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Robin M. Greenwood and Nathan Sosner

In April 2000, 30 stocks were replaced in the Nikkei 225 Index. The unusually broad index redefinition allowed for a study of the effects of index-linked trading on the excess comovement of stock returns. A large increase occurred in the correlation of trading volume of stocks added to the index with the volume of stocks that remained in the index, and opposite results occurred for the deletions. Daily index return betas of the additions rose by an average of 0.45; index return betas of the deleted stocks fell by an average of 0.63. Theoretical predictions for changes in autocorrelations and cross-serial correlations of returns of index additions and deletions were confirmed. The results are consistent with the idea that trading patterns are associated with short-run excess comovement of stock returns.

Classical finance models share the prediction that the prices of securities move together only in response to correlated shocks to expected cash flows or common variations in discount rates. In many of these models, such as Ross's (1976) arbitrage pricing theory, the deviation of prices from fundamentals is limited by the presence of smart arbitrageurs. In such an economy, investor demand that is not driven by fundamental news is irrelevant.

However useful these models may be in modeling the price process, they are difficult to reconcile with abundant evidence that security prices can move together either too little or too much to be justified by fundamentals. Pindyck and Rotemberg (1993) showed that stock returns of companies in unrelated business lines comove significantly more than can be explained by common variations in discount rates. In another famous example, Froot and Dabora (1999) studied "twin companies," those whose cash flows were perfectly correlated, and found that the returns on shares of these companies traded on different exchanges were far from being perfectly correlated.

What causes the comovement of stock returns if not fundamentals? Empirical studies have uncovered a variety of common factors in returns, such as size, value, and industry. Debate is still going on about whether these factors are related to fundamental risk or merely reflect mispricing driven by investor demand. For example, Fama and French (1992) attributed the value premium to the high risk of value stocks. Others, such as Lakonishok, Shleifer, and Vishny (1994), argued that the value premium is not caused by fundamental risk but is a result of irrational investor demand based on the extrapolation of past performance. Shleifer, Lee, and Thaler (1991) and Pindyck and Rotemberg (1993) found evidence that stock returns may be affected by correlated demand shocks that are unrelated to news about fundamentals. Commercial providers of risk models have stayed away from this debate; they generally include a broad set of factors to explain common variation in asset returns.

We argue that one driver of comovement of returns is commonality in trading activity, and we tested our hypothesis by using an unusual index redefinition of Japan's Nikkei 225 Index in April 2000.

Our primary hypothesis was that upon inclusion in the Nikkei, a stock becomes exposed to the trading shocks experienced by other Nikkei stocks because it now becomes traded in a basket with other index stocks. **Figure 1** provides a first look at this claim. Panel A plots rolling (estimated on 300-day windows) slope coefficients, or betas, from univariate ordinary least-squares (OLS) regressions of equal-weighted daily turnover of the 30 additions and 30 deletions on the equal-weighted daily turnover of the stocks that remained in the index (hereafter, remainders). Panel B plots the correlation of the turnover of additions and deletions and that of the remainders. Turnover is defined as the number of shares traded divided by total number of shares outstanding.

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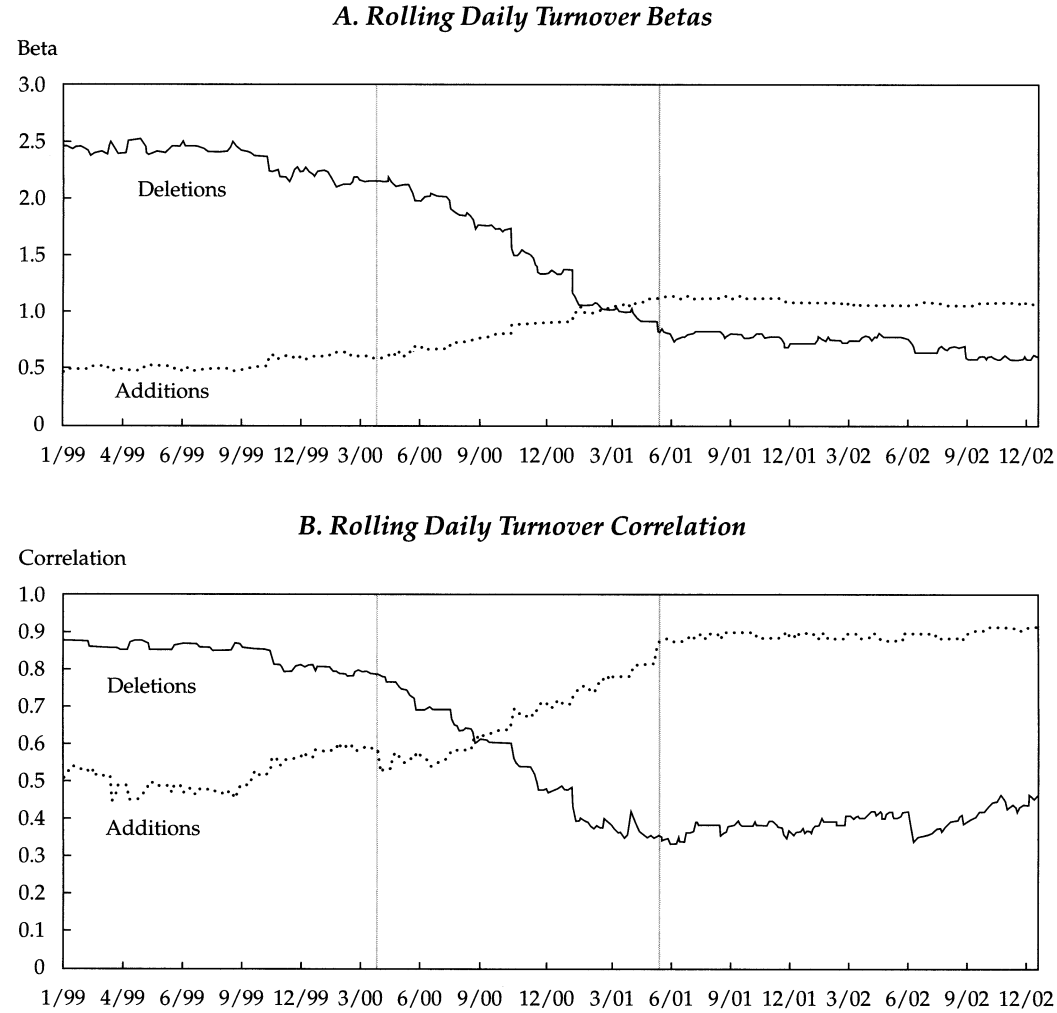
Figure 1. Comovement of Turnover of Additions to and Deletions from the Nikkei Index with Remaining Index Stocks



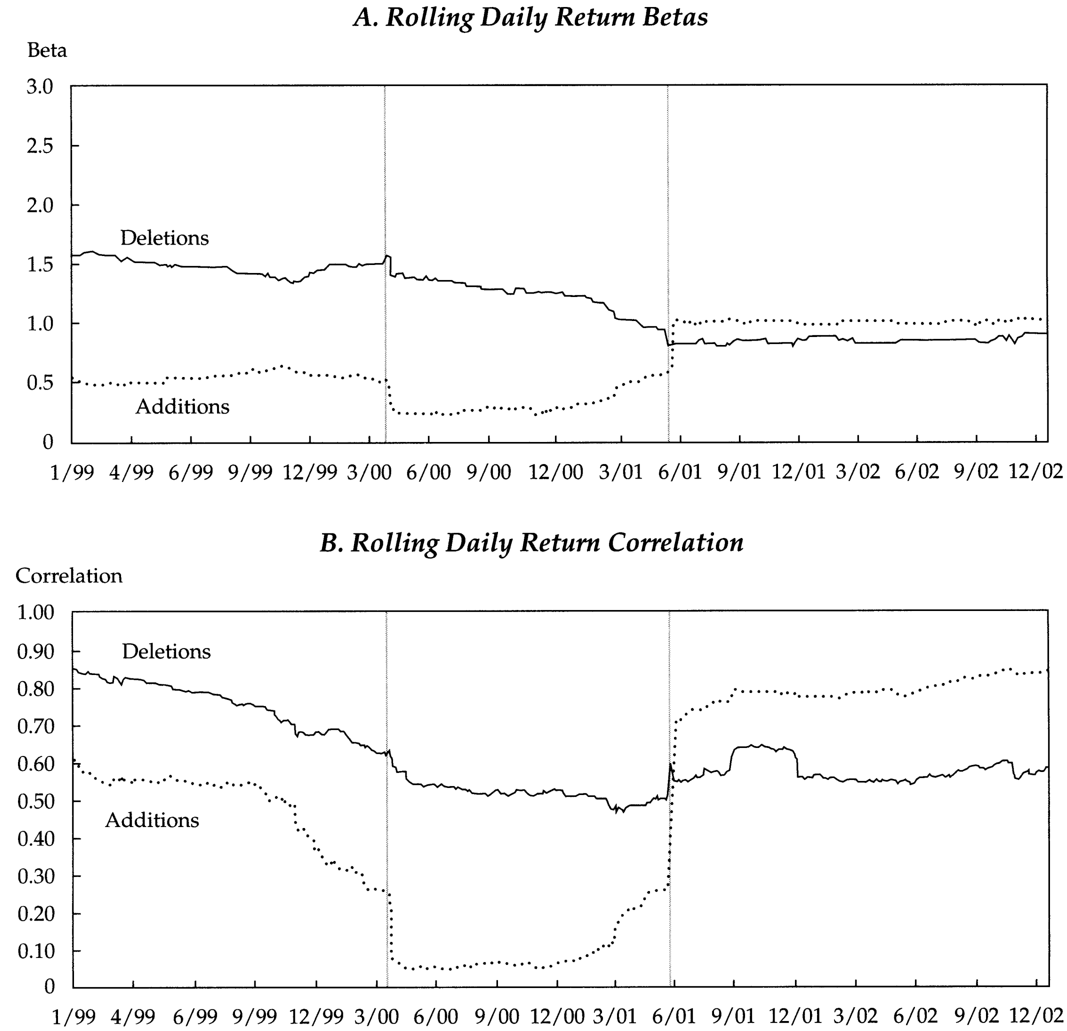
Note: The first vertical line indicates the date the index redefinition was announced; the second vertical line is the date on which the index redefinition left the 300-day window for calculating betas and correlations.

Figure 1 shows that the event caused a significant *increase* (*decrease*) in the correlation of the trading volume of the additions (deletions) with that of the remainders. The reasons are clear. First, when index funds experience inflows or outflows, they trade index stocks as a basket. Second, index arbitrageurs "delta-hedge" their index derivatives positions, which requires simultaneous trading in the basket of the underlying securities.

In the presence of limits to arbitrage, the change in trading pattern shown in Figure 1 has implications for the short-run comovement of stock returns. Specifically, stocks that trade in a basket with other stocks simply by virtue of being part of the stock index should exhibit excessive covariation in their returns because of their common exposure to shocks to investor demand.

Addition to or deletion from the index caused an exogenous change in the trading pattern, which allowed us to identify the nonfundamental trading-related comovement we described. Our main prediction was that stocks that were added to the index experienced increases in their index beta whereas stocks that were deleted from the index experienced decreases in their index betas. **Figure 2** plots in Panel A the betas of rolling univariate OLS regressions of equal-weighted daily returns of the 30 additions and 30 deletions with respect to the equal-weighted return of the remainders.[1] Panel B of Figure 2 plots the rolling correlations between the returns of portfolios of additions and deletions and the returns of remainders. Both panels of Figure 2 show a dramatic increase in the comovement

Figure 2. Comovement of Stock Returns of Additions to and Deletions from the Nikkei Index with Remaining Index Stocks



Note: The first vertical line indicates the date the index redefinition was announced; the second vertical line is the date on which the index redefinition left the 300-day window for calculating betas and correlations.

of returns of the additions with index returns, and a dramatic reduction in the comovement of returns of the deletions with index returns.

In the remainder of the article, we use the Nikkei 225 redefinition to analyze more formally the relationship between comovement of trading activity and the comovement of stock returns. Our results draw on two lines of research.

First, a series of papers, starting with Shleifer (1986), Harris and Gurel (1986), and Goetzmann and Garry (1986), documented abnormal returns upon addition to and deletion from the S&P 500 Index.[2] These results have been extensively replicated in other markets and different settings. Debate remains, however, as to the causes of these event returns. Early research supported the idea that such price changes are a result of downward-sloping investor demand curves, and more recent work suggested that investor awareness (Chen, Noronha, and Singal 2004) and increased external monitoring (Denis, McConnell, Ovtchinnikov, and Yu 2003) may also play a role. Our premise is that if the price impact of trading is responsible for the returns in these one-time events, then regular trading patterns should affect comovement and volatility of security returns on an ongoing basis.

Second, our results relate to recent work on category-based trading (e.g., Vijh 1994; Mullainathan 2000; Barberis, Shleifer, and Wurgler 2003). In univariate regressions of stock returns on the S&P 500 return, Barberis et al. found the betas of stocks added to the S&P 500 rose by a modest 0.116

whereas the betas of the deletions fell by 0.150 during their 1976–98 sample period. The increase in the betas of additions was found to be much stronger in the second half of the period, after the introduction of S&P 500 futures and options in 1982 and 1983, which is consistent with the idea that index arbitrage induces commonality in trading patterns. Vijh showed that daily market betas of additions with respect to the S&P 500 increased by an average of 0.080 during the 1975–89 sample period.

Our study extends this earlier work on comovement along several dimensions. First, we used a new technique to identify commonality in trading volume. Specifically, we created "turnover betas," which measure the covariance of turnover with the turnover of other stocks. We expect that this simple measure can be applied to measuring comovement of trading activity in broader settings than in our study and will be of use to practitioners seeking to identify commonality in returns that cannot be traced to fundamentals. Second, we studied the *reversion* of excess comovement, thereby showing that the effects of correlated investor demand are at least partly reversed within a few days. Third, we found effects an order of magnitude larger than those identified in previous work, particularly on daily returns, which suggests that trading may well be responsible for most of the short-run comovement of indexed stock returns. Fourth, the Nikkei 225 change provided the setting for a natural experiment because it involved a rewriting of the rules of index membership. Thus, it avoids the criticism that index addition or deletion reflects information on the underlying fundamentals of the stocks.

Predictions

Our basic hypotheses were derived from simple limits-to-arbitrage models, in which arbitrage capital is insufficient to offset the pricing effects of demand shocks. In the tradition of this literature, we considered a framework in which a broad class of securities is simultaneously traded for reasons unrelated to news about fundamentals but in which arbitrageurs are limited in their ability to bet against these trading shocks by the amount of risk that they can take. Because the technical details of our framework are presented in other papers, we outline only the basic predictions here.[3]

Consider a capital market that contains $N + K$ risky securities in fixed supply. N of these securities compose an equal-weighted security index, which corresponds to the methodology of the Nikkei 225. Two types of traders operate in the market—index traders and arbitrageurs. Arbitrageurs are myopic investors with exponential utility of wealth. Index traders invest randomly in the capital market but, most importantly, purchase securities in the index fund only in proportion to index weights. It may be useful to think of index traders as "category" investors, who buy and sell the index basket of securities but do not buy other stocks. In principle, all trading volume in this market comes from interactions between these index traders and the arbitrageurs.

In each period, information about the payoffs of the risky securities becomes available to investors. The information shocks are described by a two-factor model consisting of a market factor and an idiosyncratic factor. The covariance structure derived from the two-factor model can be referred to as the "fundamental covariance." There is no fundamental reason for index security returns to be more correlated than nonindex security returns.

Capital market equilibrium is obtained through the market clearing of security demands of index traders and arbitrageurs. Because index-trader demand is exogenous, price levels are determined by the willingness of arbitrageurs to absorb it. Index-trading shocks are not fully diversified away by risk-averse arbitrageurs and cause security prices to fluctuate more than can be justified by news about fundamentals.

To study changes in comovement of asset returns following redefinition of the index, we consider an event in which M index securities are replaced. We define the *remainder index return* as the equally weighted return of all securities that were in the index before the redefinition and remained in the index after the event. Because index demand shocks are the only source of trading volume, the trading volume of the deletions portfolio is perfectly correlated with the trading volume of the remainder index before the event, but after the event, the two volume series are uncorrelated. This idea is formalized in our first hypothesis.

> *Hypothesis 1. Following the redefinition event, additions (deletions) should experience increases (decreases) in the correlation of their trading volume with the trading volume of the remainders.*

Our next hypothesis describes how the betas and correlations of additions portfolio and deletions portfolio returns with the remainder stock returns should be affected by the index redefinition.

> *Hypothesis 2. Following the redefinition event, additions (deletions) should experience increases (decreases) in their return betas and correlations with the returns of the remainders.*

Our final hypothesis, not featured in existing research, was motivated by the idea that pricing effects from correlated investor demand should eventually subside. Thus, whereas security returns of index stocks should comove excessively in the short run, at long horizons, returns should revert to reflect fundamentals. The resulting effect would be negative first-order serial and cross-serial correlation of returns for index stocks.

Hypothesis 3. Following the redefinition event,
(1) autocorrelations should become more negative for the additions and less negative for the deletions and
(2) betas with respect to the lagged remainder index should become more negative for the additions and less negative for the deletions.

The predictions in Hypothesis 3 lead to the corollary that excess comovement should decline as the horizon increases. Thus, we expected our results to be stronger when changes in index beta were measured from daily returns than when changes were measured from weekly returns.

The Event: Nikkei 225 Redefinition

The Nikkei 225 is a widely followed stock index in Japan. Although time-series data on the tracking of the Nikkei are unavailable, Nomura Securities has estimated that more than ¥2.4 trillion (approximately US$23 billion) was benchmarked to the Nikkei as of April 2000. One explanation for the popularity of the index is that a liquid Nikkei 225 futures contract is traded on the Osaka Securities Exchange and the Chicago Mercantile Exchange. The importance of the index to investors can also be judged by examining average returns of stocks that are added to the index. Greenwood (2005) showed that additions to the Nikkei 225 experience average abnormal returns of more than 10 percent.

The newspaper *Nihon Keizai Shimbun* has maintained the index since 1970, following the discontinuation of the Tokyo Stock Exchange (TSE) Adjusted Stock Price Average. The index includes 225 stocks selected according to composition criteria set by the *Nihon Keizai Shimbun*. Although the index guidelines are strict, changes to index composition prior to the event we studied were infrequent—typically, one or two stocks a year.[4] Because the composition of the index had remained relatively fixed while the industrial composition of the stock market was changing, the correlation of the Nikkei with the market had fallen over time—from a daily return correlation of 95 percent in 1998 to 84 percent in the first quarter of 2000. With the aim of reviving the relevance of the index, on 14 April 2000, the *Nihon Keizai Shimbun* announced that changes in the "industrial and investment environments necessitated revision of rules covering selection of index components."[5] The change in criteria resulted in the substitution of 30 small-capitalization issues by 30 larger-cap stocks. The revision became effective at the start of trading on 24 April 2000.

The one-time redefinition caused a large amount of trading during the week between the announcement and implementation. The trading can be approximately summarized as follows. The additions became a larger share (in yen terms) of the new index than the deletions had taken in the old index. Accordingly, the weights of the stocks remaining in the index fell. The result was that investors tracking the index had to buy the additions and sell both the deletions and some fraction of the stocks remaining in the index. Greenwood (2005) described trading around the time of the redefinition.

In our analysis, we measured comovement of stock returns and volume in two ways. The first measure is the *index beta* from a univariate regression of an equal-weighted portfolio of additions and deletions on the index return. The second measure is the *correlation* between the returns of these two portfolios and the index return (equivalently, the square root of the R^2 from the univariate regression). Ideally, the fundamental characteristics of "the index" would not be affected by the redefinition. However, this is not true for the Nikkei 225 redefinition because the change in index composition mechanically induced changes in betas for all stocks. We got closer to the ideal experiment by constructing an index that included only the stocks that were in the Nikkei 225 before the event and remained in it after the event. Underlying this construction was the assumption that exposures of the remainders to fundamental risk factors did not change around the event. We then analyzed comovement by studying the beta and index correlation of additions and deletions with respect to an equal-weighted index of the remainders, not with respect to the Nikkei itself.[6] We dropped 9 of the 195 remaining stocks because of delisting, because of index removal, or because they were not in the index for long enough prior to the event. Thus, the remainder index was an equal-weighted group of 186 stocks that were present both before and after the event.

Tests and Results

We describe here the tests we carried out and the results for the comovement of turnover and stock returns of additions and deletions with the remainders. Then, we discuss changes in the time-series properties of returns of stocks affected by the redefinition. Finally, we explore changes in cross-serial correlations of additions and deletions with the remainder index.

Comovement of Turnover. We first tested whether after the event, trading of additions (deletions) became more or less correlated with trading of the remainders. Hypothesis 1 states that following the event, the additions (deletions) portfolio should experience an increase (decrease) in the correlation of its trading volume with the volume of the remainders.

Following Lo and Wang (2000), we used turnover (the number of shares traded divided by total number of shares) as a measure of volume. For each of the additions, deletions, and remainders, we calculated the number of shares traded daily divided by the total number of shares outstanding. We winsorized each turnover series at the 99th percentile to remove the largest outliers and then aggregated the data to form equal-weighted turnover for the additions, deletions, and remainders.[7] Because the resulting series was nonstationary, we followed Campbell, Grossman, and Wang (1993) and removed a lagged 200-day moving average from turnover.

To measure changes in the correlation of turnover before and after the Nikkei redefinition, we estimated the beta in the univariate regression of portfolio turnover on the equal-weighted turnover of the remainders:

$$V_{j,t} = \alpha_j + \beta_{REM,j} V_{REM,t} + u_{j,t}, \quad \text{where } j \in (\text{additions,deletions}), \tag{1}$$

in which

$V_{j,t}$ = equal-weighted turnover of stocks in portfolio j in period t

$V_{REM,t}$ = equal-weighted turnover of remainder stocks

$u_{j,t}$ = error term

We estimated Equation 1 on 300 trading days of data before and after the event. We also estimated correlations between the turnover of the additions (deletions) and the remainders in the same windows. The pre-event window began on 8 April 1999 and ended on 31 March 2000. The post-event window began on 3 July 2000 and ended on 21 August 2001. Our analysis thus left out a blackout period of data between 31 March and 3 July.[8] A crucial point is that we checked that none of the results that we present here was sensitive to the length of the window used to estimate beta.

For comparison, we constructed a matched sample of stocks for both the additions and deletions. For each of the additions or deletions, we selected a nonindex stock in the same industry with the closest market value of equity. We then computed equal-weighted turnover for the matched stocks and repeated the exercise described for the additions and deletions by estimating Equation 1 on the matched sample. Finally, we calculated a "hedge turnover" as the difference between addition (or deletion) portfolio turnover and matched portfolio turnover.

Panel A of **Table 1** shows the results of Equation 1 estimated with daily turnover data. The daily turnover beta of the portfolio of additions increased from 0.63 before the event to 1.20 after the event, a significant difference of 0.57. The matched sample did not experience any increase in comovement of turnover. The "Hedge portfolio" row shows by how much the betas of the additions portfolio changed relative to those of the matched portfolio.

The large changes in turnover beta may have been driven by time-varying volatility rather than a changing correlation, ρ, of trading activity, but the right-hand columns of the table demonstrate that this was not the case. The additions experienced large increases in turnover correlation, whereas the matched sample of stocks experienced only a small increase.

For turnover betas, the deletions showed an opposite pattern to the additions. The beta of the deletions dropped 1.31. The matched portfolio turnover beta fell only negligibly, from 0.24 to 0.19, over the same period. Panel A also shows that the change in beta was driven by a decline in correlation rather than an increase in volatility.

Panel B of Table 1 shows the estimation results based on 60 weeks of weekly data over the same pre- and post-event windows, and Panel C shows these results estimated from 24 months of monthly data. Daily regression results were confirmed at the weekly horizon. At the monthly horizon, the evidence of changes in turnover betas disappears, but the results still hold for correlations, although the economic magnitude and statistical magnitude of the changes in correlations are lower.

Comovement of Stock Returns. Hypothesis 2 states that if securities begin to trade in a more (less) correlated pattern, their returns should begin to comove more (less) because of trading shocks. **Table 2** shows slope coefficients and correlations from the regression of equal-weighted returns, $R_{j,t}$, of the 30 additions and deletions on the equal-weighted returns of the remainders, $R_{REM,t}$:

$$R_{j,t} = \alpha_j + \beta_{REM,j} R_{REM,t} + u_{j,t}, \quad \text{where } j \in (\text{additions,deletions}). \tag{2}$$

Pre- and post-event windows were defined as in Table 1 to include 300 days of returns before and after the event. Panel A shows that daily return betas of the additions increased by a statistically significant 0.45. An important point is that the

Table 1. Comovement with Remainders of Turnover of Stocks Added to and Deleted from Nikkei 225

	Beta				Correlation			
Sample	Pre-Event β	Post-Event β	Δβ	*t*-Statistic	Pre-Event ρ	Post-Event ρ	Δρ	*z*-Statistic
A. Daily turnover								
Additions	0.63	1.20	0.57	3.57	0.51	0.87	0.36	9.39
Matched sample	0.22	0.22	0.00	–0.01	0.91	0.94	0.03	2.57
Hedge portfolio	0.42	0.98	0.57	3.06	–0.28	0.36	0.64	8.10
Deletions	2.16	0.85	–1.31	–5.13	0.79	0.75	–0.03	–1.20
Matched sample	0.24	0.19	–0.05	–0.25	0.59	0.85	0.26	7.05
Hedge portfolio	1.92	0.66	–1.26	–4.44	0.47	–0.05	–0.52	–6.83
B. Weekly turnover								
Additions	0.38	1.24	0.87	3.97	0.54	0.86	0.32	8.40
Matched sample	0.17	0.27	0.10	0.29	0.90	0.94	0.04	3.24
Hedge portfolio	0.20	0.97	0.77	2.10	–0.38	0.29	0.67	8.51
Deletions	2.75	0.75	–2.00	–5.40	0.78	0.80	0.02	0.65
Matched sample	0.27	0.23	–0.03	–0.06	0.55	0.84	0.29	7.35
Hedge portfolio	2.49	0.52	–1.97	–3.50	0.42	0.09	–0.33	–4.36
C. Monthly turnover								
Additions	0.83	1.01	0.17	0.67	0.68	0.86	0.18	5.66
Matched sample	0.00	0.19	0.19	0.09	0.96	0.93	–0.03	–3.50
Hedge portfolio	0.84	0.82	–0.02	–0.01	–0.17	–0.03	0.14	1.73
Deletions	1.29	1.37	0.07	0.15	0.84	0.87	0.02	1.36
Matched sample	2.04	1.23	–0.80	–0.15	0.68	0.82	0.14	3.99
Hedge portfolio	–0.74	0.13	0.88	0.16	0.01	–0.09	–0.10	–1.22

Table 2. Comovement with Remainders of Returns of Stocks Added to and Deleted from Nikkei 225

	Beta				Correlation			
Sample	Pre-Event β	Post-Event β	Δβ	*t*-Statistic	Pre-Event ρ	Post-Event ρ	Δρ	*z*-Statistic
A. Daily returns								
Additions	0.56	1.01	0.45	2.31	0.56	0.86	0.30	8.05
Matched sample	0.75	0.81	0.05	0.39	0.93	0.94	0.01	0.97
Hedge portfolio	–0.19	0.20	0.39	2.06	–0.25	0.32	0.57	7.15
Deletions	1.47	0.85	–0.63	–2.89	0.81	0.75	–0.06	–1.88
Matched sample	0.60	0.84	0.24	1.28	0.64	0.83	0.19	5.24
Hedge portfolio	0.87	0.01	–0.86	–3.47	0.48	0.00	–0.48	–6.37
B. Weekly returns								
Additions	0.50	0.94	0.44	1.49	0.54	0.84	0.30	7.52
Matched sample	0.77	0.78	0.01	0.05	0.90	0.95	0.04	4.38
Hedge portfolio	–0.27	0.16	0.43	1.49	–0.38	0.18	0.56	7.09
Deletions	1.31	1.06	–0.26	–0.75	0.78	0.82	0.04	1.36
Matched sample	0.54	0.90	0.36	1.19	0.55	0.82	0.28	6.56
Hedge portfolio	0.77	0.16	–0.62	–1.43	0.42	0.22	–0.20	–2.73
C. Monthly returns								
Additions	0.57	0.79	0.22	0.64	0.67	0.84	0.17	5.00
Matched sample	0.76	0.75	–0.02	–0.06	0.97	0.93	–0.03	–5.29
Hedge portfolio	–0.19	0.05	0.24	0.73	–0.23	–0.10	0.13	1.63
Deletions	1.32	1.28	–0.05	–0.11	0.83	0.88	0.05	2.29
Matched sample	0.61	0.66	0.05	0.14	0.69	0.80	0.11	3.05
Hedge portfolio	0.71	0.62	–0.09	–0.18	0.07	–0.05	–0.12	–1.46

increase in beta was not driven by a reduction in the variance of remainder returns: The correlations between the returns of the additions and the returns of the remainders increased from 0.56 to 0.86.

A noted feature of the event was the difference in size and sector composition of the stocks composing the additions and deletions. The additions were primarily large-cap stocks that had experienced high positive returns during the past few years, and they were primarily in such industries as banking and electronics. The deletions were small-cap stocks that had experienced low returns and declines in liquidity during the years prior to the event. A detailed industrial breakdown of the additions and deletions is provided in **Exhibit 1**. The differences in size and sector composition of additions and deletions are important only to the extent that the change in betas may have been driven by exposure to factors related to company characteristics.

Out of concern that the results were driven by time variation in the correlation among unobserved factors, we constructed matching portfolios of stocks for the additions and deletions in the same way as in Table 1. Thus, the matching portfolio for the additions was the equal-weighted return of 30 stocks matched to the additions. We then reestimated Equation 2 for the matching portfolio as well as for the portfolio that was long the additions (or deletions) and short the matching portfolio, the "hedge portfolio."

Panel A of Table 2 shows that, for daily data, the beta of the matched sample of additions rose only modestly (from 0.75 to 0.81) whereas the increase in beta for the additions was 0.45. The deletions experienced an opposite pattern. Whereas their beta declined by 0.63, the beta of the matched sample increased by 0.24. Panel A also

Exhibit 1. Sector Composition of Additions to and Deletions from Nikkei 225 on 21 April 2000

TSE Code	Company	Sector	TSE Code	Company	Sector
Additions					
2914	Japan Tobacco	Foods	7270	Fuji Heavy Industries	Auto/Auto parts
4452	Kao	Chemicals	8035	Tokyo Electron	Trading companies
4505	Daiichi Pharmaceutical	Pharmaceuticals	8183	Seven-Eleven Japan	Retailing
4523	Eisai	Pharmaceuticals	8264	Ito Yokado	Retailing
4543	Terumo	Pharmaceuticals	8267	Jusco	Retailing
6762	TDK	Electronics	8302	IBJ	Banking
6767	Mitsumi Electric	Electronics	8319	Daiwa Bank	Banking
6781	Matsushita Comm.	Electronics	8321	Tokai Bank	Banking
6857	Advantest	Electronics	8355	Shizuoka Bank	Banking
6952	Casio Computer	Electronics	8403	Sumitomo Trust and Banking	Banking
6954	Fanuc	Electronics	8404	Yasuda Trust and Banking	Banking
6971	Kyocera	Electronics	8753	Sumitomo Marine and Fire	Insurance
6976	Taiyo Yuden	Electronics	9020	East Japan Railway	Railroads/Buses
6991	Matsushita Elec. Works	Electronics	9433	DDI	Telecomm.
7211	Mitsubishi Motors	Auto/Auto parts	9437	NTT Docomo	Telecomm.
Deletions					
1331	Nichiro	Fisheries	5331	Noritake	Glass
1501	Mitsui Mining	Mining	5351	Shinagawa Refractories	Glass
1503	Sumitomo Coal Mining	Mining	5479	Nippon Metal Industry	Iron and Steel
2108	Nippon Beet Sugar	Foods	5480	Nippon Yakin Kogyo	Iron and Steel
2601	Honen	Foods	5563	Nippon Denko	Iron and Steel
3104	Fuji Spinning	Textiles	5632	Mitsubishi Steel Mfg.	Iron and Steel
3403	Toho Rayon	Textiles	5721	Shimura Kako	Nonferrous metals
4022	Rasa Industries	Chemicals	5805	Showa Electric Wire	Nonferrous metals
4064	Nippon Carbide	Chemicals	5981	Tokyo Rope Mfg.	Nonferrous metals
4092	Nippon Chemical	Chemicals	6461	Nippon Piston Ring	Machinery
4201	Nippon Synth. Chemical	Chemicals	8061	Seika	Trading companies
4401	Asahi Denka Kogyo	Chemicals	8088	Iwatani International	Trading companies
4403	NOF Corporation	Chemicals	8236	Maruzen	Retailing
5105	Toyo Tire and Rubber	Rubber	9065	Sankyu	Land transportation
5302	Nippon Carbon	Chemicals	9302	Mitsui-Soko	Warehousing

shows that the correlation of hedged portfolio returns with the returns of the remainders increased following the event.

Panel B of Table 2 shows that for the additions, both the correlation and the slope coefficient increased when weekly data were used, although the increase is less than it was in the daily data. Results for the deletions are statistically insignificant on their own but increase in magnitude when compared with results for the matched sample. The monthly horizon results, shown in Panel C, are weak for both additions and deletions. These weaker results at longer horizons are not surprising: We would expect demand-driven comovement to be more important at short horizons but fundamentals to dictate prices in the long run.

So far, we have verified our two key predictions, namely, that both the volume and returns of stocks included in (deleted from) a stock index experience statistically significant increases (decreases) in comovement with the remainder stocks in the index. We also found that the effect of the change in the trading pattern is strong at high frequencies but disappears as the return horizon increases. In the next two sections, we take a careful look at the time-series properties of stock returns following index addition and deletion.

Time-Series Properties of Returns and Nonsynchronous Trading. Hypothesis 3 posits that changes occur in autocorrelations and cross-serial correlations following a change in index membership. For individual stocks, autocorrelations should fall after index addition and increase after index deletion. These predictions are in contrast to what one would expect if index membership *increased* the speed at which security prices incorporated new information.[9]

Table 3 shows the *variance ratios* for daily and weekly returns of additions and deletions. The variance ratio (VR) is the ratio of volatility of returns aggregated over several periods to the volatility of a one-period return. For example, if prices are mean reverting, the volatility of multiperiod returns will be low relative to that of one-period returns, yielding a low VR. The advantage of the VR over autocorrelation as a statistic is that it conveniently summarizes time-series dynamics of returns over several periods into one number.

We calculated VRs individually for each addition and deletion, rather than at the portfolio level, and compared average VRs of the groups. By analyzing the stocks individually, we avoided the possibility that changes in cross-serial correlations might affect portfolio-level autocorrelations.

The VR of stock i for returns aggregated over q periods is given by

$$VR_i(q) = \frac{\sum_{t=q}^{T}\left[\sum_{s=0}^{q-1}\left(r_{i,t-s}\right) - q\bar{r}_i\right]^2}{\sum_{t=1}^{T}\left(r_{i,t} - \bar{r}_i\right)^2} \times \left[\frac{T-1}{q(T-q-1)(1-q/T)}\right], \quad (3)$$

where T is the sample-period size and $\bar{r}_i$ is the average return of stock i. Values lower than 1 indicate negative autocorrelation of returns.

Table 3. Variance Ratios for Additions and Deletions before and after the Redefinition (*t*-statistics in parentheses)

	Additions (N = 28)					Deletions (N = 30)				
VR	Pre-Event	Post-Event	Δ	Matched Δ	Difference ΔΔ	Pre-Event	Post-Event	Δ	Matched Δ	Difference ΔΔ
A. Daily										
VR(2)	1.018	0.966	–0.052	–0.014	–0.038	0.835	0.953	0.119	–0.022	0.141
			(–3.71)	(–0.74)	(–1.66)			(6.32)	(–1.65)	(5.67)
VR(3)	0.988	0.937	–0.051	–0.044	–0.007	0.779	0.925	0.145	–0.062	0.208
			(–2.55)	(–1.68)	(–0.19)			(6.44)	(–2.65)	(5.86)
VR(4)	0.940	0.907	–0.032	–0.048	0.015	0.739	0.915	0.177	–0.064	0.241
			(–1.16)	(–1.68)	(0.35)			(6.53)	(–2.10)	(5.71)
B. Weekly										
VR(2)	0.932	0.884	–0.048	–0.009	–0.039	0.866	0.921	0.055	–0.059	0.114
			(–1.40)	(–0.27)	(–0.91)			(1.70)	(–1.91)	(2.95)
VR(3)	0.894	0.839	–0.055	0.050	–0.105	0.730	0.964	0.234	–0.049	0.282
			(–1.25)	(1.39)	(–2.10)			(5.07)	(–1.07)	(6.03)

Notes: $VR(q)$ denotes the variance ratio computed for aggregation parameter q. The paired-sample t-statistic tests the hypothesis that the change in the VR of the additions and deletions is significantly different from the change in the VR of the matched sample.

Lo and MacKinlay (1999, p. 54) provided the following intuitive representation of the VR as a linear combination of kth-order autocorrelations, $\rho(k)$:

$$VR_i(q) - 1 \approx \frac{2(q-1)}{q}\hat{\rho}(1) + \frac{2(q-2)}{q}\hat{\rho}(2) + \ldots + \frac{2}{q}\hat{\rho}(q-1). \quad (4)$$

For example, $VR(2)$ is approximately 1 plus the first-order autocorrelation of returns.

Table 3 compares average VRs before and after the event for the additions, deletions, and a matched set for each. Because our theory suggests that trading shocks affect returns only at short horizons, we restricted our attention to the first three autocorrelations in daily returns and the first two autocorrelations in weekly returns—that is, according to Equation 4, VR(2) through VR(4) for daily returns and VR(2) and VR(3) for weekly returns. Panel A is based on daily data; Panel B, on weekly. Consistent with our basic predictions, both panels show that the serial correlations of returns became more negative for additions and less negative for deletions after the event. For the additions, the first-order autocorrelation decreased by 5 percent at the daily level (Panel A). The first-order autocorrelation of the matched sample fell by only 1 percent over the same interval. The difference between the additions and the matched sample is marginally significant. In contrast, the first-order autocorrelation of the deletions increased by 12 percent, compared with –2 percent for the matched sample. The difference between these two samples is highly significant.

Panel B of Table 3 shows that the first-order autocorrelation estimated from weekly returns decreased for the additions, although this decrease is not significantly different from the corresponding change in the matched sample. For the deletions, the results weakened when returns were measured at weekly intervals, although they remain significant.

Can these changes be explained by nonsynchronous trading? In theory, estimated autocorrelations could be affected by a nontrading bias. In practice, however, the observed changes in the autocorrelations of the additions and deletions are unlikely to be caused by a time-varying nonsynchronous trading bias. Lo and MacKinlay (1999, Chapter 4) suggested that negative autocorrelations generated by nonsynchronous trading should be quite small. For plausible changes in trading frequency, one can expect changes in autocorrelation substantially lower than 1 percent. Additionally, under the assumption that trading frequency should *increase* for additions and *decrease* for deletions, the autocorrelations should become *less* negative for additions and *more* negative for deletions, contrary to what is observed in Table 3.

Although nonsynchronous trading cannot explain the changes in the autocorrelations, index demand shocks can. Information shocks have permanent effects on security prices, whereas demand shocks subsequently revert through the actions of arbitrageurs. Therefore, as the magnitude of demand shocks relative to information shocks increases, securities should exhibit higher negative autocorrelation, exactly as found in our data.

Changes in Cross-Serial Correlations. The nonsynchronous trading hypothesis cannot explain the changes in autocorrelation, but can it explain some of the changes in beta? To answer this question, we considered cross-serial correlations. If returns used to estimate stock betas are measured at a high frequency, the OLS beta may not be a consistent estimator of the true beta because of a nonsynchronous trading bias. A plausible conjecture is that the Nikkei redefinition increased the trading frequency of additions and decreased the trading frequency of deletions. If nonsynchronicity is an issue, then according to Scholes and Williams (1977) and Lo and MacKinlay (1999, Chapter 4), an increase in trading frequency should lead to additions (deletions) incorporating information faster (slower). As a result, lagged betas with respect to the remainder portfolio should decrease for additions and increase for deletions. Hypothesis 3 postulates a similar qualitative change in betas of additions and deletions but suggests that the cause is the change in their exposure to index trading.

These alternative hypotheses are important because of the implications they have for the effects of indexation on market efficiency. If short-term comovement is a result of demand shocks, then index trading induces predictable reversion of returns, reducing overall efficiency. Alternatively, if the change in short-term comovement is driven by the speed at which stocks incorporate information, index membership increases efficiency. Unfortunately, lagged betas by themselves do not allow one to distinguish between the nonsynchronicity hypothesis and the index-trading hypothesis because both predict changes in lagged betas in the same direction. In the light of the compelling evidence presented in previous sections, however, we believe that index trading is at least partially responsible for the changes in lagged betas that we will describe.[10]

Table 4 shows the results of OLS regressions of hedged portfolio returns of the additions and deletions, $R_{j,t}$, on once- and twice-lagged remainder returns, $R_{REM,t-1}$ and $R_{REM,t-2}$:

$$R_{j,t} = \alpha_j + \gamma_{1,j} R_{REM,t-1} + u_{j,t}, \quad \text{where } j \in (\text{additions,deletions}) \tag{5}$$

and

$$R_{j,t} = \alpha_j + \gamma_{1,j} R_{REM,t-1} + \gamma_{2,j} R_{REM,t-2} + u_{j,t}, \quad \text{where } j \in (\text{additions,deletions}). \tag{6}$$

Panel A of Table 4 shows the results for the additions. Before the event, returns of the additions were positively autocorrelated and positively correlated with lagged remainder returns. After the event, the additions showed a highly significant negative correlation with the lagged remainder return. The difference between γ_1 before and after the event is negative and significant. In the second specification (Equation 6), we found that the change in cross-serial correlations was slightly stronger if we allowed for an additional lag. A back-of-the-envelope calculation suggests that nearly half of the increase in beta reverted within two days ($\Delta\beta = 0.39$ from Table 2, $\Delta(\gamma_1 + \gamma_2) = -0.18$ from Table 4; 0.18/0.39 = 46 percent).

Panel B shows corresponding results of the OLS regression for the deletions. Before the event, the returns of the deletions were negatively correlated with lagged returns of the remainders. After the event, these cross-serial correlations became significantly positive. Table 2 shows that the excess comovement among the deletions greatly strengthened ($\Delta\beta = -0.86$) after deletion, and the reversion appears to have been rapid. About a third of the decrease in beta reverted within two days (from Table 4, $\Delta(\gamma_1 + \gamma_2) = 0.27$; 0.27/0.86 = 31 percent).

As we argued, partial reversion of the change in daily beta is not necessarily an indication of a nonsynchronicity bias in daily beta estimates. It is also consistent with our index-trading hypothesis. The fact that we observe an increase in the beta of additions and a decrease in the beta of deletions at longer horizons suggests that index trading plays an important role in price formation. Given the additional evidence on the importance of index trading presented here, at least a fraction of the change in lagged betas should be explained by correlated index trading.

Conclusion

We developed a set of simple predictions concerning the excess comovement of stock returns from a model in which arbitrage capital is limited. According to our predictions, shocks to index demand should be reflected for index stocks in comovement of trading volume, excess correlation among stock returns, and a negative effect on autocorrelations and cross-serial correlations of stock returns. We argued that these patterns should be present among constituents of stock indices because investors tend to categorize them together and trade them as a group. As a result, comovement with the index should change in a predictable way when stocks are added to and deleted from the index.

Table 4. Cross-Serial Correlations: 300 Days of Daily Data
(*t*-statistics in parentheses)

	Pre-Event			Post-Event			Differences		
N(Lags)	γ_1	γ_2	$\gamma_1 + \gamma_2$	γ_1	γ_2	$\gamma_1 + \gamma_2$	$\Delta\gamma_1$	$\Delta\gamma_2$	$\Delta(\gamma_1 + \gamma_2)$
A. Additions									
1	0.02			–0.09			–0.11		
	(0.47)			(–2.51)			(–2.05)		
2	0.04	0.03	0.07	–0.09	–0.02	–0.12	–0.14	–0.05	–0.18
	(1.37)	(0.73)	(1.40)	(–2.53)	(–0.60)	(–2.28)	(–2.82)	(–0.94)	(–2.61)
B. Deletions									
1	–0.15			0.14			0.29		
	(–1.23)			(2.60)			(2.19)		
2	–0.15	0.10	–0.05	0.15	0.07	0.22	0.29	–0.02	0.27
	(–1.22)	(0.79)	(–0.25)	(2.62)	(1.40)	(2.88)	(2.21)	(–0.18)	(1.27)

Notes: See Equations 5 and 6. The dependent variable is the equal-weighted return on the additions or deletions, net of the return on a portfolio of matches. The last column is the change in the sum of the slope coefficients from the bivariate regression between the post- and pre-event periods. Standard errors on changes in coefficients (in the last column) were computed under the assumption that pre- and post-event regression errors are independent.

The April 2000 redefinition of the Nikkei 225 was an ideal natural experiment for testing our hypotheses. The tests provided remarkably strong support for the theory. Following this event, additions began to move with other index securities much more than previously and the deletions began to move with other index securities much less. The changes in comovement were reflected in the return and turnover betas with respect to the remainder stock index and in the changes in correlations. We verified that the results were not driven by characteristics of the added and deleted companies, such as size or industrial sector. Most interestingly, our data showed that upon inclusion in a stock index, a stock's pricing process becomes less efficient; in our tests, returns to additions caused by excess short-run comovement with the remainders predictably reverted. Symmetrical results held for the deletions.

One implication of our results is that short-term shocks to index demand add to the transaction costs of index investing. This finding is consistent with recent work by Chen, Noronha, and Singal (2006) showing that index redefinitions cause losses to index fund investors that are trying to minimize tracking error.

Another implication of this research relates to risk models. Risk models use exposures to industries and fundamental factors to forecast volatilities and correlations of tradable assets. Our findings suggest that index membership might be an additional characteristic relevant for risk estimation—especially for models geared toward higher-frequency returns.

In general, our evidence suggests that, although demand shocks are pervasive determinants of stock returns in the short run, the forces of arbitrage cause comovement to revert in a relatively short time. We hope that subsequent research will shed more light on the speed at which arbitrage causes reversion in these pricing distortions. Important work also remains to be done on the relationship between index construction methodology and the effects of index demand shocks on security prices.

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This article qualifies for 1 PD credit.

Notes

1. The immediate change in beta around the event is a result of high returns to the additions driven by institutional rebalancing. While purchasing additions, institutions were also selling deletions and remainders, driving down their prices. Note in Figure 2 that the consequences of the redefinition lasted for 300 trading days, after which the redefinition left the window used to estimate beta.
2. See also Beneish and Whaley (1996); Lynch and Mendenhall (1997); Kaul, Mehrotra, and Morck (2000); Wurgler and Zhuravskaya (2002); Denis, McConnell, Ovtchinnikov, and Yu (2003); Chen, Noronha, and Singal (2004).
3. For example, Barberis et al. (2003); Greenwood and Sosner (2003).
4. We attempted to track down additional inclusions and deletions after 1990 but found that most of the deletions were subsequently delisted. Additional information on this redefinition and all changes in the composition of the Nikkei indices can be found on the Nihon Keizai Net web page (www.nni.nikkei.co.jp/).
5. See www.nni.nikkei.co.jp/FR/SERV/help/npr0010.html.
6. Because the actual index included the deletions before the event and the additions after the event, our results on comovement are mechanically stronger for comovement with the actual index than with the remainder index. We also experimented with replacing the remainder return with a price-weighted remainder return, which we constructed by using only the remainder stocks but with weights given by their actual Nikkei 225 weights. These results were stronger than those reported in the article.
7. "Winsorizing" sets the most extreme values to the values at the 99th percentile of the distribution.
8. We left out these data so that our results would not be contaminated by short-term correlations of volume that might have arisen from rebalancing by institutional investors as they attempted to match the new index.
9. See, for example, Scholes and Williams (1977) and Chapter 4 in Lo and MacKinlay (1999).
10. Additional evidence that index membership reduces pricing efficiency is given in Greenwood (forthcoming 2007).

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