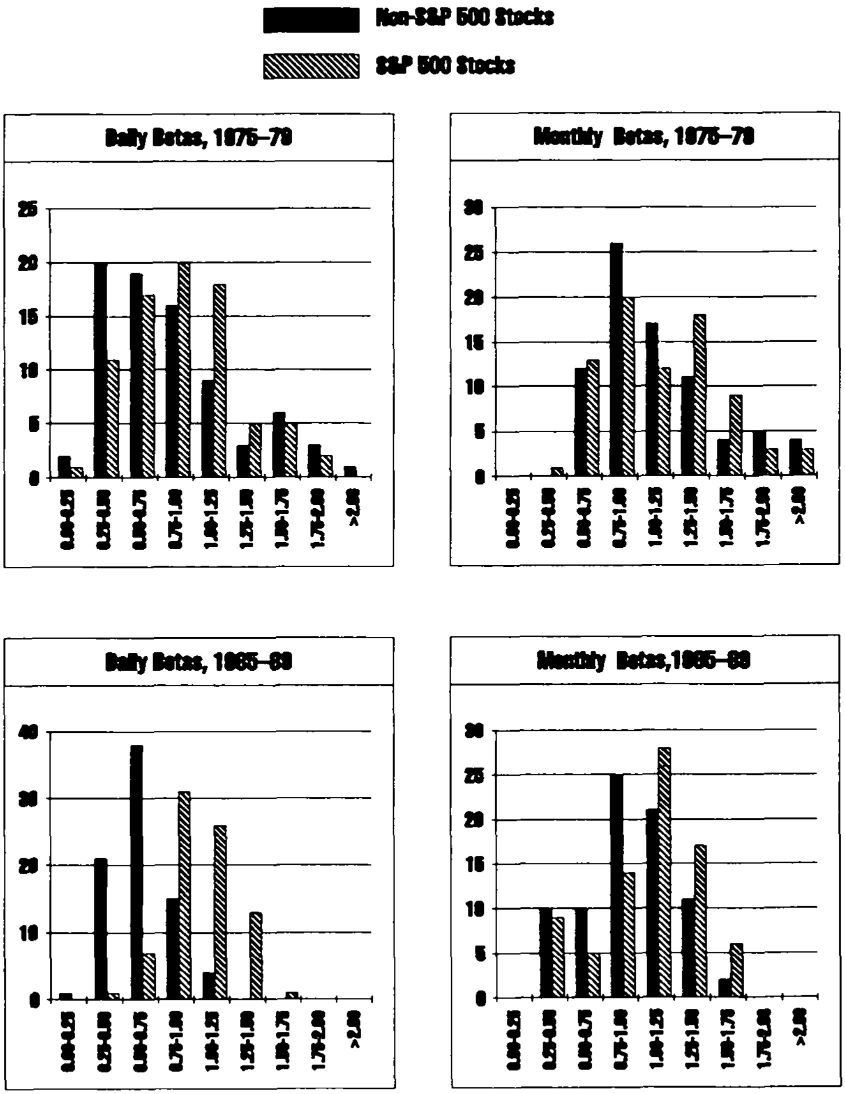

Figure 2
Cross-sectional distribution of daily and monthly betas within S&P 500 and non-S&P 500 stock groups over 1975-1979 and 1985-1989.
The shifting of S&P 500 stock betas to the right and non-S&P 500 stock betas to the left is consistent with both the price pressure and the nonsynchronous trading hypotheses. The narrower clustering of betas within either stock group is consistent with the price pressure hypothesis.

cross autocorrelations between the current returns of *j* and the earlier-period S&P 500 returns should be negative when *j* is an S&P 500 stock, and zero otherwise.

Table 11 shows before and after cross autocorrelations of stocks

Table 11
Cross autocorrelations between current stock returns and earlier-period S&P 500 index returns using daily data before and after addition of stocks to index from 1975 to 1989

			Before addition to index			After addition to index		
Period	Sample size	Lag	Average cross autocorrelation, cross-sectional standard deviation, number positive, and number negative			Average cross autocorrelation, cross-sectional standard deviation, number positive, and number negative		
1975–1979	107	1	**0.1561** (0.1030)	98	9	**0.1254** (0.0858)	100	7
		2	**0.0081** (0.0632)	59	48	**0.0220** (0.0475)	76	31
		3	**0.0415** (0.0487)	84	23	**0.0281** (0.0486)	78	29
		4	**0.0255** (0.0443)	76	31	**0.0061** (0.0485)	58	49
		5	**−0.0097** (0.0494)	50	57	**0.0091** (0.0494)	60	47
1980–1984	97	1	**0.1288** (0.0958)	87	11	**0.0971** (0.0892)	86	12
		2	**0.0230** (0.0439)	71	27	**0.0232** (0.0488)	70	28
		3	**0.0130** (0.0500)	55	43	**0.0209** (0.0493)	64	34
		4	**−0.0047** (0.0540)	46	52	**0.0121** (0.0508)	61	37
		5	**0.0072** (0.0501)	53	45	**−0.0037** (0.0469)	48	50
1985–1989	124	1	**0.1296** (0.0719)	117	7	**0.0375** (0.0779)	89	35
		2	**0.0073** (0.0506)	68	56	**−0.0127** (0.0549)	54	70
		3	**0.0137** (0.0452)	76	48	**−0.0104** (0.0475)	49	75
		4	**−0.0035** (0.0426)	60	64	**−0.0271** (0.0616)	38	86
		5	**0.0006** (0.0467)	58	66	**−0.0137** (0.0435)	45	79

The sample of 329 stocks added to the S&P 500 index satisfies the criteria listed in Table 3. Cross autocorrelations between stock returns and earlier-period S&P 500 index returns before (after) the listing date are calculated over 500 trading days ending (starting) three days before (after) the inclusion date. (A cross autocorrelation at lag 2, for example, specifies the correlation between stock returns on day t and the S&P 500 index returns on day $t-2$.) If 500 days of data are not available, the estimation interval *is* suitably shortened, but not to less than 60 trading days. Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987.

added to the S&P 500 index using daily returns. Because of large standard errors relative to the expected value of cross autocorrelations, the estimation period is increased to 500 trading days whenever possible.[17] Consistent with Lo and MacKinlay (1990a), the cross autocorrelations before and after inclusion are generally positive during 1975-1979 and 1980-1984. Furthermore, inclusion in the index does not decrease cross autocorrelations. The average correlation after inclusion decreases in three cases out of five during 1975-1979, and two cases out of five during 1980-1984. But the evidence changes substantially during 1985-1989. The first five cross autocorrelations before inclusion equal 0.1296, 0.0073, 0.0137, -0.0035, and 0.0006.

[17] Table 2 shows that autocorrelations in S&P 500 index returns are about -0.03 to -0.04. The index autocorrelation is related to individual stock cross autocorrelations as follows:

$$\rho(r_{st}, r_{s,t-l}) = \frac{\mathrm{Cov}(r_{st}, r_{s,t-l})}{\mathrm{Var}(r_{st})} = \frac{\mathrm{Cov}(\Sigma_j w_j r_{jt}, r_{st-l})}{\mathrm{Var}(r_{st})} = \sum_j w_j \left(\frac{\sigma_j}{\sigma_s}\right) \rho(r_{jt}, r_{s,t-l}).$$

The subscript s denotes the S&P 500 index. If the typical standard deviation of daily stock returns were twice the standard deviation of daily market returns, then the expected value of cross autocorrelations between stock and index returns would be the order of -0.01 to -0.02. In comparison, the corresponding standard errors are the order of $\sqrt{1/T}$, or 0.063 with 250 days of data.

The same correlations after inclusion equal 0.0375, -0.0127, -0.0104, -0.0271, and -0.0137. That all five cross autocorrelations decrease after inclusion is consistent with both the price pressure and the nonsynchronous trading hypotheses. That correlations are negative at lags 2 to 5 further suggests that price pressures are strong enough to overcome the influence of nonsynchronous trading beyond the first lag.

Table 12 documents cross autocorrelations for the matched pairs of S&P 500 and non-S&P 500 stocks. Most of these are positive during 1975-1979 and 1980-1984. During 1985-1989, however, the five cross autocorrelations between S&P 500 stock and index returns average 0.0333, -0.0104, -0.0113, -0.0136, and -0.0115. In comparison, the cross autocorrelations between non-S&P 500 stock returns and S&P 500 index returns equal 0.0916, 0.0000, 0.0004, -0.0126, and 0.0032.[18]

In Tables 11 and 12, one may be tempted to calculate the *t*-statistics by dividing the average cross autocorrelations with the cross-sectional standard deviation or calculate the *z*-statistics with frequency of positive and negative correlations. Both statistics will generally be greater than 2.00. Such statistics will, however, overstate the incremental significance of results. The negative own autocorrelations in S&P 500 index returns during 1985-1989 as reported in Table 2 predict the negative average cross autocorrelations between S&P 500 stock and index returns.

The cross autocorrelations in Tables 11 and 12 support the price-pressure hypothesis. These tables also point out an advantage of examining betas as compared with examining autocorrelations and cross autocorrelations. If the marketwide liquidity price effects arising from concentration of institutional buying or selling are substantial and persist for a few days, then changes in beta will be larger than changes in autocorrelation at any one particular lag.

6. Correcting for Microstructure Biases in Estimated Betas

This section examines the methods of obtaining unbiased estimates of stock betas. One may use Equations (5) and (7) to refine the raw

[18] Tables 11 and 12 suggest that the negative cross autocorrelations in S&P 500 stock returns during 1985-1989 could persist beyond live trading days. The cross autocorrelations over lag 6 to 10 are as follows:

Lag	6	7	8	9	10
Table 11, before inclusion	−0.0137	−0.0159	0.0032	−0.0077	0.0073
Table 11, after inclusion	−0.0218	−0.0021	0.0142	0.0091	0.0146
Table 12, non-S&P 500	−0.0158	−0.0054	0.0185	0.0085	0.0097
Table 12, S&P 500	−0.0305	−0.0120	0.0283	0.0098	0.0088

The sixth and seventh cross autocorrelations are always negative, but there appears to be no significant difference between S&P 500 and non-S&P 500 stocks over lag 6 to 10.

Table 12
Cross autocorrelations between seasoned S&P 500 and non-S&P 500 stock returns and earlier-period S&P 500 index returns using daily from 1975 to 1989

		79 seasoned non-S&P 500 stocks			79 seasoned S&P 500 stocks		
Period	Lag	Average cross autocorrelation, cross-sectional standard deviation, number positive, and number negative			Average cross autocorrelation, cross-sectional standard deviation, number positive, and number negative		
1975–79	1	**0.1313** (0.0617)	74	5	**0.1426** (0.0655)	78	1
	2	**0.0165** (0.0358)	52	27	**0.0028** (0.0356)	42	37
	3	**0.0274** (0.0342)	60	19	**0.0147** (0.0278)	55	24
	4	**0.0201** (0.0307)	60	19	**0.0252** (0.0323)	65	14
	5	**0.0273** (0.0294)	65	14	**0.0191** (0.0253)	59	20
1980–84	1	**0.1310** (0.0606)	77	2	**0.1044** (0.0635)	74	5
	2	**0.0312** (0.0304)	70	9	**0.0231** (0.0313)	63	16
	3	**0.0173** (0.0351)	58	21	**0.0065** (0.0312)	43	36
	4	**−0.0008** (0.0331)	37	42	**−0.0053** (0.0296)	36	43
	5	**0.0101** (0.0251)	47	32	**0.0068** (0.0286)	47	32
1985–89	1	**0.0916** (0.0680)	72	7	**0.0333** (0.0515)	57	22
	2	**0.0000** (0.0342)	43	36	**−0.0104** (0.0310)	28	51
	3	**0.0004** (0.0304)	38	41	**−0.0113** (0.0279)	27	52
	4	**−0.0126** (0.0369)	31	48	**−0.0136** (0.0302)	23	56
	5	**0.0032** (0.0282)	40	39	**−0.0115** (0.0267)	27	52

The sample of 79 pairs of seasoned S&P 500 and non-S&P 500 stocks satisfies the criteria listed in Table 10. Cross autocorrelations between stock returns and earlier-period S&P 500 index returns are calculated over the full five-year period. (A cross autocorrelation at lag 2. for example specifies the correlation between stock returns on day *t* and the S&P 500 index returns on day *t* – 2). Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987.

betas, but this would correct only for the price pressure effects and would be subject to the assumptions of my model. Fortunately, all microstructure biases can be corrected by using the instrumental-variable techniques proposed by Scholes and Williams (1977) and Cohen et al. (1983). Assuming that the price pressure reverts over no more than *n* periods, the Cohen et al. estimator of beta is given by

$$\hat{\beta}_{j,cob} = \frac{\Sigma_{\tau=1}^{n} \hat{\beta}_{j,ols}^{-\tau} + \hat{\beta}_{j,ols} + \Sigma_{\tau=1}^{n} \hat{\beta}_{j,ols}^{+\tau}}{\Sigma_{\tau=1}^{n} \hat{\rho}_m^{-\tau} + 1 + \Sigma_{\tau=1}^{n} \hat{\rho}_m^{+\tau}}, \tag{11}$$

where $\hat{\beta}_{j,ols}^{-\tau}$ ($\hat{\beta}_{j,ols}^{+\tau}$) is the OLS beta from regressing today's stock returns on the market returns lagging (leading) by τ periods in a univariate regression, and $\hat{\rho}_m^{-\tau}$ ($\hat{\rho}_m^{+\tau}$) is the T-period own autocorrelation in market returns estimated from the first (last) $T - \tau$ observations. The OLS and Scholes and Williams (SW) betas can be considered to be special cases of Cohen et al. betas, when n = 0 and n = 1.

Table 13 shows the OLS and Cohen et al. betas of 124 stocks added to the S&P 500 index during 1985-1989. The OLS daily betas before and after inclusion equal 0.858 and 1.069. In comparison, the Cohen et al. daily betas for *n* = 1 to 5 equal 1.030, 1.102, 1.139, 1.151, and 1.195 before inclusion, and 1.130, 1.136, 1.164, 1.262, and 1.299 after

Table 13
Scholes and Williams (1977) and Cohen et al. (1983) betas for all the 124 stocks added to the S&P 500 index from 1985 to 1989

Number of leads and lags (n)	Cohen et al. betas before addition to index	Cohen et al. betas after addition to index	Difference in betas (t-statistic)
		Weekly betas	
0 OLS	1.044	1.174	0.130 (2.84)***
1 SW	1.262	1.360	0.098 (0.42)
		Daily betas	
0 OLS	0.858	1.069	0.211 (7.08)***
1 SW	1.030	1.130	0.100 (2.71)***
2	1.102	1.136	0.033 (0.70)
3	1.139	1.164	0.025 (0.49)
4	1.151	1.262	0.110 (1.55)
5	1.195	1.299	0.104 (1.25)

The sample of 329 stocks added to the S&P 500 Index satisfies the criteria listed in Table 3. Betas before (after) the listing date are calculated over 250 trading days ending (starting) three days before (after) the inclusion date. If 250 days of data are not available, the estimation period is suitably shortened, but not to less than 60 trading days. The market returns are proxied by returns on a value-weighted portfolio of all NYSE and AMEX stocks. Cohen et al. betas are obtained as described in Section 6. All betas are calculated with log stock and log market returns. Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987.

inclusion. The before and after Cohen et al. daily betas at all lags are greater than OLS betas. The difference between before and after betas decreases at first as n increases, but then it starts increasing. With weekly returns, the OLS before and after betas equal 1.044 and 1.174. The corresponding SW betas equal 1.262 and 1.360. The difference between SW weekly betas is comparable with the difference between OLS weekly betas, but its cross-sectional standard deviation is five times greater.

Results of Table 13 highlight a potential limitation of Scholes and Williams and Cohen et al. betas. These estimators may be unbiased, but their estimation errors are very large. The squared error of estimated Cohen et al. betas can be written as

$$\mathrm{Var}(\hat{\beta}_{j,\,cob} - \beta_j \mid \hat{\rho}_m^{-\tau} \cdots \hat{\rho}_m^{+\tau}) = \frac{2n + 1 + \Sigma_{\tau=1}^{n} (2n + 1 - \tau)(\hat{\rho}_m^{-\tau} + \hat{\rho}_m^{+\tau})}{[1 + \Sigma_{\tau=1}^{n} (\hat{\rho}_m^{-\tau} + \hat{\rho}_m^{+\tau})]^2} \frac{\sigma_\epsilon^2}{(T - 2\tau)\sigma_m^2}. \quad (12)$$

Correlations $\hat{\rho}_m^{-\tau}$ and $\hat{\rho}_m^{+\tau}$ themselves have standard errors of $\sqrt{1/(T - 2\tau)}$. Over small estimation intervals, the denominator of Equations (11) and (12) can sometimes become very small, which may lead to a few large betas with large standard errors. For an extreme example, consider National Education Corp., which was added to the S&P 500 index on 1 March 1989. Its OLS weekly beta estimated over the remaining 43 weeks of 1989 equals 1.300. In comparison, the SW beta equals 12.779.

The standard errors can be reduced by increasing the length of estimation period. Table 14 shows the SW and Cohen et al. betas for 79 pairs of S&P 500 and non-S&P 500 stocks using all five years of data during 1985-1989. The OLS monthly betas of S&P 500 and non-S&P 500 stocks equal 1.063 and 0.938. In comparison, the SW monthly betas equal 0.970 and 1.005. The difference between OLS monthly betas equals 0.125, which is significant. The difference between SW monthly betas equals -0.035, which is insignificant. Similarly, the difference between OLS weekly betas is a very significant 0.279, but the difference between SW weekly betas is an insignificant 0.085.

Table 14 also presents Cohen et al. daily betas. The difference between OLS daily betas of S&P 500 and non-S&P 500 stocks equals 0.380. In comparison, the difference between before and after Cohen et al. betas from $n = 1$ to 5 equals 0.252, 0.246, 0.229, 0.249, and 0.246. (Although not reported in Table 14, the difference decreases to 0.140 for $n = 7$.) The difference between daily betas converges slowly, which may not be surprising in view of the inability of autocorrelations to die out by lag 5. Overall, the instrumental-variable techniques may reduce the microstructure biases, but unless the estimation window is very long, the estimates are very noisy.

7. Conclusions

This paper examines daily, weekly, and monthly stock returns for evidence on possible price pressure caused by the S&P 500 trading strategies. The common price pressures are examined with stock betas and with index autocorrelations and cross autocorrelations between stock returns. The estimated S&P 500 stock betas over all windows have increased and the estimated non-S&P 500 stock betas have decreased in recent years of active S&P 500 trading. The own autocorrelations in S&P 500 index daily returns and the cross autocorrelations between S&P 500 stock and index daily returns are also negative from lag 2 to 5.

Further analysis suggests that some of the increases in betas and the reductions in positive autocorrelations may be caused by increased trading frequency of the average S&P 500 stock as the volume of trade associated with these strategies increases. To abstract from the effect of reduced nonsynchroneity of S&P 500 prices, I examine a subset of stocks for which the Scholes and Williams (1977) model predicts that betas should decrease or remain unchanged. Daily betas of even this subset of stocks increase by an average of 0.113. This evidence and the evidence on negative autocorrelations suggest that S&P 500 trad-

Table 14
Scholes and Williams (1977) and Cohen et al. (1983) betas for the 79 matched pairs of seasoned S&P 500 and non-S&P 500 stocks from 1935 to 1989

Number of leads and lags (n)	Cohen et al. beta of non-S&P 500 stocks	Cohen et al. betas of S&P 500 stocks	Difference in betas (t-statistic)
		Monthly betas	
0 OLS	0.938	1.063	0.125 (2.83)***
1 SW	1.005	0.970	−0.035 (0.42)
		Weekly betas	
0 OLS	0.747	1.026	0.279 (6.53)***
1 SW	0.933	0.018	0.085 (0.42)
		Daily betas	
0 OLS	0.631	1.011	0.380 (10.66)***
1 SW	0.769	1.020	0.251 (6.42)***
2	0.789	1.035	0.246 (5.73)***
3	0.799	1.029	0.229 (4.98)***
4	0.800	1.049	0.249 (4.83)***
5	0.798	1.044	0.246 (4.53)***

The sample of 79 pairs of seasoned S&P 500 and non-S&P 500 stocks satisfies the criteria listed in Table 10. The market returns are proxied by returns on a value-weighted portfolio of all NYSE and AMEX stocks. Cohen et al. betas are obtained as described in Section 6. All betas are calculated with log stock and log market returns using the entire five years of data. Data for the month of October 1987 are excluded to remove the period affected by the market crash of 1987.

ing strategies may lead to price pressures that sometimes persist for a few days. By using a simple model, I estimate that price pressures may account for roughly 8.5 percent of daily variance of a value-weighted portfolio of NYSE/AMEX stocks. This excess volatility can be regarded as a price paid for the ability to trade the market portfolio within the existing limitations of market liquidity.

Appendix

A.1 Biases in estimated stock betas when the percentage price pressure is identical for all stocks and is uncorrelated with the true market return

This is the base model of Section 1.1, which assumes that $\eta_{jt} = \eta_t$ for all j and $\text{Cov}(\eta_t, r_{mt}) = 0$. Using Equations (1) to (4), we bias the measured betas of nonbasket stocks as

$$\hat{\beta}_{j,nb,ols} = \frac{\text{Cov}(r_{jt}, \hat{r}_{mt})}{\text{Var}(\hat{r}_{mt})} = \frac{\text{Cov}(r_{jt}, r_{mt} + W\eta_t)}{\text{Var}(r_{mt} + W\eta_t)}$$

$$= \frac{\text{Cov}(r_{jt}, r_{mt})}{\text{Var}(r_{mt}) + \text{Var}(W\eta_t)}$$

$$= \left[1 - \frac{\mathrm{Var}(\hat{r}_{mt}) - \mathrm{Var}(r_{mt})}{\mathrm{Var}(\hat{r}_{mt})}\right]\frac{\mathrm{Cov}(r_{jt}, r_{mt})}{\mathrm{Var}(r_{mt})}$$

$$= (1 - R)\beta_j < \beta_j \qquad \text{for all } \beta_j > 0 \text{ and } j = J_1 + 1,\ldots,J,$$

where R is the proportion of market volatility accounted by trading-induced price pressure. Thus betas of all nonbasket stocks are understated. The measured betas of basket stocks are biased as

$$\hat{\beta}_{j,b,ols} = \frac{\mathrm{Cov}(\hat{r}_{jt}, \hat{r}_{mt})}{\mathrm{Var}(\hat{r}_{mt})} = \frac{\mathrm{Cov}(r_{jt} + \eta_t, r_{mt} + W\eta_t)}{\mathrm{Var}(r_{mt} + W\eta_t)}$$

$$= \frac{\mathrm{Cov}(r_{jt}, r_{mt}) + \mathrm{Cov}(\eta_t, W\eta_t)}{\mathrm{Var}(r_{mt}) + \mathrm{Var}(W\eta_t)}$$

$$= \frac{\mathrm{Cov}(r_{jt}, r_{mt})}{\mathrm{Var}(r_{mt}) + \mathrm{Var}(W\eta_t)} + \frac{1}{W}\frac{\mathrm{Var}(W\eta_t)}{\mathrm{Var}(r_{mt}) + \mathrm{Var}(W\eta_t)}$$

$$= (1 - R)\beta_j + \frac{R}{W} \qquad \text{for all } j = 1,2,3,\ldots,J_1.$$

Betas of basket stocks are overstated if their true betas are less than $1/W$. Betas of basket stocks with true betas greater than $1/W$ are understated, but by less than if they were not included in the index. Inclusion in or exclusion from the index always changes betas by R/W.

A.2 Biases in estimated stock betas when the percentage price pressure varies across stocks, but is uncorrelated with the true market return

This model assumes that price pressure varies cross sectionally with some stock attribute γ_j (which could be the inverse of annualized turnover ratio for stock j, or any other measure of stock liquidity). Consider the specification $\eta_{jt} = \gamma_j \xi_t$, where ξ_t can be interpreted as the percentage price pressure for a stock with $\gamma_j = 1$. By continuing to assume $\mathrm{Cov}(\eta_{jt}, r_{mt}) = 0$ for all t, it follows that

$$\hat{r}_{jt} = r_{jt} + \eta_{jt} = r_{jt} + \gamma_j \xi_t \qquad \text{for all } j = 1,2,3,\ldots,J_1, \tag{3'}$$

$$\hat{r}_{mt} = \sum_{j=1}^{J} w_j \hat{r}_{jt} = r_{mt} + \sum_{j=1}^{J} w_j \gamma_j \xi_t = r_{mt} + W\gamma_m \xi_t, \tag{4'}$$

where $\gamma_m = \Sigma_{j=1}^{J} w_j \gamma_j / W$. The measured betas of nonbasket stocks are biased as

$$\hat{\beta}_{j,nb,ols} = \frac{\mathrm{Cov}(r_{jt}, \hat{r}_{mt})}{\mathrm{Var}(\hat{r}_{mt})} = \frac{\mathrm{Cov}(r_{jt}, r_{mt})}{\mathrm{Var}(r_{mt}) + \mathrm{Var}(W\gamma_m \xi_t)}$$

$$= \left[1 - \frac{\text{Var}(W\gamma_m\xi_t)}{\text{Var}(\hat{r}_{mt})}\right]\frac{\text{Cov}(r_{jt}, r_{mt})}{\text{Var}(r_{mt})}$$

$$= (1 - R)\beta_j \qquad \text{for all } j = J_1 + 1,\ldots,J,$$

where R is again the proportion of market volatility accounted by trading-induced price pressure. The measured betas of basket stocks are biased as

$$\hat{\beta}_{j,b,ols} = \frac{\text{Cov}(\hat{r}_{jt}, \hat{r}_{mt})}{\text{Var}(\hat{r}_{mt})} = \frac{\text{Cov}(r_{jt}, r_{mt}) + \text{Cov}(\gamma_j\xi_t, W\gamma_m\xi_t)}{\text{Var}(r_{mt}) + \text{Var}(W\gamma_m\xi_t)}$$

$$= \frac{\text{Cov}(r_{jt}, r_{mt})}{\text{Var}(r_{mt}) + \text{Var}(W\gamma_m\xi_t)} + \frac{\gamma_j}{\gamma_m}\frac{1}{W}\frac{\text{Var}(W\gamma_m\xi_t)}{\text{Var}(r_{mt}) + \text{Var}(W\gamma_m\xi_t)}$$

$$= (1 - R)\beta_j + \frac{\gamma_j}{\gamma_m}\frac{R}{W} \qquad \text{for all } j = 1,2,3,\ldots,J_1.$$

As expected, the biases are more positive for less liquid basket stocks with higher γ_j's. Inclusion in or exclusion from the index changes betas by $(\gamma_j/\gamma_m)(R/W)$.

A.3 Biases in estimated stock betas when all stocks carry the same percentage price pressure, but the price pressure is correlated with the true market return

Portfolio insurance strategies are suspected to exacerbate both the up and down moves in market level. This should make $\text{Cov}(\eta_t, r_{mt})$ positive. I use the same framework as in Section 1.1 and Appendix A.1 in this case. The expression for excess trading-induced volatility changes to

$$\text{Var}(\hat{r}_{mt}) = \text{Var}(r_{mt} + W\eta_t)$$

$$= \text{Var}(r_{mt}) + 2\,\text{Cov}(r_{mt}, W\eta_t) + \text{Var}(W\eta_t).$$

Now define R as before, but with the additional structure

$$\frac{2\text{Cov}(r_{mt}, W\eta_t) + \text{Var}(W\eta_t)}{\text{Var}(\hat{r}_{mt})} = \frac{\text{Var}(\hat{r}_{mt}) - \text{Var}(r_{mt})}{\text{Var}(\hat{r}_{mt})} = R,$$

$$\frac{2\text{Cov}(r_{mt}, W\eta_t)}{\text{Var}(\hat{r}_{mt})} = kR,$$

$$\frac{\text{Var}(W\eta_t)}{\text{Var}(\hat{r}_{mt})} = (1 - k)R.$$

Because both $\text{Cov}(\eta_t, r_{mt})$ and $\text{Var}(W\eta_t)$ are positive, k must lie between 0 and 1. The measured betas of nonbasket stocks are biased as

$$\hat{\beta}_{j,nb,ols} = \frac{\text{Cov}(r_{jt}, \hat{r}_{mt})}{\text{Var}(\hat{r}_{mt})} = \frac{\text{Cov}(r_{jt}, r_{mt}) + \text{Cov}(r_{jt}, W\eta_t)}{\text{Var}(\hat{r}_{mt})}$$

$$= \frac{\text{Cov}(r_{jt}, r_{mt})}{\text{Var}(\hat{r}_{mt})} + \frac{\text{Cov}(\alpha_j + \beta_j r_{mt} + \epsilon_{jt}, W\eta_t)}{\text{Var}(\hat{r}_{mt})}$$

$$= (1 - R)\beta_j + \frac{\text{Cov}(r_{mt}, W\eta_t)}{\text{Var}(\hat{r}_{mt})}\beta_j$$

$$= (1 - R)\beta_j + \frac{kR}{2}\beta_j$$

$$= \left(1 - \left[1 - \frac{k}{2}\right]R\right)\beta_j \qquad \text{for all } j = J_1 + 1, \ldots, J.$$

The measured betas of basket stocks are biased as

$$\hat{\beta}_{j,nb,ols} = \frac{\text{Cov}(\hat{r}_{jt}, \hat{r}_{mt})}{\text{Var}(\hat{r}_{mt})} = \frac{\text{Cov}(r_{jt} + \eta_t, r_{mt} + W\eta_t)}{\text{Var}(\hat{r}_{mt})}$$

$$= \frac{\text{Cov}(r_{jt}, r_{mt}) + \text{Cov}(r_{jt}, W\eta_t)}{\text{Var}(\hat{r}_{mt})} + \frac{\text{Cov}(\eta_t, r_{mt})}{\text{Var}(\hat{r}_{mt})}$$

$$+ \frac{\text{Cov}(\eta_t, W\eta_t)}{\text{Var}(\hat{r}_{mt})}$$

$$= \left(1 - \left[1 - \frac{k}{2}\right]R\right)\beta_j + \frac{kR}{2W} + \frac{(1 - k)R}{W}$$

$$= \left(1 - \left[1 - \frac{k}{2}\right]R\right)\beta_j + \frac{[1 - k/2]R}{W} \qquad \text{for all } j = 1,2,3,\ldots,J_1.$$

The expressions for biases in basket and nonbasket stocks are similar to the first case in Appendix A.1, with the exception that R is replaced by $[1 - k/2]R$. Inclusion in or exclusion from the index changes betas by $[1 - k/2]R/W$.

References

Basak, S., 1993, “A General Equilibrium Model of Portfolio Insurance,” working paper, Wharton School, University of Pennsylvania.

Brennan, M. J., and E. S. Schwartz. 1989, “Portfolio Insurance and Financial Market Equilibrium.” *Journal of Business,* 62, 455-471.

Cohen, K. J., G. A. Hawawini, S. F. Maier. R. A. Schwartz, and D. K. Whitcomb, 1983, “Frictions in the Trading Process and the Estimation of Systematic Risk,” *Journal of Financial Economics* 12. 263-278.

Dimson, E.. 1979. “Risk Management When Shares Are Subject to Infrequent Trading,” *Journal of Financial Economics,* 7, 197-226.

Duffie, G., P. Kupiec. and P. A. White, 1990, "A Primer on Program Trading and Stock Price Volatility: A Survey of the Issues and the Evidence," working paper, The Federal Reserve Board.

Fama, E. F., 1970, "Efficient Capital Markets: A Review of Theory and Empirical Work," *Journal of Finance, 25,* 383-417.

Fisher, L., 1966, "Some New Stock Market Indices." *Journal of Business,* 39, 191-225

Grossman, S. J., 1988a, "An Analysis of the Implications for Stock and Futures Price Volatility of Program Trading and Dynamic Heding Strategies," *Journal of Business,* 61, 275-298.

Grossman, S. J., 1988b, "Program Trading and Market Volatility: A Report on lnterday Relationships," *Financial Analysts Journal,* 44, 18-28.

Harris, L. E., 1989, "S&P 500 Cash Stock Price Volatilities," *Journal of Finance,* 44, 1155-1176.

Harris, L. E.. 1990, "The Economics of Cash Index Alternatives." *Journal of Futures Markets,* 10, 179-194.

Harris, L. E., G. Sofianos, and J. E. Shapiro, 1990, "Program Trading and Intraday Volatility." Working Paper 90-03, The New York Stock Exchange.

Ho, T. S. Y., and R. G. Macris, 1984, "Deal Bid-Ask Quotes and Transaction Prices: An Empirical Study of Some AMEX Options," *Journal of Finance, 39, 23-45.*

Holden, C. *W.*, 1990, "A Theory of Arbitrage Trading in Financial Market Equilibrium," working paper, Indiana University, Bloomington, IN.

Holthausen, R. W., R. W. Leftwich, and D. Mayers, 1987, "The Effect of Large Block Transactions on Security Prices: A Cross Sectional Analysis." *Journal of Financial* Economics, 19. 237-268.

Kraus, A., and H. R. Stall, 1972, "Price Impact of Block Trading on the New York Stock Exchange," *Journal of Finance, 27, 569-588.*

Lakonishok, J., A. Shleifer, and R. W. Vishny, 1991, "Do Institutional Traders Destabilize Stock Prices? Evidence on Herding and Feedback Trading," working paper, University of Chicago.

Lo, A. W., and A. C. MacKinlay, 1990a, "When Are Contrarian Profits due to Stock Market Overreaction?," *Review of Financial Studies,* 3, 175-205.

Lo, A. W., and A. C. MacKinlay, 1990b, "An Econometric Analysis of Nonsynchronous Trading," *Journal of Econometrics,* 45, 181-211.

McConnell, J. J., and G. C. Sanger, 1987, "The Puzzle in Post-Listing Common Stock Returns." *Journal of Finance,* 42, 119-140.

Neal, R. R., 1991, "Program Trading on the NYSE: A Descriptive Analysis and Estimates of the Intra-Day Impact on Stock Returns." working paper, University of Washington.

Roll, R., 1984, "A Simple Implicit Measure of the Effective Bid-Ask Spread in an Efficient Market," *Journal of Finance,* 39, 1127-1139.

Sachs, L., 1984, *Applied Statistics* (2d ed.), Springer Verlag, New York, chap. 7

S&P 500 Directory, 1989, Published by the Standard & Poor's Corporation, McGraw-Hill, New York.

Scholes, M. S., 1972, "The Market for Securities: Substitution vs. Price Pressure and the Effect of Information on Share Prices," *Journal of Business,* 45, 179-211.

Scholes, M. S.. and J. T. Williams, 1977, "Estimating Betas from Nonsynchronous Data," *Journal of Financial Economics,* 5, 309-327.