Of Shepherds, Sheep, and the Cross-autocorrelations in Equity Returns

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We present an economic mechanism and supportive empirical evidence for the transmission of information between equity securities first documented by Lo and MacKinlay (1990). It is argued that the past returns on stocks held by informed institutional traders will be positively correlated with the contemporaneous returns on stocks held by noninstitutional uninformed traders. Evidence consistent with this hypothesis is then presented. We document that the returns on the portfolio of stocks with the highest level of institutional ownership lead the returns on portfolios of stocks with lower levels of institutional ownership. This effect persists even after firm size is controlled for and is apparent at longer lags than the size-related lag effects documented in Lo and MacKinlay (1990).

Lo and MacKinlay (1990) document a positive correlation in weekly returns on the stocks of small firms and the lagged weekly returns of large firms. They demonstrate that this lead-lag relation is a significant source of stock index autocorrelation and can partially

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explain the observed profits from contrarian portfolio strategies.[1] They further claim that, even apart from the effect of this lead-lag relation on contrarian profits, this relation is important because it indicates a complex process of information transmission between small and large firms. In this article, a possible candidate for this information transmission mechanism is proposed and supporting empirical evidence is provided.[2]

Even though the lead-lag relation was originally observed between returns on large-firm and small-firm portfolios, it is important to recognize that firm size per se may have little economic significance for information transmission across firms. It may, however, be highly correlated with some firm characteristics that are relevant. For example, firm size may proxy for the magnitude of information produced by investors; the larger the firm, the more the information produced.[3] Because the return-generating processes of large and small firms are not independent, some of the information produced about large firms will affect investor expectations regarding the returns on smaller firms. For this reason, the prices of large-firm stocks convey information regarding the prospects of smaller-firm stocks. Without market imperfections of some sort, information transmission would be instantaneous. However, if the investors in large-firm stocks face sufficiently high costs from investing in small firms and if investors in small firms must condition only on past prices, then this information will be impounded in small-firm stock prices by the small-firm investors only after observing the past stock prices of large firms, that is, only after a lag.

There are a number of theories that are consistent with lagged information transmission between classes of investors: price pressure, lagged price adjustment by market makers, noise traders, herd behavior, information set-up costs, and legal risk faced by portfolio managers.[4] While the price pressure, noise trader, and herd behav-

[1] Before Lo and MacKinlay (1990), the standard explanation for profits from contrarian trading strategies was negative serial correlation in individual stock returns. For discussion of this issue, see Jegadeesh (1990), Zarowin (1990), Fama and French (1988), Lehman (1990), Chan (1988), and DeBondt and Thaler (1985).

[2] Further documentation for the differential effect of information on the variance of returns of large- and small-firm stock is provided by Conrad, Gultekin, and Kaul (1990). They find that the volatility of large-firm returns has a significant impact on the subsequent return volatility of small firms.

[3] This differential information production effect has been long recognized in research on the "small firm effect." Arbel, Carvell, and Strebel (1983) argue that the size effect is really a "neglected" firm effect. Since small firms are not frequently followed by a sufficiently large number of analysts, they argue that the effect may simply reflect a premium to individuals who choose to obtain information about small firms. Indeed, Levy (1988) develops this segmented markets argument into a generalized version of the Capital Asset Pricing Model and shows that in such a world the size effect vanishes.

[4] For a discussion of the price pressure hypothesis, see Kyle (1985), Admati and Pfleiderer (1988),

ior hypotheses are plausible, the framework presented here is more amenable to interpretation within the context of the last two hypotheses, information set-up costs and legal restrictions surrounding the investment activity of institutional portfolio managers. Merton (1987) argues that there is a receiver or set-up cost to information processing. Paying this fixed cost is worthwhile only if the value of adding the security to the portfolio is sufficiently large. Therefore, investors will follow only a small subset of traded assets. This would imply that institutional investors who perform systematic investigations would concentrate their attention, and consequently their investments, on assets for which the volume of available information is large relative to the information set-up cost. On average, these would tend to be larger firms.

As recognized by Merton (1987), the fact that professional money managers have to satisfy "prudence" requirements affects their investment strategies. The common law "prudent man" rule governs the investment behavior of institutional portfolio managers.[5] According to this rule, portfolio managers, in their fiduciary capacity, are required to make "prudent" investments. In a court of law, prudence is evaluated not only in a portfolio context but also in the context of individual investments.[6] If an investment is deemed to be imprudent, the law requires the fiduciary to be personally liable for any losses.[7] Thus, institutional investors have the incentive to invest in only a subset of marketed assets. For want of better words, firms in this subset are called IF (institutionally favored) firms and the others IU (institutionally unfavored) firms.

If we embed this segmented market paradigm into a dynamic model of equity pricing in which investors condition their demand only on past prices [Hellwig (1982)], a lead-lag relation between IU and IF firms will emerge. The prices of IF firms will impound the information produced by informed investors. Although some of this information

and Blume (1976); for lagged price adjustment by market makers, see Chan (1993); for noise traders, see DeLong et al. (1990) and Shleifer and Summers (1990); for herd behavior, see Scharfstein and Stein (1990).

5 For evidence on the effect of the prudent man rule on the investment behavior of institutional investors, see Badrinath, Gay, and Kale (1989).

6 A case in point is the decision by the New York Court of Appeals in the matter of Bank of New York (Spitzer), 35 N.Y. 2d 512, 517, 364 N.Y.S.2d 164, 170, 323 N.E.2d 700, 704 (1974).

7 See Section 404 of ERISA for a description of the "prudent man" rule. See Section 409 of ERISA and Section 36 of the Investment Company Act of 1940 for a description of these penalties. The magnitude of these penalties can be quite large. For example, Financial Programs Inc., a mutual fund manager, was alleged to be in violation of the "prudent man" rule because it committed $21 million of the fund's assets to over-the-counter securities that were speculative, unseasoned, and in limited supply. The fund's offer of settlement, among other things, included a payment of $2.5 million to the plaintiff and the promise to refrain from performing investment advisory services to new clients for 180 days [Ratner (1978)].

will be firm specific, a portion of it may be of a general nature and, thus, may be relevant in the pricing of IU stocks. Because of market segmentation, informed investors will not be able to impound this information in the prices of IU firms. However, by observing the prices of IF stocks, investors in IU firms will find information relevant to the pricing of their shares. By trading on this information they will impound the information from the lagged prices of the IF firms into the current prices of the IU firms.

The contribution of this article is in providing evidence consistent with the above information transmission mechanism and, thus, possibly explain the economic basis for the cross-autocorrelation in equity returns observed by Lo and MacKinlay (1990). It is found that, when equity portfolios are formed on the basis of the level of institutional ownership in firms, the returns on the portfolio of firms with the highest levels of institutional ownership lead the returns of portfolios with lower levels of institutional ownership by as much as two months. On the other hand, when portfolios are size-based, the lead-lag period is generally no more than one month. The significance of the institutional ownership-based lead-lag relation persists, in monthly as well as in weekly returns, even after controlling for firm size. Interestingly, in weekly returns, when firm size is controlled for, significance is observed only at eight- and nine-week lags. This indicates that the stock price performance of firms with high institutional ownership, and not the performance of large firms, is a leading indicator of subsequent equity market performance. It is, thus, possible that the primary path for information transmission in equity markets is between returns on IF and IU firms.

The article is organized as follows. The next section presents some background on the role of institutions in equity markets and their equity demand patterns. Section 2 develops the hypothesis relating institutional investment regularities with equity price dynamics. Section 3 presents the empirical evidence on this hypothesis. Section 4 contains some concluding remarks. A suggestive rational expectations formalization of the hypothesis developed in Section 3 is presented in the Appendix.

1. Institutional Ownership: Background

In order to argue that institutional investing plays an important role in determining the dynamics of equity prices, we first establish the importance of institutional investors in equity markets. We then document the patterns in their equity investment choices to illustrate the role of "prudence" in these decisions. The insights gained from these investigations enable us to construct our hypothesis regarding the effect of institutional trading on equity price dynamics, in particular, on cross-autocorrelations in equity returns.

1.1 Data sources

The sample used in these investigations consists of all firms on the NYSE and AMEX for which complete monthly and daily returns series are available on the Center for Research in Security Prices (CRSP) tapes for the period 1981–1988. This period was chosen because of limited data availability on institutional ownership. Our source has these data only from the end of year 1980.[8] The data on institutional ownership are obtained from Spectrum 3/Spectrum 4 Institutional 13(f) Common Stock Holdings and Transactions provided by CDA Investment Technologies, Inc., for the years 1980, 1982, 1984, 1986, and 1988.[9] The level of institutional ownership in these data is as of the end of the year for each of these years. Equity returns are obtained from CRSP (NYSE/ASE) tapes, and data on other firm characteristics are from COMPUSTAT tapes.

1.2 Institutional equity portfolio characteristics

To determine whether institutional investors have different considerations in choosing their equity investments than do individual investors, we first investigate some characteristics of firms that are in institutional equity portfolios. The choice of firm characteristics is motivated by the study on patterns of institutional ownership by Badrinath, Gay, and Kale (1989) (BGK). These authors conjectured that, because of the "prudent man" rule and the penalties associated with it, institutional investors give significant consideration to firm characteristics in addition to the usual risk and return criteria. In other words, institutional portfolio managers choose their investments such that they have a safety net in case any of the investments goes sour and the manager is required to defend his or her investment decision in a court of law. In order to validate this conjecture, these authors investigated the relation between various firm characteristics and the level of institutional ownership. Our choice of firm-specific variables and their definitions are identical to those in the BGK study. The main difference is that our sample contains institutional investment and firm-specific data for five years instead of for the one-year (1985) sample in the BGK study.

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[8] The lead-lag relation on the basis of firm size documented later for this shorter period is, however, apparent for the longer period 1963–1988.

[9] These data are quite expensive and, therefore, five years' data at two-year intervals was purchased. Given the findings in this article, it is unlikely that, had the tests been conducted on all the nine years, the results would have been significantly different.

Table 1 presents median values of several characteristics of firms in institutional portfolios. For each year in our sample, firms are arranged according to the level of institutional ownership, defined as the fraction of outstanding shares of the firm owned by institutions, and divided into five quintile portfolios. Portfolio 1 contains the 20 percent of firms with the lowest levels of institutional ownership, and portfolio 5 the 20 percent with the highest. Values for institutional ownership levels presented in the second column of Table 1 highlight the importance of institutions in equity markets. On average, institutions owned between 17.7 and 29.6 percent of the equity of sample firms during the period. It is also noteworthy that their level of ownership shows an upward trend over the period.

Median values of firm characteristics presented in the table highlight some of the patterns in the determination of institutional equity investment decisions. Characteristics of firms in institutional portfolios in our sample are generally consistent with the findings in the BGK study. Firm size and number of years of listing are higher for firms with higher institutional ownership in all of the five years. Further, as is to be expected, the median firm size for the entire sample increases over the years. On the other hand, median firm age, which should increase over the years, if for no other reason than the passage of time, does not show any particular pattern. This lack of pattern seems to be owing to the inclusion of younger firms in the lowest ownership portfolio over the years. As Table 1 indicates, for the first three years, median values for firm age for portfolio 1 are approximately 13 years, whereas for the last two years, 1986 and 1988, the median firm ages are 7.125 and 3.750, respectively. Level of institutional ownership seems to be positively related to share turnover and beta. Additionally, while the median values for beta do not show a monotonic trend over the years, the median value for the sample for share turnover increased until 1986 to 0.516 and then decreased to 0.363 for 1988. Firms with higher institutional ownership have lower values for standard deviation of returns for all years. While BGK did not find a significant relation for dividend yield or leverage, firms with higher institutional ownership in our sample tend to have lower median values for leverage and higher median values for dividend yields. Median dividend yield for the entire sample has been steadily decreasing over the years; from 3.4 percent in 1980 to 1.9 percent in 1988.

The data, therefore, indicate that the level of institutional interest in a stock may depend upon other factors in addition to the traditional risk and return characteristics of the stock. In fact, the data clearly show that institutions invest disproportionately more in the stocks of firms that meet obvious prudence requirements.

Table 1
Median values of characteristics of firms in institutional portfolios by levels of institutional ownership

Quintile number	Fraction owned by institutions	Debt/total assets	Annual trading volume, 10^6	Dividend yield	Annual share turnover	Firm size (total assets), 10^6	Jensen's performance measure	Beta	Standard deviation of stock returns	Years exchange listed
					A: For 1980					
1	0.017	0.233	1.274	0.026	0.364	372.3	−0.024	0.969	0.064	13.500
2	0.074	0.225	1.501	0.033	0.339	640.4	−0.073	0.897	0.058	12.750
3	0.176	0.208	2.348	0.034	0.352	1,189.1	0.031	0.887	0.053	13.750
4	0.326	0.278	5.163	0.036	0.386	3,465.2	0.018	0.919	0.049	16.580
5	0.524	0.128	9.124	0.038	0.393	8,078.3	0.014	0.853	0.045	18.580
All	0.177	0.187	2.830	0.034	0.370	1,543.9	−0.006	0.897	0.052	15.540
					B: For 1982					
1	0.023	0.205	0.857	0.018	0.242	319.7	0.250	0.702	0.062	12.790
2	0.093	0.221	1.411	0.023	0.294	634.5	0.226	0.729	0.056	14.670
3	0.208	0.211	2.883	0.030	0.385	1,431.2	0.207	0.816	0.055	14.580
4	0.356	0.205	6.354	0.033	0.412	4,377.7	0.276	0.943	0.051	18.330
5	0.541	0.122	13.032	0.035	0.509	9,223.8	0.288	0.977	0.048	20.500
All	0.209	0.185	3.040	0.029	0.376	1,618.7	0.249	0.858	0.053	15.750
					C: For 1984					
1	0.043	0.192	0.827	0.007	0.190	352.6	−0.159	0.783	0.051	14.090
2	0.131	0.199	1.920	0.018	0.308	794.3	−0.113	0.751	0.048	15.080
3	0.252	0.171	3.329	0.028	0.378	1,446.9	−0.022	0.792	0.045	15.670
4	0.395	0.168	7.340	0.030	0.449	4,270.8	−0.028	1.019	0.041	19.250
5	0.577	0.125	17.740	0.032	0.608	8,887.6	−0.035	1.193	0.043	22.500
All	0.252	0.169	3.740	0.026	0.389	1,753.9	−0.060	0.923	0.044	16.580

Table 1 presents cross-sectional institutional ownership and firm attributes for the years 1980, 1982, 1984, 1986, and 1988. In each year firms are divided into five quintiles based on the level of institutional ownership.

Table 1
Continued

Quintile number	Fraction owned by institutions	Debt/total assets	Annual trading volume, 10^6	Dividend yield	Annual share turnover	Firm size (total assets), 10^6	Jensen's performance measure	Beta	Standard deviation of stock returns	Years exchange listed
					D: For 1986					
1	0.048	0.154	1.294	0.000	0.236	344.0	−0.013	0.554	0.061	7.125
2	0.156	0.202	2.726	0.008	0.414	733.8	−0.031	0.695	0.053	15.170
3	0.297	0.226	5.220	0.022	0.513	1,593.0	0.085	0.767	0.044	15.960
4	0.444	0.187	14.035	0.024	0.628	5,298.2	−0.025	0.895	0.042	22.170
5	0.619	0.159	26.227	0.023	0.802	10,899.5	0.066	1.070	0.042	22.420
All	0.296	0.187	5.781	0.018	0.516	1,965.4	0.020	0.836	0.046	17.250
					E: For 1988					
1	0.039	0.187	1.269	0.000	0.162	388.0	0.068	0.406	0.057	3.750
2	0.145	0.223	1.849	0.008	0.259	596.3	0.091	0.450	0.051	8.500
3	0.283	0.247	3.943	0.018	0.338	1,280.7	0.110	0.528	0.042	16.330
4	0.446	0.189	13.550	0.026	0.487	4,764.8	0.081	0.743	0.039	20.000
5	0.624	0.163	24.680	0.025	0.640	10,386.5	0.003	0.995	0.039	23.500
All	0.282	0.203	4.828	0.019	0.363	1,711.3	0.071	0.649	0.042	16.750

1.3 Firm size and institutional ownership

The importance of firm size in equity price dynamics has already been established by previous researchers [for example, by Lo and MacKinlay (1990)]. Our earlier analysis highlights the positive correlation ($\rho = .594$) between the level of institutional ownership and firm size. This high positive correlation naturally leads to the question of whether the size effects are subsumed by institutional ownership effects or vice versa. To better focus on the role of institutional investors, we divide our sample of firms in the following manner. In each of the five years, the sample of firms is divided into five approximately equal portfolios on the basis of either firm size or level of institutional ownership, and these portfolios are adjusted every year in the case of firm size and every two years in the case of institutional ownership. In addition, because these two variables are highly positively correlated, portfolios are also formed on the basis of firm size keeping institutional ownership approximately constant across portfolios and on the basis of institutional ownership controlled for size.

More specifically, the procedures used in Reinganum (1981), Basu (1983), and Cook and Rozeff (1984) are employed. To segment the sample by size while controlling institutional ownership, firms are first ranked according to the level of institutional ownership. On the basis of this ranking, they are divided into five portfolios, where the first portfolio consists of firms with the lowest levels of institutional ownership and the fifth with the highest. Using this ranking, the firms within each of these five institutional ownership portfolios are ranked on the basis of firm size. Then, each of the institutional portfolios is split into five size-based portfolios. Firms from the lowest firm size portfolio from each of the five institutional ownership portfolios are then collected into one portfolio (portfolio 1). Firms from the next lowest size portfolios in each of the institutional ownership portfolios are grouped into the next portfolio (portfolio 2), and so on. This method ensures that the five portfolios so formed are well dispersed according to levels of institutional ownership and, at the same time, the size of firms in portfolio 1 is considerably lower than that in portfolio 2 and so on. Thus, these portfolios are different in terms of firm size but similar in terms of institutional ownership. A similar procedure was utilized to form five portfolios that had essentially similar firm size but varied in institutional ownership.

The efficacy of this procedure is apparent from the median values reported in Table 2. Panel A of Table 2 reports the median firm size in millions of dollars for each of the five portfolios formed by each of the four methods. When portfolios are formed on the basis of firm size, the median firm size in the lowest quintile is approximately \$170 million and that in the highest quintile is over \$20 billion. Sim-

Table 2
Median firm size and institutional ownership in portfolios

Portfolio constructed by	Size	Institutional ownership	Size controlled for ownership	Ownership controlled for size
		A: Median firm size		
Portfolio 1	170.6	447.6	217.8	1,553.2
Portfolio 2	633.7	629.9	692.1	1,582.2
Portfolio 3	1,656.9	1,356.6	1,361.9	1,599.1
Portfolio 4	5,091.2	3,888.3	3,306.0	1,709.6
Portfolio 5	20,814.5	9,079.1	17,302.1	1,823.1
		B: Median institutional ownership		
Portfolio 1	0.068	0.021	0.203	0.025
Portfolio 2	0.129	0.098	0.209	0.130
Portfolio 3	0.225	0.214	0.215	0.231
Portfolio 4	0.337	0.363	0.216	0.340
Portfolio 5	0.438	0.562	0.220	0.520

In Table 2, quintile portfolios are constructed in four different ways: (i) by firm size measured as market value of equity, (ii) level of institutional ownership measured as the fraction of outstanding shares owned by institutions, (iii) by firm size controlled for institutional ownership, and (iv) by institutional ownership controlled for firm size. Firm size is in millions of dollars. Since portfolios are adjusted every year for firm size and every two years for institutional ownership, the number of firms in each portfolio varies over time in the range 314 to 413. Portfolio 1 is the smallest quintile and portfolio 5 is the largest quintile. For the entire sample, the median size is $1,581.7 million and the median level of institutional ownership is 0.198.

ilar patterns are apparent for median firm sizes for portfolios formed on the basis of institutional ownership reported in the second column of panel A. These numbers are consistent with the high positive correlation between firm size and institutional ownership mentioned earlier. The last column in the panel reports median values for firm size for portfolios formed on the basis of institutional ownership with firm size controlled as per the procedure outlined above. The constancy of median firm value across portfolios highlights the efficacy of the procedure. Panel B of the table reports levels of institutional ownership in each of the portfolios. The fourth column reports levels of institutional ownership in portfolios after controlling for firm size. Despite the similarity in the dispersion of firm size in these portfolios (column 4 of panel A), median institutional ownership ranges from as little as 2.5 percent in the lowest quintile to 52 percent in the highest quintile. Similarly, the efficacy of the procedure for forming portfolios on the basis of firm size after controlling for institutional ownership is evidenced by approximately similar median values for institutional ownership among portfolios (column 3 in panel B) and different firm sizes across portfolios (column 3 in panel A).

1.4 Stability of institutional ownership levels over time

As documented above, institutions invest disproportionately in assets meeting prudence requirements. This raises the question of whether these institutions invest in a subset of these prudent assets which is stable over time or whether they turn over their portfolios over time so as to hold a large number of different assets within the prudent category. This issue of stability is investigated for each of the four sample partitions in Tables 3, 4, 5, and 6, respectively.

Each of these tables contains five panels; the first four depict ownership stability for consecutive periods, such as from 1980 to 1982, and the fifth panel for the nine-year period 1980–1988. In each panel we present the transition frequencies between portfolios. For example, Table 3 does this for portfolios formed on the basis of firm size. The number 0.68 in the first row of column 1 in panel A implies that 68 percent of the firms that were in portfolio 1, the one with the smallest sized firms, in 1980 were again listed in portfolio 1 in 1982. The number 0.14 in the fourth row of column 5 in panel D implies that 14 percent of the firms that were in portfolio 4 in 1986 moved up to portfolio 5 in the 1988 classification.

From Table 3 it is apparent that the majority of firms retain their portfolio classification over the years. Firms in portfolio 5 are the most likely to maintain their portfolio classification. In fact, at least 85 percent of the firms in portfolio 5 maintained their classification in consecutive periods. For portfolio 1 firms this number is lower, at 68 percent. The maximum movement within classifications seems to be in portfolios 2 and 3. For the entire period 1980–1988, the 82 percent of the firms that were in portfolio 5 in 1980 were also in the same portfolio in 1988. These values are much smaller for the other four portfolios. Table 4 presents similar values for portfolios formed on the basis of the level of institutional ownership. The overall inferences are similar to those for portfolios formed on the basis of firm size. The movement of firms among portfolios is, however, significantly more common. For example, in size-based portfolios, no firm that was classified in portfolio 1 in 1980 was in portfolio 5 in 1988 (first row in column 5 of panel E in Table 3). For ownership-based portfolios, on the other hand, 8 percent of the firms moved from portfolio 1 to portfolio 5 in the nine years. Tables 5 and 6 provide these transition frequencies when portfolios are formed on the basis of firm size controlled for ownership and institutional ownership controlled for size, respectively. Inferences regarding stability of institutional ownership over time are similar to the earlier portfolio classifications. Finally, the values in the tables indicate that, with the exception of portfolios formed on the basis of firm size controlled for ownership (Table 5), a firm is more likely to move to a higher ranked portfolio than to move to a lower one. In Tables 3, 4, and 6 this is true not only in the overall sample (panels E but, almost always, also for consecutive year samples. For portfolios formed on the basis of firm size controlled for ownership, this is true only for the overall period 1980–1988.

Table 3
Intertemporal stability in institutional ownership over the period 1980–1988 in portfolios formed on the basis of firm size

	1	2	3	4	5
			A: 1980–1982		
1	0.68	0.28	0.04	0.00	0.00
2	0.11	0.56	0.30	0.03	0.00
3	0.01	0.16	0.54	0.29	0.00
4	0.00	0.02	0.16	0.61	0.21
5	0.00	0.00	0.00	0.14	0.85
			B: 1982–1984		
1	0.71	0.26	0.01	0.00	0.01
2	0.10	0.61	0.28	0.01	0.00
3	0.02	0.13	0.64	0.20	0.00
4	0.00	0.01	0.11	0.77	0.10
5	0.00	0.00	0.00	0.06	0.93
			C: 1984–1986		
1	0.82	0.16	0.02	0.01	0.00
2	0.11	0.60	0.28	0.01	0.00
3	0.01	0.13	0.64	0.22	0.00
4	0.00	0.02	0.10	0.73	0.15
5	0.00	0.00	0.01	0.10	0.89
			D: 1986–1988		
1	0.85	0.13	0.02	0.00	0.00
2	0.16	0.65	0.19	0.00	0.00
3	0.01	0.16	0.66	0.17	0.00
4	0.00	0.01	0.08	0.73	0.14
5	0.00	0.00	0.00	0.07	0.93
			E: Overall: 1980–1988		
1	0.42	0.30	0.22	0.06	0.00
2	0.14	0.30	0.36	0.17	0.02
3	0.05	0.12	0.32	0.42	0.09
4	0.01	0.02	0.10	0.43	0.43
5	0.00	0.02	0.02	0.15	0.82

In Table 3, five equal portfolios are formed on the basis of firm size in each of the five years 1980, 1982, 1984, 1986, and 1988. Since portfolios are adjusted every year for firm size and every two years for institutional ownership, the number of firms in each portfolio varies over time in the range 314 to 413. Portfolio 1 contains the smallest firms and portfolio 5 the largest. A value in the table represents the fraction of firms that moved from the column portfolio to the row portfolio in the following year. For example, the fraction 0.28 in row 1 and column 2 of panel A implies that 28 percent of the firms that were in portfolio 1 in 1980 were classified in portfolio 2 in 1982.

2. Institutional Ownership and Cross-autocorrelations: Hypothesis

The above investigations into institutional ownership patterns yield some insights that can provide a rationale for an institutional role in equity price dynamics. The finding above is that institutions invest primarily in a restricted subset of stocks. If this fact is conjoined with the assumption that institutions are disproportionately more likely to engage in information-gathering activities, then it is possible to construct a theory that explains cross-autocorrelations in equity returns.

Table 4
Intertemporal stability in institutional ownership over the period 1980–1988 in portfolios formed on the basis of institutional ownership

	1	2	3	4	5
			A: 1980–1982		
1	0.58	0.30	0.09	0.03	0.00
2	0.16	0.52	0.26	0.05	0.01
3	0.02	0.19	0.52	0.24	0.04
4	0.00	0.01	0.18	0.56	0.25
5	0.00	0.00	0.01	0.20	0.78
			B: 1982–1984		
1	0.59	0.34	0.06	0.01	0.01
2	0.17	0.47	0.30	0.06	0.01
3	0.02	0.15	0.51	0.29	0.02
4	0.01	0.02	0.17	0.57	0.23
5	0.01	0.00	0.03	0.14	0.82
			C: 1984–1986		
1	0.61	0.30	0.08	0.00	0.00
2	0.10	0.50	0.31	0.08	0.01
3	0.02	0.15	0.50	0.30	0.03
4	0.01	0.02	0.12	0.57	0.28
5	0.01	0.00	0.02	0.17	0.80
			D: 1986–1988		
1	0.57	0.38	0.03	0.00	0.01
2	0.07	0.51	0.36	0.06	0.00
3	0.02	0.11	0.53	0.30	0.04
4	0.00	0.01	0.11	0.63	0.23
5	0.00	0.01	0.01	0.13	0.84
			E: Overall: 1980–1988		
1	0.21	0.29	0.27	0.16	0.08
2	0.10	0.21	0.39	0.22	0.09
3	0.06	0.09	0.24	0.46	0.14
4	0.02	0.02	0.09	0.42	0.44
5	0.01	0.02	0.03	0.20	0.75

In Table 4, five equal portfolios are formed on the basis of institutional ownership in each of the five years 1980, 1982, 1984, 1986, and 1988. Since portfolios are adjusted every year for firm size and every two years for institutional ownership, the number of firms in each portfolio varies over time in the range 314 to 413. Portfolio 1 contains firms with the lowest level of institutional ownership and portfolio 5 the highest. A value in the table represents the fraction of firms that moved from the column portfolio to the row portfolio in the following year. For example, the fraction 0.30 in row 1 and column 2 of panel A implies that 30 percent of the firms that were in portfolio 1 in 1980 were classified in portfolio 2 in 1982.

The intuition underlying the theory is as follows. Informed institutional investors investigate and invest in the stocks of only IF (institutionally favored) firms. However, because the prospects of IF and IU (institutionally unfavored) firms are positively correlated, their investigation of IF firms produces information also on IU firms. Prudence restrictions prevent this information from being immediately impounded in IU firm stock prices. The share prices of IF firms that reflect the information of the informed, however, are observable to the uninformed and provide some information on the future prospects

Table 5
Intertemporal stability in institutional ownership over the period 1980–1988 in portfolios formed on the basis of firm size after controlling for institutional ownership

	1	2	3	4	5
			A: 1980–1982		
1	0.61	0.28	0.09	0.02	0.00
2	0.25	0.36	0.31	0.08	0.01
3	0.10	0.23	0.38	0.25	0.04
4	0.02	0.08	0.23	0.44	0.23
5	0.00	0.01	0.02	0.21	0.76
			B: 1982–1984		
1	0.60	0.26	0.09	0.02	0.02
2	0.26	0.39	0.24	0.10	0.01
3	0.07	0.23	0.42	0.26	0.03
4	0.02	0.07	0.25	0.49	0.17
5	0.00	0.03	0.04	0.16	0.77
			C: 1984–1986		
1	0.64	0.31	0.05	0.01	0.00
2	0.28	0.41	0.25	0.05	0.01
3	0.09	0.21	0.45	0.23	0.01
4	0.02	0.08	0.23	0.52	0.15
5	0.00	0.01	0.03	0.20	0.76
			D: 1986–1988		
1	0.73	0.20	0.06	0.01	0.00
2	0.26	0.48	0.21	0.04	0.00
3	0.06	0.28	0.43	0.23	0.00
4	0.01	0.06	0.27	0.50	0.18
5	0.00	0.00	0.01	0.18	0.80
			E: Overall: 1980–1988		
1	0.43	0.29	0.17	0.09	0.02
2	0.20	0.32	0.25	0.19	0.04
3	0.12	0.24	0.24	0.27	0.12
4	0.08	0.10	0.26	0.27	0.29
5	0.01	0.04	0.08	0.24	0.63

In Table 5, five equal portfolios are formed on the basis of firm size in each of the five years 1980, 1982, 1984, 1986, and 1988. Since portfolios are adjutsed every year for firm size and every two years for institutional ownership, the number of firms in each poirtfolio varies over time in the range 314 to 413. Portfolio 1 contains the smallest firms and portfolio 5 the largest. A value in the table represents the fraction of firms that moved from the column portfolio to the row portfolio in the following year. For example, the fraction 0.28 in row 1 and column 2 of panel A implies that 28 percent of the firms that were in portfolio 1 in 1980 were classified in portfolio 2 in 1982.

of IU firms. Therefore, if the uninformed trade on this information, they will drive up (down) the price of IU firm shares *after* observing favorable (unfavorable) price changes in IF firm shares.

In the Appendix, we provide a formal model of the above theory. This model is formulated within the multiperiod expectations framework of Hellwig (1982). In the model, there are two risky assets trading on the market, an IF asset and an IU asset, in an infinite sequence of periods. There is also a riskless asset with constant return per period. There are two investors, informed (institutions) and uninformed. The informed can trade in only the IF asset, whereas the uninformed can

Table 6
Intertemporal stability in institutional ownership over the period 1980–1988 in portfolios formed on the basis of institutional ownership after controlling for firm size

	1	2	3	4	5
			A: 1980–1982		
1	0.65	0.21	0.05	0.06	0.02
2	0.20	0.41	0.27	0.10	0.02
3	0.04	0.24	0.39	0.26	0.07
4	0.01	0.10	0.24	0.39	0.25
5	0.00	0.02	0.05	0.22	0.70
			B: 1982–1984		
1	0.61	0.21	0.11	0.06	0.01
2	0.15	0.41	0.26	0.14	0.03
3	0.06	0.24	0.36	0.26	0.09
4	0.02	0.08	0.28	0.35	0.26
5	0.03	0.03	0.06	0.23	0.65
			C: 1984–1986		
1	0.58	0.29	0.07	0.04	0.01
2	0.10	0.44	0.31	0.12	0.03
3	0.02	0.17	0.38	0.32	0.11
4	0.02	0.06	0.20	0.40	0.31
5	0.01	0.01	0.09	0.24	0.65
			D: 1986–1988		
1	0.58	0.32	0.07	0.02	0.01
2	0.07	0.49	0.30	0.11	0.02
3	0.02	0.12	0.49	0.30	0.06
4	0.00	0.03	0.18	0.48	0.30
5	0.00	0.03	0.05	0.23	0.69
			E: Overall: 1980–1988		
1	0.28	0.31	0.17	0.16	0.07
2	0.10	0.21	0.33	0.19	0.17
3	0.03	0.16	0.26	0.32	0.23
4	0.02	0.13	0.22	0.29	0.33
5	0.03	0.05	0.11	0.32	0.48

In Table 6, five equal portfolios are formed on the basis of institutional ownership in each of the five years 1980, 1982, 1984, 1986, and 1988. Since portfolios are adjusted every year for firm size and every two years for institutional ownership, the number of firms in each portfolio varies over time in the range 314 to 413. Portfolio 1 contains firms with the lowest level of institutional ownership and portfolio 5 the highest. A value in the table represents the fraction of firms that moved from the column portfolio to the row portfolio in the following year. For example, the fraction 0.21 in row 1 and column 2 of panel A implies that 21 percent of the firms that were in portfolio 1 in 1980 were classified in portfolio 2 in 1982.

trade in the IF and the IU asset. The restriction that the informed trade in only the IF asset is a stylized way to capture the differential investment costs postulated by Merton (1987) and/or restrictions imposed by the prudent man rule.

The demand for risky assets in both markets, as in Hellwig (1982), is determined by the myopic mean-variance criterion. Using this criterion, it is possible to derive demand equations for both informed and uninformed investors. At each date, investors in both markets observe the entire dividend histories of both assets. However, as in

Hellwig (1982), at that time they can condition their actions on the price path of the assets only up to the previous period; that is, they cannot condition their current demand on current prices. Informed investors, however, observe signals that allow them to better forecast the innovations in the future dividends. Because only the informed investors in the IF market receive the signal, this information will first be impounded in prices in the IF market. In the IU market, this information will be partially impounded after the uninformed traders observe prices in the IF market. In the Appendix, we demonstrate that in this setting there exists a rational expectations equilibrium in which IU asset prices depend linearly on previous prices of IF assets. In fact, the functional form of this equilibrium pricing relation is consistent with the simple lead-lag white noise statistical model of Lo and MacKinlay (1990, Equation 19) in which a common factor is impounded into the return of different securities at different lags.

3. Institutional Ownership and Cross-autocorrelations: Evidence

In this section, our hypothesis regarding institutional ownership and equity price dynamics is tested. Cross-autocorrelations in equity market returns are documented between portfolios formed on the basis of both firm size and the level of institutional ownership. It is first shown that the positive correlation between current weekly returns on smaller firms and the lagged returns on larger firms is apparent also in monthly returns. One advantage of using monthly returns rather than shorter-horizon returns is that the positive cross-autocorrelation generated by different nontrading probabilities for different portfolio groups is virtually eliminated. In fact, the magnitude of the autocorrelation generated by nonsynchronous trading, computed using the estimator in Lo and MacKinlay (1990, Equation 32), is of the order of 10^{-8}. For facilitation of comparison with earlier studies, results are reported also for weekly return series. The inferences regarding lagged relations are identical to those obtained using monthly data.

The main finding of this section, however, is that the leading indicator of future stock price performance may not be the portfolio of large firms but the portfolio of firms that have the highest level of institutional ownership. It is documented that the returns on this portfolio lead the returns on the portfolios with lower institutional ownership by as much as two months in both monthly and weekly data.

3.1 Cross-autocorrelations in monthly equity returns

Monthly returns for the above portfolios were obtained from CRSP, and extensive diagnostic tests were conducted to investigate the properties of these monthly portfolio return series. For all the portfolio return series used in the subsequent analysis, the Kolmogorov-Smirnov D statistic did not reject the null hypothesis of normality. First-lag autocorrelations were not significant when a standard error approximation of $2/\sqrt{T}$ was used. No significant autocorrelations were detected when these tests were repeated for 6-, 12-, 18-, and 24-month lags.[10] Autocorrelation patterns for the absolute return series were also examined. Variance dependence would indicate that small (large) price changes are followed by small (large) price changes of either sign; therefore, the absolute return series should display significant lags even if no autocorrelation is observed in the return series. No such behavior was evident. Similarly, autocorrelation was absent in squared return series.[11] Finally, the asymptotically locally most powerful test for the existence of ARCH effects given in Engle (1982, pp. 1000–1001) did not reject the null that error terms are not conditionally heteroskedastic.[12] Therefore, consistent with Akgiray (1989), the findings indicate that the monthly portfolio return series exhibit little, if any, serial dependence.

Table 7 presents the cross-autocorrelation matrices for the portfolio return series. There are three matrices for each of the four portfolio construction methods. The top matrix is the contemporaneous correlation matrix, the middle one is for correlations between contemporaneous returns and first lags, and the bottom matrix presents correlations between contemporaneous and second lag returns. As is to be expected, the correlation coefficients in the top matrices in all four panels are very high, implying that portfolio returns are highly correlated. The correlation coefficients in the middle matrices, in general, indicate the existence of cross-autocorrelations and are consistent with those documented by Lo and MacKinlay (1990) for weekly portfolio returns. The asymmetry between the correlations of lagged highest quintile (portfolio 5) returns with the lower quintile contemporaneous returns versus the correlations of the lagged returns of the lower quintile with the contemporaneous returns of the highest quintile is striking. For example, the correlation between $R_{1,t}$ and $R_{5,t-1}$ is .251 in panel A, whereas the correlation between $R_{5,t}$ and $R_{1,t-1}$ is only .113. This pattern of asymmetry, apparent in all of the middle matrices of four panels, is indicative of the lead-lag relations in monthly equity re-

[10] This approximation is the 2 standard error approximation where $1/\sqrt{T}$ is the asymptotic standard deviation of the autocorrelation coefficient. This test is valid only under the null hypothesis of no autocorrelation in the true process.

[11] This analysis was replicated for residuals from an AR1 process with virtually identical results.

[12] In fact, the critical range for the $\chi^2(1)$ test statistic was 0.004 (left tail) to 3.84 (right tail). The computed statistic values were in the range 0.2 to 0.4.

Table 7
Cross-autocorrelations in equity returns of NYSE/AMEX firms during the period 1980–1988

	$R_{1,t}$	$R_{2,t}$	$R_{3,t}$	$R_{4,t}$	$R_{5,t}$	$R_{1,t}$	$R_{2,t}$	$R_{3,t}$	$R_{4,t}$	$R_{5,t}$
	A: By firm size					B: By institutional ownership				
$R_{1,t}$	1.000	.946	.904	.857	.779	1.000	.960	.935	.898	.859
$R_{2,t}$	.946	1.000	.976	.946	.886	.960	1.000	.975	.952	.919
$R_{3,t}$	.904	.976	1.000	.978	.926	.935	.975	1.000	.982	.960
$R_{4,t}$	.857	.946	.978	1.000	.968	.898	.952	.982	1.000	.986
$R_{5,t}$	.779	.886	.926	.968	1.000	.859	.919	.960	.986	1.000
$R_{1,t-1}$	.308	.259	.210	.143	.113	.213	.226	.178	.152	.123
$R_{2,t-1}$	.317	.268	.209	.146	.107	.255	.272	.213	.188	.161
$R_{3,t-1}$	.305	.261	.191	.132	.088	.247	.256	.190	.169	.138
$R_{4,t-1}$	.299	.267	.199	.145	.098	.261	.264	.207	.182	.153
$R_{5,t-1}$	.251	.226	.160	.116	.065	.262	.262	.207	.185	.157
$R_{1,t-2}$	.101	.015	−.019	−.086	−.106	.078	.051	−.018	−.073	−.116
$R_{2,t-2}$	.131	.038	.008	−.057	−.078	.109	.082	.018	−.046	−.083
$R_{3,t-2}$	.132	.039	.014	−.045	−.055	.094	.066	.007	−.060	−.087
$R_{4,t-2}$	.133	.042	.022	−.036	−.043	.116	.090	.031	−.036	−.060
$R_{5,t-2}$	.096	.015	.013	−.042	−.042	.119	.091	.033	−.037	−.062
	C: By firm size controlled for institutional ownership					D: By institutional ownership controlled for firm size				
$R_{1,t}$	1.000	.967	.942	.916	.846	1.000	.969	.957	.944	.927
$R_{2,t}$	.967	1.000	.982	.958	.901	.969	1.000	.982	.976	.961
$R_{3,t}$	.942	.982	1.000	.979	.939	.957	.982	1.000	.989	.981
$R_{4,t}$	.916	.958	.979	1.000	.971	.944	.976	.989	1.000	.990
$R_{5,t}$	.846	.901	.939	.971	1.000	.927	.961	.981	.900	1.000
$R_{1,t-1}$	.315	.259	.212	.176	.149	.182	.159	.181	.184	.202
$R_{2,t-1}$	.312	.252	.198	.163	.126	.196	.168	.189	.189	.209
$R_{3,t-1}$	.307	.255	.197	.163	.123	.210	.178	.201	.203	.222
$R_{4,t-1}$	.279	.232	.183	.145	.109	.230	.199	.222	.219	.240
$R_{5,t-1}$	.237	.193	.147	.112	.078	.250	.219	.241	.236	.255
$R_{1,t-2}$	.055	.016	−.016	−.032	−.041	.063	.030	.007	−.013	−.039
$R_{2,t-2}$	.068	.023	−.002	−.013	−.022	.047	.016	−.012	−.033	−.060
$R_{3,t-2}$	.078	.033	.013	.001	−.002	.067	.036	.008	−.010	−.039
$R_{4,t-2}$	.055	.013	−.006	−.004	−.019	.083	.049	.016	−.004	−.033
$R_{5,t-2}$	.047	.008	−.006	−.008	−.011	.088	.056	.023	.006	−.023

In Table 7, four schemes are used to divide the sample of firms into five approximately equal portfolios: (A) by size measured as market value of outstanding equity, (B) by level of institutional ownership, (C) by firm size controlled for institutional ownership, and (D) by institutional ownership controlled for firm size. Portfolio 1 is always the lowest quintile portfolio and portfolio 5 the highest. Since the portfolio is adjusted every year in the case of size and every two years in the case of institutional ownership, the number of firms in a portfolio varies over the period in the range 314–413.

turns. To a lesser but still noticeable extent, the asymmetry exists even in the bottom matrices, which report correlations at two-month lags.

To investigate lead-lag relations in equity returns further we estimate the following regression on portfolios formed by the four methods:

$$R_{s,t} = \alpha + \beta_0 R_{L,t} + \beta_{-1} R_{L,t-1} + \beta_{-2} R_{L,t-2} + \beta_{-3} R_{L,t-3} + \beta_{-4} R_{L,t-4} + \tilde{\varepsilon}_t \quad (1)$$

where $R_{s,t}$ is the excess (over risk-free rate) return of the lower quintiles of firms (i.e., firms in one of portfolios 1 through 4) and $R_{L,t}$ is the contemporaneous excess return on the highest quintile of firms (i.e., portfolio 5). $R_{L,t-i}$ and $R_{s,t-i}$ are the excess return i months earlier on portfolio 5 and the lower quintiles, respectively.

The null hypothesis is that, except for the coefficient on the contemporaneous return (β_0), all other coefficients should be zero. The hypothesis presented in the earlier section predicts a positive relation between lagged returns of IF firms and contemporaneous returns of IU firms. The regression model in Equation (1) tests for these effects, and the prediction is that one or more of the coefficients on lagged returns would be positive.

Table 8 presents the results from estimating Equation (1) on portfolios formed on the basis of firm size (panel A) and firm size controlled for institutional ownership (panel B). The coefficient of the one-month lagged return on portfolio 5 is significant for all of the four portfolios in panel A. Thus, the positive cross-autocorrelation documented by Lo and MacKinlay (1990) for weekly returns is evident also in monthly returns. The magnitude of this coefficient decreases as the size of the firms in the portfolio increases, .217 (t = 3.37) for portfolio 1 and .051 (t = 2.15) for portfolio 4. Thus, it seems that the impact of lagged returns is inversely related to the size of the firm. Second, the coefficients for the contemporaneous excess returns on the largest portfolio β_0 are positive, significant, and close to 1 for each of the four portfolios, indicating that the portfolio of largest firms captures the systematic risk adequately. Panel B reports the results from estimating Equation (1) on returns of portfolios that vary by firm size but where institutional ownership is held approximately constant. In this case, while the inferences are not dramatically different, the following two observations can be made. First, the coefficient of β_{-1} is not significantly different from zero for portfolio 4 and the magnitudes of the estimated β_{-1} coefficients seem to be lower than those in panel A.

Panel A of Table 9 presents the result from estimating Equation (1) on returns of portfolios formed on the basis of institutional ownership. The β_{-1} coefficients are significantly greater than zero for portfolios 1, 2, and 4. Additionally, the β_{-2} coefficients, representing the relation of returns on low institutional investment portfolios with returns on the highest institutional ownership portfolio two months ago, is also positive for all four portfolios and is significant at conventional levels for portfolios 1, 2, and 3. Panel B of Table 9 presents results from estimating Equation (1) on returns of portfolios formed on the basis of institutional ownership with firm size held approximately equal across the five portfolios. The β_{-1} coefficients are negative for all the four portfolios and are significantly different from zero for two.

Table 8
Returns on the portfolio of largest firms as predictors for returns on portfolios of smaller firms

Portfolio	α	β_0	β_{-1}	β_{-2}	β_{-3}	β_{-4}	Adj. R^2
			A: Portfolios by firm size				
1	−.005	0.923	0.217	0.141	0.047	−0.054	.67
	(−1.61)	(14.28)*	(3.37)*	(2.19)*	(0.73)	(−0.82)	
2	−0.005	0.945	0.170	0.048	0.004	−0.024	.82
	(−2.39)*	(21.83)*	(3.94)*	(1.12)	(0.09)	(−0.56)	
3	−0.004	1.013	0.099	0.054	0.004	−0.048	.87
	(−2.40)*	(27.36)*	(2.68)*	(1.46)	(0.10)	(−1.28)	
4	−0.001	1.013	0.051	−0.002	−0.007	−0.048	.94
	(−0.75)	(42.25)*	(2.15)*	(−0.09)	(−0.31)	(−1.98)*	
	B: Portfolios by firm size controlled for institutional ownership						
1	−0.002	1.047	0.199	0.058	−0.007	−0.041	.75
	(−0.63)	(17.82)*	(3.40)*	(0.99)	(−0.12)	(−0.70)	
2	−0.005	1.074	0.138	0.016	−0.020	−0.044	.84
	(−2.10)*	(23.56)*	(3.03)*	(0.36)	(−0.44)	(−0.95)	
3	−0.002	1.081	0.080	0.007	−0.048	−0.015	.89
	(−1.47)	(30.51)*	(2.27)*	(0.19)	(−1.36)	(−0.42)	
4	−0.002	1.027	0.025	0.007	−0.027	−0.037	.95
	(−1.84)**	(45.51)*	(1.57)	(0.29)	(−1.21)	(−1.63)	

In panel A of Table 8, the sample of firms is divided into five portfolios based on firm size measured by the market value of equity. In panel B, the sample is divided into five portfolios based on firm size after controlling for institutional ownership. The estimated regression is

$$R_{s,t} = \alpha + \beta_0 R_{L,t} + \beta_{-1} R_{L,t-1} + \beta_{-2} R_{L,t-2} + \beta_{-3} R_{L,t-3} + \beta_{-4} R_{L,t-4} + \tilde{\varepsilon}_t.$$

$R_{s,t}$ is the excess (over risk-free rate) monthly return of the portfolio of smaller firms on NYSE and AMEX at time t, and $R_{L,t-k}$, $k = 0, \ldots, 4$ are the contemporaneous and lagged excess monthly returns on the portfolio of largest firms for the period 1981–1988. Portfolio 1 constitutes the smallest firms and portfolio 5 the largest. Regression estimates are presented for portfolios 1 through 4. Since portfolios are adjusted at the end of every year, the number of firms in the portfolios varies from 314 to 413 firms. (t-statistics are in parentheses.)
*Significant at the .05 level.
**Significant at the .10 level.

Interestingly, β_{-2} coefficients are all positive and significantly different from zero. Thus, it seems that institutional ownership-based lead-lag relation persists even after controlling for firm size.[13]

[13] It has been argued by Boudoukh, Richardson, and Whitelaw (1994) that a portion of the cross-correlation in weekly equity returns can be attributed to autocorrelation in equity returns. Despite the fact that the monthly return series used in the above tests do not exhibit autocorrelation, the impact of autocorrelation on the findings was analyzed by including lagged returns of portfolios with lower institutional holdings in the analysis. The significance of the previously documented lead-lag relation was not lost, and the inference that returns on portfolios of firms with high institutional ownership lead the returns on portfolios with lower institutional ownership by as much as two months was unchanged.

Table 9
Returns on the portfolio of firms with highest institutional ownership as predictors for returns on portfolios of firms with lowest institutional ownership

Portfolio	α	β_0	β_{-1}	β_{-2}	β_{-3}	β_{-4}	Adj. R^2
			A: Portfolios by institutional ownership				
1	−0.004	0.771	0.094	0.143	0.015	0.021	.77
	(−1.61)	(18.90)*	(2.29)*	(3.47)*	(0.35)	(0.50)	
2	−0.003	0.872	0.091	0.131	0.005	0.033	.88
	(−1.78)**	(27.10)*	(2.81)*	(4.01)*	(0.17)	(1.02)	
3	−0.004	0.880	0.037	0.082	0.005	0.019	.93
	(−2.94)*	(38.58)*	(1.60)	(3.53)*	(0.23)	(0.81)	
4	−0.001	0.936	0.027	0.020	0.004	0.027	.97
	(−0.86)	(62.97)*	(1.83)**	(1.31)	(0.26)	(1.77)**	
			B: Portfolios by institutional ownership controlled for firm size				
1	−0.002	0.761	−0.010	0.098	−0.012	0.030	.87
	(−1.07)	(26.41)*	(−0.33)	(3.28)*	(−0.39)	(1.02)	
2	−0.001	0.875	−0.046	0.086	−0.012	0.017	.93
	(−1.08)	(38.01)*	(−1.92)**	(3.62)*	(−0.50)	(0.71)	
3	−0.001	0.955	−0.022	0.062	−0.042	0.032	.96
	(−1.16)	(54.28)*	(−1.18)	(3.41)*	(−2.29)*	(1.76)**	
4	−0.001	0.967	−0.028	0.035	0.006	0.002	.98
	(−1.20)	(72.95)*	(−2.02)*	(2.52)*	(0.47)	(0.16)	

In panel A of Table 9, the sample of firms is divided into five portfolios based on institutional ownership. In panel B, the sample is divided into five portfolios based on institutional ownership after controlling for firm size. The estimated regression is

$$R_{s,t} = \alpha + \beta_0 R_{L,t} + \beta_{-1} R_{L,t-1} + \beta_{-2} R_{L,t-2} + \beta_{-3} R_{L,t-3} + \beta_{-4} R_{L,t-4} + \tilde{\varepsilon}_t.$$

$R_{s,t}$ is the excess (over risk-free rate) monthly return of the portfolio of firms with lowest institutional ownership on NYSE and AMEX at time t, and $R_{L,t-k}$, $k = 0, \ldots, 4$ are the contemporaneous and lagged excess monthly returns on the portfolio of firms with the highest institutional ownership for the period 1981–1988. Portfolio 1 constitutes the smallest ownership firms and portfolio 5 the highest. Regression estimates are presented for portfolios 1 through 4. Since portfolios are adjusted at the end of every year, the number of firms in the portfolios varies from 314 to 413 firms. (t-statistics are in parentheses.)
*Significant at the .05 level.
**Significant at the .10 level.

3.2 Cross-autocorrelations in weekly equity returns

Analysis of the lead-lag relation was next performed on weekly portfolio return series. Weekly returns were computed from the Daily Return CRSP tapes, and the following regression was estimated for portfolios formed according to the four different classification schemes:

$$\begin{aligned} R_{s,t} &= \alpha + \beta_0 R_{L,t} + \beta_{-1} R_{L,t-1} + \beta_{-2} R_{L,t-2} + \cdots \\ &\quad + \beta_{-9} R_{L,t-9} + \beta_{-10} R_{L,t-10} + \tilde{\varepsilon}_t \end{aligned} \tag{2}$$

where $R_{s,t}$ is the excess (over risk-free rate) weekly return of the portfolio of smallest firms (with lowest institutional ownership) on NYSE and AMEX at time t and $R_{L,t-k}$, $k = 0, \ldots, 10$ are the contemporaneous and lagged excess weekly returns on the portfolio of largest firms (with the highest institutional ownership) for the period 1981–1988.

Table 10 presents the results from estimating Equation (2) on returns from portfolios formed according to firm size (panel A) and for portfolios formed by firm size controlled for institutional ownership (panel B). The results in both panels are generally consistent with the earlier finding of one-month lags for monthly returns. The coefficients β_{-1}, β_{-3}, and β_{-4} are positive and significantly different from zero for all portfolios. The significance of the four-week period is similar to that of the one-month lag documented earlier. The coefficients β_{-2} on the two-week prior returns, except for portfolio 1, are, however, not significantly different from zero. We are unable to explain this lack of significance. Except for this anomaly, therefore, our earlier findings seem to hold in tests conducted on weekly returns.

Table 11 presents the results from estimating Equation (2) on returns on portfolios formed on the basis of institutional ownership (panel A) and for portfolios formed on the basis of ownership controlled for size (panel B). The values in panel A indicate that coefficients β_{-1} and β_{-3} are positive and significant for all portfolios, and the puzzle of negative β_{-2} coefficients remains. The coefficients β_{-8} and β_{-9}, roughly equivalent to a two-month period, are positive and significantly different from zero. This finding is particularly interesting given that the coefficients on earlier weeks β_{-4} through β_{-7}, with one exception, are zero. Thus, the stock prices of lower institutional interest portfolios react to changes in the highest institutional interest portfolios only after approximately seven weeks. It does not appear to be an effect that permeates at a slow rate over time. The results on portfolios formed on the basis of institutional ownership controlled for size offer clearer support for the longer lag. Unlike panel A, β_{-1} coefficients are not significantly different from zero for portfolios 1 and 3, and for the other two portfolios they are positive and significant only at the 10 percent level. The coefficients β_{-3} and β_{-4}, which were positive and significantly greater than zero in panel A, are no longer different from zero. The coefficients consistent with the two-month lag, β_{-8} and β_{-9}, are, however, positive and are significant in six out of eight cases.

4. Conclusion

In this article, the hypothesis that different levels of institutional interest in equities may induce cross-autocorrelation in equity returns. The hypothesis is that, because of differential information set-up costs [Merton (1987)] and/or legal restrictions arising from the "prudent man" rule, informed investors invest in the equity of only a subset of

Table 10
Returns on the portfolio of largest firms as predictors for returns on portfolios of smaller firms

Portfolio	α	β_0	β_{-1}	β_{-2}	β_{-3}	β_{-4}	β_{-5}	β_{-6}	β_{-7}	β_{-8}	β_{-9}	β_{-10}	Adj. R^2
A: Portfolios by firm size													
1	−0.001 (−1.2)	0.664 (25.5)*	0.257 (9.8)*	0.054 (2.0)*	0.086 (3.3)*	0.107 (4.1)*	0.000 (0.0)	0.028 (1.1)	0.036 (1.4)	0.038 (1.4)	0.026 (1.0)	0.018 (0.7)	.62
2	−0.001 (−2.5)*	0.750 (38.2)*	0.233 (11.8)*	0.005 (0.2)	0.066 (3.3)*	0.066 (3.4)*	−0.005 (−0.3)	0.029 (1.5)	0.018 (0.9)	0.009 (0.4)	0.009 (0.5)	−0.012 (−0.6)	.77
3	−0.001 (−3.1)*	0.854 (52.8)*	0.216 (13.3)*	−0.016 (1.0)	0.063 (3.9)*	0.038 (2.3)*	−0.021 (−1.3)	0.026 (1.6)	0.030 (1.9)**	−0.003 (−0.2)	0.007 (0.4)	−0.003 (−0.2)	.86
4	−0.000 (−1.21)	0.924 (80.7)*	0.121 (10.6)*	−0.004 (−0.4)	0.036 (3.1)*	0.024 (2.1)*	−0.016 (−1.4)	0.023 (2.1)*	−0.001 (−0.1)	−0.012 (−1.0)	−0.01 (−0.1)	−0.004 (−0.4)	.93
B: Portfolios by firm size controlled for institutional ownership													
1	−0.000 (−0.1)	0.811 (32.4)*	0.243 (9.6)*	0.048 (1.9)**	0.079 (3.2)*	0.081 (3.2)*	−0.011 (−0.4)	0.046 (1.85)**	0.017 (0.7)	0.005 (0.2)	0.010 (0.4)	−0.016 (−0.6)	.72
2	−0.001 (−2.1)*	0.890 (46.0)*	0.193 (9.9)*	0.020 (1.0)	0.067 (3.4)*	0.057 (2.9)*	0.002 (0.1)	0.025 (1.3)	0.008 (0.4)	−0.005 (−0.3)	−0.008 (−0.4)	−0.023 (−1.2)	.82
3	−0.001 (−1.7)**	0.938 (57.4)*	0.146 (8.9)*	0.015 (0.9)	0.042 (2.6)*	0.035 (2.2)*	−0.012 (−0.8)	0.025 (1.6)	0.010 (0.6)	−0.007 (−0.5)	−0.011 (−0.7)	−0.018 (−1.1)	.88
4	−0.000 (−1.6)	0.946 (86.4)*	0.093 (8.4)*	−0.001 (−0.1)	0.028 (2.6)*	0.021 (1.9)**	−0.021 (−1.9)**	0.016 (1.4)	0.004 (0.4)	−0.013 (−1.2)	0.002 (0.2)	−0.030 (−2.7)*	.94

In panel A of Table 10, the sample of firms is divided into five portfolios based on firm size measured by the market value of equity. In panel B, the sample is divided into five portfolios based on firm size after controlling for institutional ownership. The estimated regression is

$$R_{s,t} = \alpha + \beta_0 R_{L,t} + \beta_{-1} R_{L,t-1} + \beta_{-2} R_{L,t-2} + \cdots + \beta_{-9} R_{L,t-9} + \beta_{-10} R_{L,t-10} + \tilde{\varepsilon}_t.$$

$R_{s,t}$ is the excess (over risk-free rate) weekly return of the portfolio of smaller firms on NYSE and AMEX at time t, and $R_{L,t-k}$, $k = 0, \ldots, 10$ are the contemporaneous and lagged excess weekly returns on the portfolio of largest firms for the period 1981–1988. Portfolio 1 constitutes the smallest firms and portfolio 5 the largest. Regression estimates are presented for portfolios 1 through 4. Since portfolios are adjusted at the end of every year, the number of firms in the portfolios varies from 380 to 420 firms. (t-statistics are in parentheses.)

*Significant at the .05 level.

**Significant at the .10 level.

Table 11
Returns on the portfolio of firms with highest institutional ownership as predictors for returns on portfolios of firms with lowest institutional ownership

Portfolio	α	β_0	β_{-1}	β_{-2}	β_{-3}	β_{-4}	β_{-5}	β_{-6}	β_{-7}	β_{-8}	β_{-9}	β_{-10}	Adj. R^2
A: Portfolios by institutional ownership													
1	−0.000	0.641	0.154	−0.004	0.033	0.056	−0.011	0.003	0.019	0.063	0.040	0.027	.74
	(−1.1)	(34.8)*	(8.3)*	(−0.2)	(1.8)**	(3.0)*	(−0.6)	(0.2)	(1.0)	(3.4)*	(2.2)*	(1.4)	
2	−0.000	0.765	0.143	−0.005	0.040	0.023	0.001	0.010	0.024	0.043	0.038	0.028	.85
	(−1.2)	(49.5)*	(9.2)*	(−0.3)	(2.6)*	(1.5)	(0.1)	(0.6)	(1.5)	(2.6)*	(2.5)*	(1.8)**	
3	−0.001	0.804	0.107	−0.023	0.023	0.017	−0.007	0.004	0.016	0.028	0.032	0.019	.91
	(−2.6)*	(68.9)*	(9.1)	(−1.9)**	(2.0)*	(1.4)	(−0.6)	(0.4)	(1.4)	(2.4)*	(2.7)*	(1.6)	
4	−0.000	0.901	0.064	−0.020	0.025	0.012	−0.002	−0.005	0.002	0.022	0.005	0.016	.96
	(−0.7)	(110)*	(7.7)*	(−2.4)*	(1.8)**	(1.4)	(−0.25)	(−0.6)	(0.3)	(2.7)*	(0.6)	(1.9)**	
B: Portfolios by institutional ownership controlled for firm size													
1	−0.000	0.742	0.019	−0.011	−0.010	0.024	−0.022	−0.009	0.009	0.050	0.032	0.016	.84
	(−0.6)	(49.7)*	(1.2)	(−0.7)	(−0.6)	(1.6)	(−1.4)	(−0.6)	(0.6)	(3.3)*	(2.1)*	(1.1)	
2	−0.000	0.845	0.021	−0.018	−0.001	−0.001	−0.017	−0.001	0.007	0.029	0.025	0.019	.91
	(−0.6)	(68.8)*	(1.7)**	(−1.5)	(−0.1)	(−0.1)	(−1.3)	(−0.1)	(0.5)	(2.3)*	(2.1)*	(1.5)	
3	−0.000	0.918	0.013	−0.008	0.000	0.009	−0.013	0.004	0.002	0.029	0.016	0.000	.95
	(−0.9)	(93.5)*	(1.3)	(−0.8)	(0.0)	(0.9)	(−1.3)	(0.4)	(0.2)	(2.9)*	(1.6)	(0.0)	
4	−0.000	0.934	0.016	−0.006	−0.005	−0.001	−0.016	0.006	0.004	0.005	0.019	−0.003	.96
	(−0.5)	(109)*	(1.9)**	(−0.7)	(−0.6)	(−0.1)	(−1.8)**	(0.7)	(0.4)	(0.6)	(2.2)*	(−0.4)	

In panel A of Table 11, the sample of firms is divided into five portfolios based on institutional ownership. In panel B, the sample is divided into five portfolios based on institutional ownership after controlling for firm size. The estimated regression is

$$R_{s,t} = \alpha + \beta_0 R_{L,t} + \beta_{-1} R_{L,t-1} + \beta_{-2} R_{L,t-2} + \cdots + \beta_{-9} R_{L,t-9} + \beta_{-10} R_{L,t-10} + \tilde{\varepsilon}_t.$$

$R_{s,t}$ is the excess (over risk-free rate) weekly return of the portfolio of firms with lowest institutional ownership on NYSE and AMEX at time t, and $R_{L,t-k}$, $k = 0, \ldots, 10$ are the contemporaneous and lagged excess weekly returns on the portfolio of firms with the highest institutional ownership for the period 1981–1988. Portfolio 1 constitutes the smallest ownership firms and portfolio 5 the highest. Regression estimates are presented for portfolios 1 through 4. Since portfolios are adjusted at the end of every year, the number of firms in the portfolios varies from 314 to 413 firms. (t-statistics are in parentheses.)

*Significant at the .05 level.

**Significant at the .10 level.

traded firms. In this setting, uninformed investors can use past prices of these stocks to predict prices of the other stocks. Empirical tests on stock market data are conducted to investigate this hypothesis. The empirical findings confirm the conjecture that size may not be the only economically relevant determinant of cross-equity price dynamics; level of institutional ownership may also play a significant role. Returns on stocks with high levels of institutional ownership lead, by as much as two months, the returns on stocks with lower levels of institutional ownership. The lead-lag relation induced by the level of institutional ownership persists even when firm size is controlled. Thus, the institutional ownership-induced lead-lag relation may be a candidate for the information transmission mechanism conjectured by Lo and MacKinlay (1990).

The findings reported in this article, despite their significance, raise an interesting issue: the fact that the reaction in stocks of firms with low levels of institutional ownership is not observed until two months after the change in the prices of stocks with a high level of institutional interest. One would expect the time taken by uninformed investors to incorporate past price data into their current demand to be fairly short. Even if investors quickly incorporated price data (e.g., on a daily basis) into their current demand, monthly lags could still be observed because the monthly return is the sum of daily returns. However, significant lead-lag relations are observed even at the two-month interval. A possible way to reconcile this finding with theory would be to assume that investors update their information sets infrequently. Casual empiricism indicates that this may indeed be the case for such institutional investors as pension funds.

Appendix

There are two risky assets trading on the market, an IF asset and an IU asset, in an infinite sequence of periods, $t = 1, 2, \ldots$. There is also a riskless asset with constant return r per period and let $R = 1 + r$. The prices and the exogenously given dividend stream on the IU and IF assets are denoted by $\tilde{P}_t$ and $\tilde{P}_t^*$ and $\tilde{D}_t$ and $\tilde{D}_t^*$, respectively. There are two investors, informed and uninformed. The informed can trade in only the IF asset, whereas the uninformed can trade in the IF and the IU asset.

An investor buying either risky asset ex-dividend at time t knows that he will receive a dividend at $t + 1$ and at that date can resell the asset. Thus, the gross return in period $t + 1$ from holding the IU (IF) asset is given by $\tilde{V}_{t+1} = \tilde{D}_{t+1} + \tilde{P}_{t+1}(\tilde{V}_{t+1}^* = \tilde{D}_{t+1}^* + \tilde{P}_{t+1}^*)$. The demand for risky assets in both markets, as in Hellwig (1982), is determined by the myopic mean-variance criterion. Let $z_t(z_t^*)$ denote demand of the uninformed investors in the IU (IF) market at time t, and let Z_t^* be the informed demand in the IF market. Recall that, by assumption, the informed demand in the IU market is zero. The first-order conditions for the uninformed investor, given myopic mean-variance maximization, are

$$E[\tilde{V}_{t+1}^* - R\tilde{P}_t^* \mid \mathbf{U}_t] - a\{z_t^* \operatorname{VAR}[\tilde{V}_{t+1}^* \mid \mathbf{U}_t] + z_t \operatorname{COV}[\tilde{V}_{t+1}^*, \tilde{V}_{t+1} \mid \mathbf{U}_t]\} = 0$$

and

$$E[\tilde{V}_{t+1} - R\tilde{P}_t \mid \mathbf{U}_t] - a\{z_t \operatorname{VAR}[\tilde{V}_{t+1} \mid \mathbf{U}_t] + z_t^* \operatorname{COV}[\tilde{V}_{t+1}^*, \tilde{V}_{t+1} \mid \mathbf{U}_t]\} = 0,$$

where $\mathbf{U}_t$ is the information set of the uninformed at time t and a is their risk-aversion parameter. Solving the above equations for asset demands yields

$$z_t^* = \frac{\begin{array}{c} E[\tilde{V}_{t+1}^* - R\tilde{P}_t \mid \mathbf{U}_t] \operatorname{VAR}[\tilde{V}_{t+1}^* \mid \mathbf{U}_t] \\ -E[\tilde{V}_{t+1} - R\tilde{P}_t \mid \mathbf{U}_t] \operatorname{COV}[\tilde{V}_{t+1}^*, \tilde{V}_{t+1} \mid \mathbf{U}_t] \end{array}}{\begin{array}{c} a\{\operatorname{VAR}[\tilde{V}_{t+1}^* \mid \mathbf{U}_t] \operatorname{VAR}[\tilde{V}_{t+1} \mid \mathbf{U}_t] - \\ (\operatorname{COV}[\tilde{V}_{t+1}^*, \tilde{V}_{t+1} \mid \mathbf{U}_t])^2\} \end{array}} \tag{A1a}$$

and

$$z_t = \frac{\begin{array}{c} E[\tilde{V}_{t+1} - R\tilde{P}_t \mid \mathbf{U}_t] \operatorname{VAR}[\tilde{V}_{t+1}^* \mid \mathbf{U}_t] \\ -E[\tilde{V}_{t+1}^* - R\tilde{P}_t \mid \mathbf{U}_t] \operatorname{COV}[\tilde{V}_{t+1}^*, \tilde{V}_{t+1} \mid \mathbf{U}_t] \end{array}}{\begin{array}{c} a\{\operatorname{VAR}[\tilde{V}_{t+1}^* \mid \mathbf{U}_t] \operatorname{VAR}[\tilde{V}_{t+1} \mid \mathbf{U}_t] \\ -(\operatorname{COV}[\tilde{V}_{t+1}^*, \tilde{V}_{t+1} \mid \mathbf{U}_t])^2\} \end{array}}. \tag{A1b}$$

Similarly, the asset demand for the informed is given by

$$\tilde{Z}_t^* = \frac{E[\tilde{V}_{t+1}^* \mid \mathbf{I}_t] - R\tilde{P}_t^*}{a^* \operatorname{VAR}[V_{t+1}^* \mid \mathbf{I}_t]}, \tag{A1c}$$

where a^* represents the risk-aversion of the informed investors and $\mathbf{I}_t$ represents their information set at time t. The contents of the information sets of both investor types is discussed later.

Next, define the following price-generating processes:

$$\tilde{X}_t = \mu_X + \sum_{i=0}^{t} \tilde{\varepsilon}_i \text{ and } \tilde{W}_t = \mu_W + \sum_{i=0}^{t} \tilde{\eta}_i, \tag{A2}$$

where $\{\tilde{\varepsilon}_i\}$ ($\{\tilde{\eta}_i\}$) are assumed to be independent identically distributed (iid) normal random variables with mean 0 and standard deviation $\sigma_\varepsilon(\sigma_\eta)$. These two series are further assumed to be orthogonal, that is, for all i and $kE[\tilde{\varepsilon}_i \tilde{\eta}_k] = 0$. Next, the dividend processes for the two risky assets are given by

$$\tilde{D}_t^* = \tilde{X}_t, \tilde{D}_t = \rho \tilde{X}_t + \tilde{W}_t, \rho \in (0, 1]. \tag{A3}$$

This implies that dividends on the IU asset are positively correlated with dividends on the IF asset.

At time t, investors in both markets observe the entire dividend histories of both assets. However, as in Hellwig (1982), at time t they can condition their actions on the price path of the assets only up to time $t-1$. Informed investors, however, observe two signals $\tilde{y}_t^1$ and $\tilde{y}_t^2$ that allow them to forecast the innovations in the dividend series occurring at times $t+1$ and $t+2$, that is, $\tilde{y}_t^1 = \tilde{\varepsilon}_{t+1}$ and $\tilde{y}_t^2 = \tilde{\varepsilon}_{t+2}$. Thus, at time t, $\mathbf{I}_t$ includes $\{\tilde{D}_s^*, s \leq t\}$, $\{\tilde{D}_s, s \leq t\}$, $\{\tilde{P}_s^*, s \leq t-1\}$, $\{\tilde{P}_s, s \leq t-1\}$, and $\{\tilde{y}_t^1, \tilde{y}_t^2\}$, and $\mathbf{U}_t$ includes $\{\tilde{D}_s^*, s \leq t\}$, $\{\tilde{D}_s, s \leq t\}$, $\{\tilde{P}_s^*, s \leq t-1\}$, and $\{\tilde{P}_s, s \leq t-1\}$.

For a given price series $(\tilde{P}_t^*)$, Equations (A1a) and (A1c) determine asset demands in the IF market. In equilibrium, these demands must equal the total supply of the risky asset assumed, without loss of generality, to equal one. Thus, the equilibrium price sequence in the informed market must satisfy

$$1 = z_t^* + Z_t^* \text{ for all } t = 0, 1, \ldots, \tag{A4}$$

where z_t^* and Z_t^* are defined in Equations (A1a) and (A1c). On the other hand, in the IU market, only the uninformed can invest. Therefore, the market equilibrium condition is

$$1 = z_t \text{ for all } t = 0, 1, \ldots, \tag{A5}$$

where z_t is defined in Equation (A1b).

Because the innovations in the dividend stream are iid by assumption and the two innovations processes are orthogonal, all information about the future dividend stream is captured by $\tilde{D}_t^*$, $\tilde{y}_t^1$, and $\tilde{y}_t^2$. In a linear rational expectations equilibrium (LREE), asset prices depend linearly on the relevant information, that is,

$$\tilde{P}_t^* = \pi_0 + \pi_1 \tilde{D}_t^* + \pi_2 \tilde{y}_t^1 + \pi_3 \tilde{y}_t^2. \tag{A6}$$

A solution for the π_0, π_1, π_2, and π_3 satisfying the market-clearing conditions defines the LREE. The following proposition characterizes the LREE in the market.

Proposition 1. *The LREE pricing function is given by*

$$\tilde{P}_t^* = C + \frac{1}{r}\tilde{D}_t^* + \frac{1}{r}\tilde{y}_t^1 + \frac{1}{rR}\tilde{y}_t^2 \tag{A7}$$

and

$$\tilde{P}_t = \frac{1}{r}(B + \rho R r \tilde{P}^*_{t-1} - \rho R \tilde{D}^*_t + \tilde{D}_t), \tag{A8}$$

where B and C are scalars defined as follows:

$$C = -\frac{aa^*\sigma_\varepsilon^2 r(1 + R^2 + \rho R^2 r^2)}{R^2(a + aR^2 + a^* r^4)} \quad \textit{and}$$

$$B = \left(\frac{R^2 r^2}{1 + R^2}\right)\left\{a\sigma_\varepsilon^2 \rho\left(\rho - \frac{1 + R^2}{R^2 r^4}\right) - a\sigma_\eta^2\left(\frac{1 + R^2}{r^4}\right) - \rho C r\left(\frac{1 + R^2}{Rr^2} - 1\right)\right\}. \tag{A9}$$

Proof. By definition, $\tilde{y}_t^1 = \tilde{\varepsilon}_{t+1}$, $\tilde{y}_t^2 = \tilde{\varepsilon}_{t+2}$, $\hat{D}^*_{t+1} = \hat{D}^*_t + \tilde{\varepsilon}_{t+1}$, $\hat{D}^*_{t+2} = \hat{D}^*_t + \tilde{\varepsilon}_{t+1} + \tilde{\varepsilon}_{t+2}$, and $\tilde{V}^*_{t+1} = \tilde{P}^*_{t+1} + \tilde{D}^*_{t+1}$. Applying the definitions of conditional expectation, conditional variance, and conditional covariance, given the marketing pricing functions (A7) and (A8), yields

$$\begin{aligned}
E[\tilde{V}^*_{t+1} - R\tilde{P}^*_t \mid \mathbf{U}_t] &= -Cr, \\
\mathrm{VAR}[\tilde{V}_{t+1} \mid \mathbf{U}_t] &= \sigma_\eta^2 \frac{R^2}{r^2} + \rho\sigma_\varepsilon^2 \frac{1}{r^2}, \\
E[\tilde{V}_{t+1} - R\tilde{P}_t \mid \mathbf{U}_t] &= -B - \rho R r C, \\
\mathrm{COV}[\tilde{V}^*_{t+1}, \tilde{V}_{t+1} \mid \mathbf{U}_t] &= \rho\sigma_\varepsilon^2, \\
\mathrm{VAR}[\tilde{V}^*_{t+1} \mid \mathbf{U}_t] &= \sigma_\varepsilon^2 \frac{1 + R^2}{R^2 r^2}, \\
E[\tilde{V}^*_{t+1} - R\tilde{P}^*_t \mid \mathbf{I}_t] &= -Cr, \text{ and} \\
\mathrm{VAR}[\tilde{V}^*_{t+1} \mid \mathbf{I}_t] &= \sigma_\varepsilon^2 \frac{1}{R^2 r^2}.
\end{aligned}$$

Substituting these results in the asset demand equations (A1a through A1c) determines asset demands in the two markets. Solving for B and C by imposing the market clearing conditions establishes the proposition. ■

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