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Index tracking and beta arbitrage effects in comovement☆

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ABSTRACT

This paper develops a stylised model for S&P 500 index changes with two beta-based styles: index trackers and beta arbitrageurs who trade in both high and low beta event stocks to exploit mean reversion towards one. Arbitrageurs engage in common or contrarian trading patterns relative to index funds depending on whether historical betas are below or above one. Thus, the overall comovement effect has two distinct components. After index additions, pre-event low beta stocks drive the overall beta increases due to common demand – albeit for different reasons - from indexers and arbitrageurs. By contrast, arbitrageur shorting of high beta additions diminishes or sometimes reverses the beta increases for these stocks driven by indexers. Analogous results hold for index deletions.

1. Introduction

Barberis, Shleifer, and Wurgler (2005) (hereafter, BSW) pioneered a comovement approach to the study of S&P 500 index changes based on the presumption that the beta increases following index inclusion events are mostly unrelated to changes in fundamentals.[1] They posit that these increases can be rationalised by non-fundamental factors such as style (category) or preferred habitat (clientele) effects or by slow information diffusion.[2] The BSW paper sparked a number of related empirical studies supporting and challenging their viewpoint for both the US and other countries. Claessens and Yafeh (2013) found support for significant post-addition (daily) beta increases in most of their sample of 40 developed and emerging country indexes 2001–2010.[3] Like BSW, they establish that category or habitat views can explain most of their findings, but information diffusion also plays some role.[4] Chen, Singal, and Whitelaw (2016) interpret comovement as an asset class effect. Greenwood (2008) refer to the preferred habit and category views as a demand-based effect reflecting index funds demand for added stocks.[5]

It is difficult to explain salient aspects of comovement within the simple BSW framework. Chen et al. (2016) were the first to recognise this and extended the BSW framework to compare the comovement of the added stocks with both S&P 500 and non-S&P 500 stocks. Employing robust univariate daily regressions, they argue that most evidence of excess comovement disappears and that added stocks behave like momentum winners.[6] This paper's first contribution is that it extends the Chen et al. (2016) framework in a different direction. It drills down to

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[1] There is also a separate literature on price movements around index changes. See, for example, Harris and Gurel (1986), Shleifer (1986), and Wurgler and Zhuravskaya (2002).

[2] See Barberis and Shleifer (2003) for more discussion on style investing.

[3] For more supportive evidence on return comovement, see Greenwood (2008) and Greenwood and Sosner (2007) for Japan, Chelley-Steeley and Steeley (1999) for Europe, and Mase (2008) for the UK.

[4] The concept of comovement has been applied to other assets – consider the discussion of the financialisation of commodities by Tang and Xiong (2012) - and other investment styles. Related research includes Li, Yin, and Zhao (2020) on program trading as an investment habitat, Boyer (2011) on S&P/Barra value and growth indexes, Green and Hwang (2009) on stock splits, and Kumar and Lee (2006) on stocks with correlated retail investor trading.

[5] Comovement involving other approaches has occasionally been considered by the literature. See, for example, the Hameed and Xie (2018) study based on dividend preference.

[6] See also Kasch and Sarkar (2014) and von Drathen (2014) for critiques of comovement.

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allow for another class of investors – beta arbitrageurs – that trade on the assumption that betas tend to mean regress towards one in the long run.[7] Beta arbitrageurs are active investors such as hedge funds whilst index trackers are passive investors like some exchange-traded funds (ETFs).[8] Their behaviour directly impacts on event stocks' beta changes around the announcement date and after the implementation date. Since they can potentially use leverage to achieve high alphas, their portfolios can overweight low-beta stocks and underweight or short high-beta added stocks and this leads to separate post-index addition patterns for low- and high-beta added stocks.

Our comovement model that newly allows for two styles, provides a rich set of new hypotheses to be tested. It postulates that low beta additions drive the overall BSW index inclusion effect as both index trackers and arbitrageurs take common long positions. The reason is that the investment strategies of both indexers and beta arbitrageurs are complementary in these cases. For instance, common buying of low beta added stocks leads to more pronounced beta increases for these stocks, especially for arbitrageurs who can take leveraged long positions. Similarly, high beta index deletions are more likely to produce the negative stock deletion effect as both indexers and arbitrageurs sell and/or take short positions. Our model produces novel comovement predictions for high beta index additions and low beta deletions as beta arbitrageurs and indexers can potentially take contrasting positions. For high beta additions, it predicts that indexer buying and arbitrageur shorting leads to offsetting effects. The overall effect is non-positive (zero or negative) beta changes. Analogously, for low beta deletions, it predicts that indexer selling and (leveraged) arbitrageur long positions also have contrary effects. It predicts that the overall effect is non-negative (zero or positive) beta changes in this instance also.

The paper's second contribution is that produces a novel set of significant empirical results at both daily and monthly frequencies. This contrasts with most studies such as Chen et al. (2016) that employ analysis at the daily level only. The monthly comovement results are both highly significant and economically meaningful. They explain the insignificant BSW monthly results in terms of their sample being truncated in 1998 (the first year of the dot.com boom).[9] Extending their estimation period 1976–1998 to 1976–2000, the number of S&P additions increases by some 83 (i.e., 24.4%) and the mean monthly beta change for additions is now 0.125 and significant at the 1% level. The implication of our monthly results is that comovement is a long run phenomenon and our results are inconsistent with the BSW interpretation that comovement due to fundamentals explains a larger fraction of monthly beta changes than daily beta changes.

Our predictions are tested using a sample of 733 and 671 S&P 500 additions at the daily and monthly frequencies, respectively; whilst the deletions sample contains 192 and 154 observations at the daily and monthly frequencies, respectively. The additions sample spans the 1976–2015 period and the deletions sample the 1979–2015 period.[10] Overall, we find significant comovement effects or beta increases of 0.128 and 0.105 for the daily and monthly additions, respectively. Note however that these are the weighted average of a typically larger increase for defensive stock additions but no change for their aggressive stock counterparts. Below we focus discussion on the monthly results because this is the first paper to report and explain significant monthly results and because these results are more striking than the daily results. We suggest that this is because style sentiment is not just a short run (daily or weekly) phenomenon as BSW conclude from their insignificant monthly comovement results.

The first monthly effect we reveal is a substantial and highly significant index inclusion impact of 0.345 for the 261 pre-event defensive stocks 1976–2015. This is more than three times larger than the overall comovement effect of 0.105. The beta change for the remaining 410 high beta stocks is statistically insignificant due to the opposing positions taken by indexers and arbitrageurs. Whilst indexers have to buy these added stocks after the official index change implementation date, arbitrageurs are not constrained in this respect. Thus, they can buy these stocks cheaply prior to the index change announcement as part of a leveraged low beta style. In summary, the rather small overall monthly comovement effect of 0.105 is the weighted average of two contrasting effects: a large index inclusion effect of 0.345 for defensive stock additions and an insignificant effect for high beta additions where indexer and arbitrageur actions offset one another. More interestingly, post-deletion daily and monthly betas are both statistically significant at the 5% level and can be rationalised in an analogous fashion. These results contrast sharply with the BSW insignificant deletion results at the daily, weekly, and monthly frequencies for their shorter 1979-1998sample period.

The remainder of this paper is thus organized: Section 2 presents a new extended theoretical model and outlines a series of hypotheses to be tested. Section 3 discusses the data and empirical methodology, whilst Section 4 presents the full sample and subsample results. A final section concludes.

2. A stylised comovement model

The extant comovement literature has assumed that the beta changes around index inclusions (deletions are downplayed) are driven by the demand from indexers wishing to rebalance their portfolios. Thus, an asset class demand-based view of index additions has emerged (Chen et al., 2016). This ignores the role of beta arbitrageurs who can trade added or deleted stocks as part of their strategy.[11] These arbitrageurs can exploit the predictable behaviour of passive indexers who are leveraged constrained and also prevented from adjusting their portfolios until after the official implementation of index changes. Moreover, arbitrageurs can use either short or leveraged long positions to arbitrage the long run tendency of betas to mean revert towards one depending on whether the index additions are high or low beta stocks by, for instance, adopting elements of a defensive equity strategy (Black, 1972; Jensen, Black, & Scholes, 1972).[12]

Below we extend the Chen et al. (2016) framework by outlining a stylised comovement model with two sets of investors: indexers and beta arbitrageurs. The objective is to develop a model for newly added and deleted index stocks that can help explain both positive and negative post-addition beta changes following index changes. We also solve the model for the betas of deleted stocks and test its predictions.

[7] Although examining announcement excess returns, rather than comovement, Vijh and Wang (2022) note the importance of considering other investors (i.e., active fund managers) as well as passive index funds.

[8] There is little research on the providers of liquidity to index trackers. Interestingly Chang, Hong, and Liskovic (2015) identify the role of hedge funds in this context.

[9] We replicate the insignificant BSW monthly beta change of 0.042 for 324 additions with another insignificant coefficient of 0.036 for 340 additions, where both are estimated over the 1976–1998 period.

[10] The deletions samples are smaller for reasons such as companies being involved in M&As, ceasing trading or opting to go private.

[11] It also ignores the role of liquidity suppliers like hedge funds. To our knowledge, there is no evidence on these in the context of the S&P 500 changes. However, Chang et al. (2015) have identified hedge funds in this role in the context of Russell 1000 and 2000 index changes.

[12] Baker, Bradley, and Wurgler (2011) show that this strategy produces significantly positive risk-adjusted returns.

2.1. Comovement and indexing

Consider a general comovement framework in the spirit of the BSW and Chen et al. (2016) univariate models:

$$r_t = b_{rt}f_t + c_{1t}u_{1t} + c_{2t}u_{2t} + e_{rt} \quad (1)$$

$$x_{1t} = b_{1t}f_t + u_{1t} + e_{1t}$$

$$x_{2t} = b_{2t}f_t + u_{2t} + e_{2t}$$

where r_t represents the return on an individual stock that is changing membership between group 1 (non-index stocks in the case of S&P 500 additions) with group return x_{1t}, and group 2 (index stocks), with group return x_{2t}. In this model, returns on (individual and group) stocks are determined by f_t, the fundamental, common return shock, group-specific non-fundamental return shocks, u_{it},and an idiosyncratic return shock, e_{it}. We assume:

$$var(e_{it}) \equiv \sigma^2_{eit}, var(u_{it}) \equiv \sigma^2_{uit}, var(f_t) \equiv \sigma^2_{ft} \quad (2)$$

$$cov(u_{1t}, u_{2t}) = 0$$

$$cov(u_{it}, f_t) = cov(e_{it}, f_t) = cov(u_{it}, e_{jt}) = 0 \forall i, j$$

Chen et al. (2016) suggest that the excess comovement hypothesis can be encapsulated by the sensitivities (i.e., the c_{it}) of individual stocks in (1) to the group-specific non-fundamental return shocks, u_{it}. In this context, the positions of beta arbitrageurs are driven both by fundamentals and the predictable behaviour of passive funds who have to adjust their portfolios due to category changes. Their short and leveraged long positions impact on u_{it} in our model and this differentiates it from the Chen et al. (2016) model for stock additions.

In particular, employing underbars and overbars to designate loadings before and after a stock switches from non-index status to index inclusion, excess comovement implies:

$$\underline{c}_{1t} = \underline{c}_1 > 0 \text{ and } \underline{c}_{2t} = \underline{c}_2 = 0 \quad (3)$$

$$\overline{c}_{1t} = \overline{c}_1 = 0 \text{ and } \overline{c}_{2t} = \overline{c}_2 > 0 \quad (4)$$

In other words, when a stock is allocated to a particular group, it becomes positively correlated with that group's non-fundamental return shock such as sentiment, whilst becoming uncorrelated with the non-fundamental returns shock of the group it has departed. For example, a stock newly entering the S&P 500 will not only become more prominent, but it will also be purchased by indexers and beta arbitrageurs, driving an increased correlation between that stock and the index. Leveraged long arbitrageur positions in low beta added stocks can exacerbate the beta increases for these stocks as we see in the next subsection.

2.2. Comovement with indexers and beta arbitrageurs

Beta arbitrageurs focus on extremely low or high beta stocks as these offer the possibility of greatest profits as their betas slowly mean revert towards one. Thus they divide all index event stocks into low and high beta groups based on their mean historical beta. Since they can use leverage to achieve higher alphas, their portfolios are based on overweighting pre-event low-beta (defensive) stocks and underweighting or shorting high-beta or aggressive stocks. It follows that their correlated trading may increase excess comovement for low beta added stocks while their contrarian (relative to index investors) trading may anomalously reverse it for high beta added stocks.

Passive funds hold portfolios to track the S&P 500 and have to rebalance when the index changes. The model setup for return on stocks must be adjusted when changes to the index are announced and some new target stocks are to be included. Before the announcement, arbitrageurs are pursuing their beta strategy.[13] They will target low and high beta (rather than those with betas close to 1) stocks among the S&P additions.[14] This implies that comovement between such stocks is jointly determined by these two styles. In that case, the loadings of individual stocks on the group-specific non-fundamental returns shocks can be written as:

$$c_{2t} = c^{index}_{2t} + c^{arb}_{2t} \quad (5)$$

where c^{index}_{2t} is the sensitivity driven by index trackers, whilst c^{arb}_{2t} reflects the sensitivity due to (beta) arbitrageurs. In our model both c^{index}_{2t} and c^{arb}_{2t}impact on the group-specific non-fundamental return shocks, u_{it}, and this clearly differentiates our model from that of Chen et al. (2016).

In terms of post-addition sensitivities to S&P 500 index tracking behaviour, we assume that analogously to (4):

$$\overline{c}^{index}_{2t} = \overline{c}^{index}_2 > 0. \quad (6)$$

In other words, $\overline{c}^{index}_{2t}$ is always positive due to the index inclusion effect. However, given that arbitrageur strategies are conditional on historical betas, the crucial insight is that $\overline{c}^{arb}_{2t}$ varies in sign depending on the leg (underweighting high beta or overweighting low beta stocks) of the arbitrage strategy being applied to event stocks. For target event stocks (index additions) with low (below mean) historical betas, the assumption is:

$$\overline{c}^{arb}_{2t} = \overline{c}^{arb}_2 > 0 \Rightarrow \overline{c}_{2t} = \left(\overline{c}^{index}_2 + \overline{c}^{arb}_2\right) > 0 \quad (7)$$

This is because the correlated excess demand and trading for the same low beta stocks by both index trackers and arbitrageurs is self-reinforcing with respect to its impact on their betas. This is consistent with a more pronounced index addition effect for such stocks.

By contrast, for target added stocks with high historical betas, shorting by arbitrageurs implies:

$$\overline{c}^{arb}_{2t} = \overline{c}^{arb}_2 < 0 \quad (8)$$

In this case, arbitrageur and indexer trading has conflicting impacts. In particular, if indexer demand is less than the supply from arbitrageurs wishing to short high beta stocks then:

$$\overline{c}_{2t} = \left(\overline{c}^{index}_2 + \overline{c}^{arb}_2\right) < 0 \quad (9)$$

The implication is that aggressive shorting by arbitrageur investors can result in falling betas for added stocks with high historical betas. Thus, the impact of two opposing investment styles results in our first novel prediction of non-positive beta changes for high beta added stocks.

What about deleted stocks? The conventional assumption is that stocks deleted from the index are in excess supply - index trackers have to sell these - and so analogously to (3):

$$\underline{\underline{c}}^{index}_{2t} = \underline{\underline{c}}^{index}_2 = 0 \quad (10)$$

where the double underbars represent a deleted stock. For instance, high beta deleted stocks may be the subject of active shorting by arbitrageurs ahead of the announcement date. Hence, the latter and indexer selling will drive down the prices of high beta deleted stocks leading to pronounced falling post-deletion betas. Equally, defensive deleted stocks may also attract demand from arbitrageurs after the implementation date when their prices have fallen. Indeed, if these stocks are part of leveraged arbitrage positions, then the positive arbitrage effect can

[13] While passive funds are prevented from adjusting their portfolios until on or after the index announcement date, no such constraints apply to hedge funds. Indeed, Matovic and Coakley (2020) find that significant Bloomberg searches on index changes begin seven working days ahead of the announcement date.

[14] In principle, they could choose to sell them at a profit to S&P 500 index trackers or continue to hold to take advantage of the price increase from indexer demand. We assume the latter.

prevail over the usual indexer deletion effect. Hence, the net impact can be:

$$\underline{\underline{c}}_{2t}^{arb} = \underline{\underline{c}}_{2}^{arb} > 0 \Rightarrow \underline{\underline{c}}_{2t} = \left(\underline{\underline{c}}_{2}^{index} + \underline{\underline{c}}_{2}^{arb}\right) > 0 \tag{11}$$

Our second novel comovement effect involves non-decreasing or increasing betas from leveraged arbitrageur demand for defensive deleted stocks. Note the latter will be in excess supply and so can be acquired relatively cheaply.

2.3. Hypotheses

From (1), (3) and (4), and following Chen et al. (2016), let the generating process before a stock enters the index be:

$$r_t = \underline{b}_r f_t + \underline{c}_1 u_{1t} + e_{rt} \tag{12}$$

$$x_{1t} = \underline{b}_1 f_t + u_{1t} + e_{1t}$$

$$x_{2t} = \underline{b}_2 f_t + u_{2t} + e_{2t}$$

After the stock enters the index:

$$r_t = \overline{b}_r f_t + \overline{c}_2 u_{2t} + e_{rt} \tag{13}$$

$$x_{1t} = \overline{b}_1 f_t + u_{1t} + e_{1t}$$

$$x_{2t} = \overline{b}_2 f_t + u_{2t} + e_{2t}$$

The extant evidence on comovement is garnered from a univariate regression such as:

$$r_t = \alpha + \beta x_{2t} + \epsilon_t \tag{14}$$

Noting that the slope coefficient $\beta = \frac{cov(r_t, x_{2t})}{var(x_{2t})}$, using the assumptions in (2) and stating pre-addition that $var(x_{2t}) \equiv \underline{\sigma}_{x2}^2$,Chen et al. (2016) show that the pre-addition beta is:

$$\underline{\beta} = \frac{Cov(\underline{b}_r f_t + \underline{c}_1 u_{1t} + e_{rt}, \underline{b}_2 f_t + u_{2t} + e_{2t})}{Var(\underline{b}_2 f_t + u_{2t} + e_{2t})} = \frac{\underline{b}_r \underline{b}_2 \underline{\sigma}_f^2}{\underline{\sigma}_{x2}^2} \tag{15}$$

Allowing post-addition, $var(x_{2t}) \equiv \overline{\sigma}_{x2}^2$,Chen et al. (2016) also show that the post-addition beta is:

$$\overline{\beta} = \frac{Cov(\overline{b}_r f_t + \overline{c}_2 u_{2t} + e_{rt}, \overline{b}_2 f_t + u_{2t} + e_{2t})}{Var(\overline{b}_2 f_t + u_{2t} + e_{2t})} = \frac{\overline{b}_r \overline{b}_2 \overline{\sigma}_f^2 + \overline{c}_2 \overline{\sigma}_{u2}^2}{\overline{\sigma}_{x2}^2} \tag{16}$$

Therefore, assuming that parameters other than c and the non-fundamental return shocks remain constant across the index/non-index boundary, the post-addition change in beta is:

$$\overline{\beta} - \underline{\beta} = \frac{\overline{c}_2 \sigma_{u2}^2}{\sigma_{x2}^2} \tag{17}$$

where, for example, $var(x_{2t}) \equiv \underline{\sigma}_{x2}^2 \equiv \overline{\sigma}_{x2}^2 \equiv \sigma_{x2}^2$.Eq. (17) shows that the sign of the post-addition beta change is determined solely by the sign of $\overline{c}_2$, the coefficient on the group-specific nonfundamental shock. Conditions (4) or (7) yield the standard result that the change in beta for added stocks is positive. This leads to the following familiar comovement effect hypothesis for added stocks.

Hypothesis 1A. The overall comovement effect implies that stocks added to an index exhibit a post-addition beta increase.

Note that Hypothesis 1A refers to the overall comovement effect as it applies to all – both low and high beta - added stocks.

Our model includes both indexers and beta arbitrageurs. Passive indexers automatically buy all added stocks. By contrast, arbitrageur's trading patterns depend on whether the added stocks exhibit low or high betas. In particular, they can take leveraged long positions in low beta added stocks as index inclusion may enhance their growth opportunities. Thus, common arbitrageur and index demand for low beta added stocks can lead to more pronounced comovement effects for such added stocks. This leads to the following hypothesis:

Hypothesis 1B. Low beta or defensive stock additions exhibit a more pronounced index inclusion effect than the overall index inclusion effect.

The index inclusion effect for the low beta group of added stocks is likely to exceed the overall comovement effect because the excess demand from index trackers is reinforced by arbitrageurs[15] using leveraged positions in low beta added stocks. This resonates with the Claessens and Yafeh (2013) finding that post-addition beta increases typically involve low beta added stocks.

On the other hand, arbitrageur investment in high beta added stocks is likely to be in the opposite direction to that of indexers. Vijh (1994) was the first to establish evidence of anomalous decreasing betas for his early sample of added stocks but this has been largely overlooked in the literature. Although high beta added stocks will be in demand by index trackers, beta arbitrageurs can short these stocks ahead of indexer buying. The latter effect counters the beta increases from indexer demand. If this effect is sufficiently strong – or if condition (9) holds - then the upshot is non-positive beta changes. These can involve either no significant beta change where indexer and arbitrageur positions offset one another or even anomalous negative beta changes if arbitrageur short positions dominate the long indexer positions. This is summarised in Hypothesis 1C:

Hypothesis 1C. The index inclusion effect is anomalously non-positive for high beta added stocks.

The set of Hypotheses 1A, 1B, and 1C has two very important implications. The first is that the overall comovement effect is simply a weighted average of two contrasting effects: the pronounced index inclusion effect for low beta added stocks only and the non-positive arbitrageur effect for high beta stocks. The second is an insignificant overall comovement effect for index additions does not imply a complete absence of comovement. Rather, it signifies that the sum of large contrasting effects for the low and high beta groups of added stocks can at times cancel out.

The above arguments carry over to deleted stocks also. We predict analogous patterns for deleted index stocks although these have been relatively neglected in the literature due to the BSW findings of insignificant overall beta changes. Extending Chen et al. (2016), we posit that the generating processes when a stock is deleted from an index are:

$$r_t = \underline{\underline{b}}_r f_t + \underline{\underline{c}}_1 u_{1t} + \underline{\underline{c}}_2 u_{2t} + e_{rt} \tag{18}$$

$$x_{1t} = \underline{\underline{b}}_1 f_t + u_{1t} + e_{1t}$$

$$x_{2t} = \underline{\underline{b}}_2 f_t + u_{2t} + e_{2t}$$

$$var(e_{it}) \equiv \underline{\underline{\sigma}}_{ei}^2, var(u_{it}) \equiv \underline{\underline{\sigma}}_{ui}^2, var(f_t) \equiv \underline{\underline{\sigma}}_f^2, var(x_t) \equiv \underline{\underline{\sigma}}_{x2}^2$$

In particular, even though the stock has now moved back to the non-index group, it is still influenced by the non-fundamental shock from the index group. In some ways, this could be thought of as a legacy issue representing the persistent attention of arbitrageur strategies since they can invest across group boundaries. Consequently, the post-deletion beta ($\underline{\underline{\beta}}$) can be given as:

[15] This qualification is inserted to account for other (e.g., value investing) styles not included in our model.

$$\underline{\underline{\beta}} = \frac{Cov\left(\underline{\underline{b}}_r f_t + \underline{\underline{c}}_1 u_{1t} + \underline{\underline{c}}_2 u_{2t} + e_{rt}, \underline{\underline{b}}_2 f_t + u_{2t} + e_{2t}\right)}{Var\left(\underline{\underline{b}}_2 f_t + u_{2t} + e_{2t}\right)} = \frac{\underline{\underline{b}}_r \underline{\underline{b}}_2 \underline{\underline{\sigma}}_f^2 + \underline{\underline{c}}_2 \underline{\underline{\sigma}}_{u2}^2}{\underline{\underline{\sigma}}_{x2}^2} \quad (19)$$

and assuming:

$$b_r \equiv \underline{\underline{b}}_r = \overline{b}_r; b_1 \equiv \underline{\underline{b}}_1 = \overline{b}_1; b_2 \equiv \underline{\underline{b}}_2 = \overline{b}_2$$

$$\sigma_f^2 \equiv \underline{\underline{\sigma}}_f^2 = \overline{\sigma}_f^2; \sigma_{ui}^2 \equiv \underline{\underline{\sigma}}_{ui}^2 = \overline{\sigma}_{ui}^2; \sigma_{ei}^2 \equiv \underline{\underline{\sigma}}_{ei}^2 = \overline{\sigma}_{ei}^2$$

then the post-deletion change in beta is:

$$\underline{\underline{\beta}} - \overline{\beta} = \frac{\left(\underline{\underline{c}}_2 - \overline{c}_2\right)\sigma_{u2}^2}{\sigma_{x2}^2} \quad (20)$$

Eq. (20) shows that the sign of the post-deletion beta change is determined by the sign of $\left(\underline{\underline{c}}_2 - \overline{c}_2\right)$. For example, if $\underline{\underline{c}}_2 = 0$ and $\overline{c}_2 > 0$, then the standard result holds and one observes common selling patterns and thus beta decreases for deleted stocks. This leads to the following hypothesis.

Hypothesis 2A. The overall index deletion effect is negative.

This overall deletion effect is averaged over all deleted stocks. This effect would almost certainly be negative in a world of indexers only. By contrast, the pronounced deletion effect for high beta deleted stocks reflects a combination of the excess supply effects of selling activity by index investors and arbitrageur shorting activity This yields the following hypothesis.

Hypothesis 2B. Pre-event aggressive deleted stocks exhibit a more pronounced deletion effect than the overall deletion effect.

Our stylised model can also explain why some deleted stocks may exhibit non-negative change in betas for deleted stocks with low pre-event betas. Such stocks may be attractive for arbitrageur leveraged long positions as they are in excess supply and so can be acquired relatively cheaply. Arbitrageurs can also take short positions ahead of the announcement date, thus generating an early falling price trend for these stocks. Together these imply that, if $\underline{\underline{c}}_2$ is positive and sufficiently large, then the post-deletion change in beta can actually be either zero or anomalously positive as shown in (20). This leads to the following hypothesis.

Hypothesis 2C. The index deletion effect for defensive stocks is non-negative.

The overall comovement deletion effect is simply the weighted average of the index deletion effects for low and high beta stocks. We posit that offsetting changes in these two effects probably explain the BSW findings of insignificant beta changes for index deletions at different frequencies and why deletions have been overlooked in the literature.

3. Data and empirical methodology

3.1. Data

The data employed include S&P 500 index inclusion and deletion events over the September 1976 (when the S&P began to publish event data) to December 2015 period. The list of event firms is taken from the Compustat North America database. Overall, there are 905 inclusion and 878 deletion events. Following BSW, addition events are excluded if the firm involves restructuring or spinning off a firm already in the index, if the firm is involved in a merger or takeover around the event, or a firm is taken private.[16]

These exclusions result in 733 addition events at the daily frequency and 671 at the monthly frequency from 1976 to 2015. The number of deletion events are 192 and 154 at the daily and monthly frequencies, respectively, from 1979 to 2015. The corresponding BSW deletions were 76 and 45, for daily and monthly samples, respectively, and are also much smaller than their addition events numbers of 425 and 324, for daily and monthly samples, respectively.

3.2. Methodology

Analogously to BSW, we estimate univariate model (14) where logged returns on individual event stocks r_t, are regressed on the S&P 500 index logged return, x_{2t}. The returns on the S&P 500 are taken from the CRSP Index on the S&P 500 Universe file. For daily data, we follow the extant literature in employing a one-year pre- and post-event window to estimate the value of the corresponding betas for each event stock after excluding the event month. For monthly data, the pre- and post-event window is 36 months before and 36 months after, respectively.[17] The post-addition change in beta for an individual event stock is defined as $\Delta\beta = \overline{\beta} - \underline{\beta}$, where $\overline{\beta}$ is the post-addition beta estimate and $\underline{\beta}$ is the pre-addition beta estimate as in our model. Likewise, the post-deletion change in beta for an event stock is defined as $\Delta\beta = \underline{\underline{\beta}} - \overline{\beta}$ where $\underline{\underline{\beta}}$ is the post-deletion beta estimate and $\overline{\beta}$ is the pre-deletion beta estimate.

To begin, the overall mean change in all event stock betas is estimated and a t-test is used to examine the significance of the average change in beta across stocks. Subsequently, the sample is then divided into pre-event low beta (defensive) and high beta (aggressive) beta groups that are typically associated with low and high pre-addition median betas. These groups enable us to take account of arbitrageur behaviour. The same procedure is repeated for evaluating the average beta change for each group.

4. Empirical findings

Sub-section 4.1 discusses the empirical results for S&P addition events for both the full sample period and the 1976–2000 and 2001–2015 periods. Sub-section 4.2 discusses the corresponding deletion event results.

4.1. S&P 500 addition results

4.1.1. Full sample period

Table 1 reports the results from the univariate regressions at the daily and monthly frequencies for the full sample of S&P 500 addition events from 1976 to 2015. In particular, it presents the overall comovement results and those for the pre-addition low and high beta groups, respectively.

Panels A and B show that the overall beta increases for added stocks are 0.128 and 0.105 after additions at the daily and monthly frequencies, respectively. Both these are significant at the 1% level. Our results unequivocally support the overall comovement effect in Hypothesis 1A for the full sample period. The daily result is very similar to that of Chen et al. (2016) who find a daily beta increase of 0.125 for their sample of 680 addition events over the 1976–2012 period. The

[16] Being taken private was not mentioned by BSW as it is a later phenomenon.

[17] Our data finishes at the end of 2017. Thus, the monthly betas for 2015 are estimated with a minimum of 24 observations.

Table 1
Daily and monthly beta changes for S&P 500 additions 1976–2015.

Sample	N	Mean $\underline{\beta}$	Mean $\overline{\beta}$	Mean $\Delta\beta$ (s.e.)
Panel A Daily				
Full sample	733	1.013	1.141	0.128*** (0.016)
Low beta	414	0.642	0.853	0.211*** (0.016)
High beta	319	1.494	1.515	0.021 (0.028)
Panel B Monthly				
Full sample	671	1.187	1.292	0.105*** (0.029)
Low beta	261	0.611	0.956	0.345*** (0.035)
High beta	410	1.554	1.507	−0.047 (0.040)

The following univariate regression is estimated for stocks added to the S&P 500 index from 1976 to 2015:
$r_t = \alpha + \beta x_{2t} + \epsilon_t$
where r_t is the return on the event stock and x_{2t} is the S&P500 index return. The daily pre-event estimation period covers a one-year window ending at the end of the month preceding the announcement month while the post-event period covers the one-year window starting the month after the effective date. The averaged difference between the mean post-addition ($\overline{\beta}$) and mean pre-addition ($\underline{\beta}$) betas gives the overall comovement effect ($\Delta\beta$). Panel A reports the daily results for the full sample and for the low and high beta groups which are divided based on the value of beta before the additions. The stock is assigned to the low beta group if its beta was lower than 1 while it is assigned to the high beta group if its beta was higher than 1 before the addition (no stock has a beta of one). Panel B reports the corresponding results for monthly data. The pre- and post-event windows in this case are extended to 36 months each.
***, **, and * represent significance at 1%, 5%, and 10% levels, respectively.

significant monthly result is novel, as to our knowledge, only insignificant overall monthly changes have been reported in the literature thus far.[18]

Table 1 also shows that the overall effects hide large contrasting changes between the pre-event low and high beta groups. The beta increases for defensive stocks at both frequencies are statistically significant at the 1% level and, strikingly, are also several times larger than the overall beta increases. The monthly beta increase for defensive stocks at 0.345 is more than three times the overall monthly comovement effect of 0.105 while the corresponding daily beta increase of 0.211 is almost double the overall increase of 0.128. These results support Hypothesis 1B for the subset of pre-event defensive added stocks.

How can one explain these dramatic increases for defensive added stocks? While indexers are required to buy these stocks to track the changed index, such low beta stocks are also attractive to arbitrageurs as candidates for leveraged long positions leading to common excess demand. Thus, for low beta additions, long positions by both indexers and beta arbitrageurs lead to more pronounced comovement effects. This provides one explanation of the puzzle of low pre-addition beta stocks raised by Claessens and Yafeh (2013). Our monthly defensive beta group exhibits stronger beta increases than the daily defensive beta group.[19] These results add weight to the view that comovement is not a short term phenomenon.

By contrast, Table 1 shows that the comovement effect is both small and statistically insignificant for high beta added stocks at the daily and monthly frequencies. These high beta stocks account for some 43.5% and 61.1% of the total daily and monthly added stocks, respectively. How can one explain these insignificant changes? Our stylised model predicts that these they reflect the influence of beta arbitrageurs (or other unconstrained investors) shorting such stocks as predicted in our theoretical model. Shorting such stocks lowers their prices and thus their betas. The results are consistent with the non-positive effect predicted by Hypothesis 1C.

Finally, the monthly test results may not be directly comparable to the daily test results if members of the subsamples are not the same.[20] To alleviate this concern, we replicate Table 1 with comparable subsamples. In this robustness test we include all stocks that do not change their categories when the data frequency changes. For instance, a stock is included only if it is a defensive stock at both daily and monthly frequencies or if it is an aggressive stock at both daily and monthly frequencies before addition events. This yields some 462 stocks where 215 stocks are in the low-beta group and 247 stocks are in the high-beta group. The results given in Table A1 of the Appendix are consistent with our findings for the larger sample of stocks in Table 1.

In summary, the overall comovement effect results at both the monthly and daily frequencies are statistically significant at the 1% level. First, the overall monthly effect is significant in both statistical and economic terms and this effect is novel in the comovement literature. Second, the biggest beta increases are observed for the pre-event defensive stock group where arbitrageurs and indexers take common positions, albeit for different reasons. Finally, the shorting behaviour by beta arbitrageurs (and other unconstrained investors) of aggressive added stocks offsets the buying from index trackers and thus the comovement effect for such stocks is statistically insignificant.

4.1.2. 1976–2000 and 2001–2015 periods

Table 2 reports the post-addition monthly results for the beta groups over the 1976–2000 (for comparability with BSW) and 2001–2015 periods.

The overall monthly comovement effect of 0.125 during 1976–2000 is significant at the 1% level. This is larger than the corresponding daily effect of 0.072 during 2001–2015 that is significant at the 10% level only.[21] Both findings support Hypothesis 1A. In both subperiods, the defensive group beta changes are large and significant at the 1% level and they drive the overall beta increases in line with Hypothesis 1B. The aggressive stock results are insignificant and significantly negative over 1976–2000 and 2001–2015, respectively. These support Hypothesis 1C. It is noteworthy that while the overall beta increase 2001–2015 is both small (i.e., 0.072) and marginally (10% level) significant, the beta changes for low and high beta additions are several times larger and both are significant at the 1% level.

Table 3 reports daily addition event results over the 1976–2000 and 2001–2015 periods.

Panels A and B indicate that the overall comovement effect was 0.16 and 0.072 over 1976–2000 and 2001–2015 periods, respectively. Both results are significant at the 1% level and they support Hypothesis 1A for these separate periods. Our daily beta change estimates over both subperiods are very close to those in the literature. BSW report a significant finding of 0.151 for 455 additions 1976–2000, while Chen et al. (2016) report a significant 0.071 for 214 additions, 2001–2012. Table 3 shows that the defensive beta group additions exhibit highly significant beta changes of 0.208 and 0.217 during 1976–2000 and 2001–2015, respectively, in line with Hypothesis 1B. While the beta change of 0.082 is significant at the 5% level for aggressive added stocks 1976–2000, it is

[18] See, most notably, BSW for their 1976–1998 sample insignificant results. Chen et al. (2016) do not report monthly results in their recent study.
[19] We thank an anonymous referee for the point that the monthly sample is not directly comparable to the daily sample given that whilst the daily sample has 250 post-addition observations over a 1-year window, the monthly sample has 36 observations over a 3-year window.
[20] We are grateful to an anonymous referee for this helpful insight.
[21] Unreported results show that the net beta increase was statistically insignificant over the 1976–1998 period and this result is in line that of BSW. The final years of the dot.com bubble have a large effect here.

Table 2
Monthly beta changes after S&P 500 additions 1976–2000 and 2001–2015.

Sample	N	Mean $\underline{\beta}$	Mean $\overline{\beta}$	Mean $\Delta\beta$ (s.e.)
Panel A 1976–2000				
Full sample	423	1.248	1.373	0.125*** (0.038)
Low beta	140	0.682	1.035	0.353*** (0.050)
High beta	283	1.528	1.54	0.012 (0.049)
Panel B 2001–2015				
Full sample	248	1.083	1.155	0.072* (0.045)
Low beta	121	0.529	0.865	0.335*** (0.049)
High beta	127	1.611	1.431	−0.179*** (0.068)

For each stock added to the S&P 500 index during 1976–2015 the univariate regression:
$r_t = \alpha + \beta x_{2t} + \epsilon_t$
is estimated using monthly data. The pre- and post-addition window is 36 months before and is 36 months after the addition event, respectively. The averaged difference between the mean post-addition ($\overline{\beta}$) and mean pre-addition ($\underline{\beta}$) betas gives the overall comovement effect ($\Delta\beta$). Panel A presents results for 1976–2000 while panel B reports results for 2001–2015. Both panels report full sample results and those for the Low β and High β samples based on the value of beta before additions.
***, **, and * represent significance at 1%, 5%, and 10% levels, respectively.

Table 3
Daily beta changes after S&P 500 additions 1976–2000 and 2001–2015.

Sample	N	Mean $\underline{\beta}$	Mean $\overline{\beta}$	Mean $\Delta\beta$ (s.e.)
Panel A 1976–2000				
Full sample	464	0.97	1.13	0.16*** (0.02)
Low beta	288	0.631	0.839	0.208*** (0.02)
High beta	176	1.525	1.607	0.082** (0.042)
Panel B 2001–2015				
Full sample	269	1.087	1.16	0.072*** (0.023)
Low beta	126	0.668	0.884	0.217*** (0.024)
High beta	143	1.457	1.403	−0.055* (0.035)

For each stock added to the S&P 500 index during 1976–2015, the univariate regression:
$r_t = \alpha + \beta x_{2t} + \epsilon_t$
is estimated using daily data. The pre- and post-addition window is the 12 months before and after the addition event month, respectively. The averaged difference between the mean post-addition ($\overline{\beta}$) and mean pre-addition ($\underline{\beta}$) betas gives the overall comovement effect ($\Delta\beta$). Panel A reports results for 1976–2000, while Panel B reports them for 2001–2015. Both panels report full sample results and those for the Low β and High β samples based on the value of beta before additions.
***, **, and * represent significance at 1%, 5%, and 10% levels, respectively.

negative and smaller at −0.055 during 2001–2015, albeit at the 10% level.

To sum up, the daily and monthly stock addition results for the two (sub) periods are broadly consistent with the full sample results but with one difference. The anomalous arbitrageur effect – beta decreases for the aggressive added stocks – is statistically significant at both frequencies

Table 4
Daily and monthly beta changes for S&P 500 deletions 1979–2015.

Sample	N	Mean $\overline{\beta}$	Mean $\underline{\beta}$	Mean $\Delta\beta$ (s.e.)
Panel A Daily				
Full sample	192	1.077	0.985	−0.092** (0.045)
Low beta	98	0.623	0.637	0.014 (0.036)
High beta	94	1.551	1.348	−0.203*** (0.083)
Panel B Monthly				
Full sample	154	1.216	1.39	0.175** (0.075)
Low beta	61	0.523	0.922	0.399*** (0.074)
High beta	93	1.67	1.697	0.027 (0.112)

For each stock deleted from the S&P 500 index during 1979–2015, the univariate regression:
$r_t = \alpha + \beta x_{2t} + \epsilon_t$
is estimated using daily data. The pre- and post-deletion window for daily tests, is 12 months before and after deletion event, respectively. For the monthly tests, pre- and post-deletion windows are 36 months. Panel A reports the daily results and Panel B the monthly results. Both panels report full sample results and those for the Low β and High β samples based on the value of beta before deletions.
***, **, and * represent significance at 1%, 5%, and 10% levels, respectively.

for the 2001–2015 period while it is insignificant for the full sample period.

4.2. S&P 500 deletion results

4.2.1. Full sample period

Table 4 reports detailed results from the univariate regressions at the daily and monthly frequencies for S&P 500 deletion events 1979–2015.

Panel A shows that the overall daily comovement deletion effect of −0.092 is significant at the 5% level. This supports Hypothesis 2A. This negative exclusion effect is driven by the high beta group with a mean beta decrease of −0.203 that is significant at the 1% level. The latter result supports Hypothesis 2B. Note that the low beta deleted stocks exhibit no significant beta change in line with Hypothesis 2C.

By contrast, the monthly results in Panel B are more novel. They indicate that the overall monthly comovement deletion effect is 0.175 and, anomalously, significantly positive at the 5% level which rejects Hypothesis 2A. The statistical significance for both daily and monthly results contrasts sharply with the corresponding insignificant results found by BSW, admittedly for shorter sample periods 1979–2000 and 1979–1998, respectively. The low beta deletion group produces a highly significant beta increase of 0.399 consistent with Hypothesis 2C. Index tracker sales creates excess supply for deleted stocks, pushing their prices downwards and his makes them attractive for leveraged long arbitrageur positions. Finally, the high beta deletion group now shows no significant beta change.

4.2.2. 1979–2000 and 2001–2015 periods

Table 5 reports monthly post-deletion beta changes during 1979–2000 and 2001–2015 while Table 6 reports the corresponding daily beta changes.

Recall from Table 4 that the monthly beta change for all deleted stocks was surprisingly significantly positive 1979–2015. Table 5, Panel A shows that the corresponding 1979–2000 beta change is insignificant while Panel B indicates that it is 0.284 and significant at the 1% level 2001–2015. Both sub-period results reject Hypothesis 2A that the beta change is negative. One can infer from these results that the 2001–2015 result is likely driving the significant post deletion effect over the 1979–2015 period.

The Table 5 Panel A and B results indicate a 0.357 and 0.509 beta

Table 5
Monthly beta changes after S&P 500 deletions 1979–2000 and 2001–2015.

Sample	N	Mean $\overline{\beta}$	Mean $\underline{\underline{\beta}}$	Mean $\Delta\beta$ (s.e.)
Panel A 1979–2000				
Full sample	71	0.85	0.896	0.046 (0.082)
Low beta	44	0.516	0.873	0.357*** (0.073)
High beta	27	1.393	0.934	−0.46*** (0.131)
Panel B 2001–2015				
Full sample	83	1.529	1.813	0.284*** (0.119)
Low beta	17	0.541	1.05	0.509*** (0.191)
High beta	66	1.783	2.01	0.227* (0.142)

For each stock deleted from the S&P 500 index during 1979–2015 the univariate regression:
$r_t = \alpha + \beta x_{2t} + \epsilon_t$
is examined using monthly data. The pre- and post-deletion window is 36 months before and after the deletion event, respectively. Panel A reports the 1976–2000 results and Panel B the 2001–2015 results. Both panels report full sample results and those for the Low β and High β samples based on the value of beta before deletions.
***, **, and * represent significance at 1%, 5%, and 10% levels, respectively.

Table 6
Daily beta changes after S&P 500 deletions 1979–2000 and 2001–2015.

Sample	N	Mean $\overline{\beta}$	Mean $\underline{\underline{\beta}}$	Mean $\Delta\beta$ (s.e.)
Panel A 1979–2000				
Full sample	92	0.78	0.592	−0.189*** (0.058)
Low beta	72	0.606	0.565	−0.042 (0.045)
High beta	20	1.408	0.689	−0.718*** (0.167)
Panel B 2001–2015				
Full sample	100	1.351	1.348	−0.003 (0.067)
Low beta	26	0.67	0.839	0.168*** (0.044)
High beta	74	1.59	1.527	−0.063 (0.089)

For each stock deleted from the S&P 500 index during 1979–2015 the univariate regression:
$r_t = \alpha + \beta x_{2t} + \epsilon_t$
is estimated using daily data. The pre- and post-deletion window is 12 months before and after deletion event, respectively. Panel A reports the results for 1979–2000 while Panel B reports results for 2001–2015. Both panels report full sample results and those for the Low β and High β samples based on the value of beta before deletions.
***, **, and * represent significance at 1%, 5%, and 10% levels, respectively.

increase for defensive deletions for 1979–2000 and 2001–2015, respectively. Both are significant at the 1% level and support Hypotheses 2C. These large and highly significant beta changes likely stem from the leveraged long positions of arbitrageurs. This is consistent with Hypothesis 2C that defensive stocks display anomalously increasing betas taking advantage of the excess supply of such stocks.[22] Finally, Panel A also shows a highly significant beta fall of −0.46 for high beta deletions and this supports Hypothesis 2C.

Table 6 reports daily post-deletion beta changes during 1979–2000 and 2001–2015. Recall from Table 4 that the daily beta change for the full deletion sample period 1979–2015 was significantly negative. It is striking from Table 6 that only the 1979–2000 daily beta change of −0.189 strongly supports the overall comovement deletion effect of Hypothesis 2A. Since the daily post-deletion sample period extends to 2001, this suggests that full sample period change is driven by the dot.com boom and bust. The insignificant effect for low beta deletions in the earlier period and the highly significant 0.168 increase for the latter period are both consistent with the nonnegative effect predicted by Hypothesis 2C. The results indicate that the index deletion effect of −0.718 for 1979–2000 for the high beta group is extremely large and significant in line with Hypothesis 2B and this is what is driving the full sample result.

To sum up, the detailed results for the 1979–2000 and 2001–2015 periods shed light on the contrasting daily and monthly deletion results for the full sample period. The anomalous positive monthly deletion effect for the full sample seems to be driven by the low beta sub-sample and especially so in the 2001–2015 period. By contrast, the significantly negative daily deletion effect of −0.092 for the full sample 1979–2015 seems more a product of the dot.com boom and bust and the highly significant −0.718 beta change produced by high beta deletions 1979–2000.

5. Conclusions

This paper departs from previous studies in assuming that comovement is influenced by two distinct beta-based investment styles whose interaction impacts on the betas of stocks added to and deleted from the S&P 500 index. It develops a stylised model in the spirit of Barberis et al. (2005) and Chen et al. (2016) to include beta arbitrageurs as well index trackers. The model shows that the overall comovement effect is a weighted average of the index tracking and arbitrageur effects given by disaggregating event (added or deleted) stocks into pre-event aggressive and defensive groups.

Our results shed new light on puzzling aspects of the extant comovement literature. First, the arbitrageur effect for added stocks can explain the anomalous beta decreases for pre-event aggressive stocks that arbitrageurs can short. The high proportion of added stocks with falling betas confirms the Vijh (1994) effect that has been overlooked in the literature. Second, with two investment styles, the positive index inclusion effect reflected by increasing betas is reinforced by arbitrageurs taking long (possibly leveraged) positions in pre-addition low beta stocks. This can explain the Claessens and Yafeh (2013) observation that low pre-addition betas are associated with a significant overall comovement effect. Third, an insignificant overall comovement effect (i.e., no beta change) is interpreted in the extant literature as an absence of comovement. By contrast, our results show that this can typically be explained by much stronger and highly significant index tracking and arbitrageur effects, offsetting one another for pre-event defensive and aggressive stocks.

Finally, perhaps the most original finding is the significant comovement effects following stock deletions from the S&P 500. Here our monthly sample of 154 deletions, 1979–2015, yields an anomalous beta increase of 0.175 that is significant at the 1% level. This can be explained by the arbitrageur effect of 0.399 from investors taking leveraged long positions in defensive stocks outweighing the index tracking effect of the aggressive stocks. All results are robust to several factors. In particular, they remain qualitatively similar when we divide our full sample into two subperiods and when we employ daily data.

[22] One possible explanation may be that deleted low beta stocks provide attractive leveraged long position opportunities to active investors pursuing a betting against beta strategy. See Frazzini and Pedersen (2014).

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Appendix

Table A1
Robustness test for daily and monthly beta changes for S&P additions 1976–2015.

Sample	N	Mean $\underline{\beta}$	Mean $\overline{\beta}$	Mean $\Delta\beta$ (s.e.)
Panel A Daily				
Full sample	462	1.091	1.205	0.114*** (0.019)
Low beta	215	0.588	0.788	0.200*** (0.019)
High beta	247	1.529	1.569	0.040 (0.032)
Panel B Monthly				
Full sample	462	1.194	1.342	0.148*** (0.035)
Low beta	215	0.606	0.888	0.282*** (0.034)
High beta	247	1.706	1.737	0.031 (0.058)

This table replicates Table 1 but where stock observations are included only if the added stocks do not change category from low to high beta or from high to low beta when the frequency changes from daily to monthly.
***, **, and * represent significance at 1%, 5%, and 10% levels, respectively.

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