Exploiting stochastic dominance to generate abnormal stock returns
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Abstract

We construct zero cost portfolios based on second and third degree stochastic dominance and show that they produce systematic, statistically significant, abnormal returns. These returns are robust with respect to the single index CAPM, the Fama-French 3-factor model, the Carhart 4-factor model and the liquidity 5-factor model. They are also robust with respect to momentum portfolios, transactions costs, varying time periods and when broken down by a range of risk factors, such as firm size, leverage, age, return volatility, cash flow volatility and trading volume.

1. Introduction

This paper examines the relationship between the existence of second and third degree stochastic dominance and the behavior of stock returns. Stochastic dominance (SD) is a general approach to expected utility maximization, which is the cornerstone of modern investment theory and practice. Contrary to the popular but restrictive mean-variance framework,[1] the stochastic dominance framework requires neither a specific utility function nor a specific return distribution. Under the general assumption that investors are risk averse, SD provides the probabilistic conditions under which all non-satiating, risk-averse investors prefer one risky asset to another. For example, the rules for second degree stochastic dominance (SSD) state the necessary and sufficient conditions under which one asset is preferred to another by all risk-averse expected

[1] Within the comprehensive framework of utility maximization mean-variance (MV) optimization, based on a single measure of risk, is the special case that is most widely accepted throughout the financial profession. MV, however, has a major shortcoming in that the conditions for it to be analytically consistent with expected utility maximization, such as quadratic utility functions or normally distributed returns, seldom hold in practice. See, for example, Mandelbrot (1963). Furthermore, it has been shown that risk measures other than variance, such as the third and the fourth moments of return distributions - skewness and kurtosis respectively - do matter to investors, who show a preference for positive skewness and an aversion to kurtosis (see, Kraus and Litzenberger (1976), Athayde and Flôres (1997), Fang and Lai (1997), Dittmar (2002), Post et. al. (2008)).

utility maximizers.[2] The rules for third degree stochastic dominance (TSD) state the necessary and sufficient conditions under which one asset is preferred to another by all prudent risk-averse expected utility maximizers.

Much of the empirical SD literature is dedicated to examining the efficiency of indices or specific portfolios. It finds that the indices and portfolios available to academics and practitioners for asset pricing and benchmarking are generally inefficient (e.g. Shanken (1987), Gibbons et al. (1989), Shalit and Yitzhaki (1994), Anderson (1996), Fama and French (1998), Post (2003), Kuosmanen (2004), Linton, Maasoumi and Whang (2005), Post and Versijp (2007)).[3] More recent studies investigate how stochastic dominance rules can be used to construct efficient portfolios (e.g. Kopa and Post, 2011, Clark et al., 2011, Kuosmanen, 2004).

This paper diverges from the mainstream SD empirical literature in that rather than concentrating on portfolio efficiency, it seeks to determine whether ex-post SD relations provide exploitable information on ex-ante returns. More specifically, it examines whether the rules of second and third degree stochastic dominance can be used to construct zero cost portfolios that yield out-of-sample systematic abnormal returns.[4] The study is based on the argument that investors will exploit the ex-post dominances by buying (selling) dominant (dominated) stocks, which will cause their prices to rise (fall). This creates capital gains (losses) for investors holding the dominant (dominated) stocks and reduces (increases) future returns. Our intuition is that, ceteris paribus, over the adjustment period ex-post dominant stocks will over-perform and ex-post dominated stocks will under-perform.

Our empirical treatment targets second and third degree stochastic dominance and proceeds as follows. For each month of the sample period we identify the dominant and dominated stocks in the 2nd or 3rd degree based on their daily returns from the previous 6 months. Once the dominance status of each stock has been determined, we form portfolios for each month that are long on dominant stocks and short on dominated stocks and examine the returns of these arbitrage portfolios up to 12 months into the holding period. The returns of the arbitrage portfolios are then used to examine our hypothesis for the UK market; i.e. that ex-post SD relations provide exploitable information on ex-ante returns.

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[2] See, for example, Hanoch and Levy (1969), Hadar and Russell (1969), and Rothschild and Stiglitz (1970). The rules are typically obtained by comparing the areas under the cumulative distributions of portfolio returns (e.g. see Levy, 2006).

[3] On the other hand, some recent papers show that the efficiency of market indices cannot typically be rejected (e.g. Levy and Roll (2010) and Ni, Malevergne, Sornette and Woehrmann (2011)).

[4] Besides Shalit and Yitzhaki (1994), there is some preliminary, indirect evidence of a relationship between SD and stock market returns: Fong et al. (2005) on momentum; Shalit and Yitzhaki (2005) on diversification; Post (2005) on risk seeking behaviour; and Clark and Kassimatis (2012) on marginal conditional stochastic dominance.

In the paper's major contribution to the literature, our results show that the zero cost SSD and TSD portfolios produce systematic, statistically significant, abnormal returns. These returns are robust when tested against the CAPM, the Fama-French 3-factor model and an extended 5-factor model that includes a momentum and a liquidity factor. Further tests suggest that the SD premia are not related to any of the conventional risk factors cited in the financial literature, such as firm size, leverage, age, return volatility, cash flow volatility and trading volume. They are also robust with respect to transactions costs and varying time periods.

2. Stochastic Dominance rules and investor preferences

2.1 Second order stochastic dominance

The basic premise of expected utility optimization is that investors are rational, non-satiating and risk averse. Each investor has a utility function $u(r)$ satisfying the following conditions:

$$u'(r) \geq 0, \;\; u''(r) \leq 0 \quad \forall r \tag{1}$$

where primes denote derivatives and r is the rate of return of an investment, and each investor aims to maximize the expected value of his/her utility function. Let *X* and *Y* represent two assets, $F(\cdot)$ is the cumulative distribution function (CDF) of the return on asset *X*, and $G(\cdot)$ is the CDF of the return on asset *Y*. We can say that *X* dominates *Y* in the sense of second degree stochastic dominance if and only if

$$F_2(\eta) \leq G_2(\eta) \quad \forall \eta \in R \tag{2a}$$

Where

$$F_2(\eta) = \int_{-\infty}^{\eta} F(r)dr \text{ and } G_2(\eta) = \int_{-\infty}^{\eta} G(r)dr \;\; \forall \eta \in R \tag{2b}$$

and $F_2(\eta) < G_2(\eta)$ for at least one η. Then, for any utility function satisfying conditions (1) and any two assets *X* and *Y* satisfying condition (2), we can say

$$E[u(r_X)] > E[u(r_Y)] \tag{3}$$

With respect to the mean-variance models employed in the risk based explanations, we can say *X* dominates *Y* in the sense of mean-variance criterion (E(r), σ), where σ is the standard deviation, if and only if:

$$E(r_X) \geq E(r_Y) \tag{4a}$$

and

$$\sigma_X \leq \sigma_Y \tag{4b}$$

with at least one of them strict.[5]

Tests of second order stochastic dominance amount to measuring the difference in the integrals of the CDFs of returns on two risky investments.

2.2 Third order stochastic dominance

In addition to the conditions in (1), third order stochastic dominance (TSD) assumes prudence. This implies

$$u'''(r) \geq 0 \tag{5}$$

If conditions (1) and (5) hold, we can say that *X* dominates *Y* in the sense of third order stochastic dominance (TSD) if and only if:

$$E(r_X) \geq E(r_Y) \tag{6}$$

and
$$F_3(\eta) \leq G_3(\eta) \qquad \forall \eta \in R \tag{7a}$$

where
$$F_3(\eta) = \int_{-\infty}^{\eta} F_2(r)dr \text{ and } G_3(\eta) = \int_{-\infty}^{\eta} G_2(r)dr \ \ \forall \eta \in R \tag{7b}$$

and $F_3(\eta) < G_3(\eta)$ for at least one *x*. Then, for any utility function satisfying conditions (1) and (5) and any two assets *X* and *Y* satisfying conditions (6) and (7a), we can say

$$E[u(r_X)] > E[u(r_Y)] \tag{8}$$

Tests of third order stochastic dominance amount to measuring the difference in the integrals of equation (7a).

3. Data and Methodology

For the empirical analysis we proceed in two stages. In the first stage, called the ranking period, the SD arbitrage portfolios are generated as follows. For each month in the sample period we use a 6-month ranking period to test for 2nd and 3rd degree dominance in all pairs of stocks.[6] Then, each month, we allocate stocks to one of four groups: i) stocks which dominate others and are not dominated by other stocks, ii) stocks which are dominated by others and do not dominate any other stocks, iii) stocks which dominate some stocks and are dominated by other stocks, and iv) stocks which do not dominate and are not dominated by any other stock. Based on our hypothesis, we expect demand for the stocks in the 1st group and supply for the stocks in the 2nd group to increase. For stocks in the 3rd and 4th groups we cannot make any inference about their

[5] See Gotoh and Konno (2000).

[6] The 6-month ranking period is compatible with the requirements of the statistics we compute and also corresponds to the most widely used ranking period for the momentum portfolios (see: Griffin et.al., 2003, Lesmond et. al., 2004), which we use to compare our results.

demand or supply due to dominance. Thus, a dominant stock is one that dominates at least one other stock but is not dominated by any other stock (DOMINANT) and a dominated stock is one that is dominated by at least one other stock but does not dominate any other stock (DOMINATED). We sell short equal amounts of dominated stocks and use the proceeds to purchase equal amounts of dominant stocks.[7] For example, suppose that there are m dominated stocks, n dominant stocks and the total amount of the short sale is equal to S. The amount of each dominated stock sold short will be equal to S/m. The amount of each dominant stock purchased will be S/n.[8] In the second stage, called the holding period, the portfolios are tested for abnormal returns. The test for abnormal returns is a test of the hypothesis that when dominance has been identified, investors will purchase dominant stocks and sell dominated stocks. As dominant stocks are purchased, their price will rise with a resulting capital gain for owners of these stocks. As dominated stocks are sold, their price will fall with a resulting capital gain for short sellers. There are four holding periods: 3 months, 6 months, 9 months, and 12 months. Again following common practice in similar studies, we skip one month between the ranking and the holding periods.[9]

Our sample is composed of daily stock returns (including dividends) over the period March 1992 to February 2013[10] from the U.K. stock market.[11] The UK market is deep and mature with trading rules and regulatory safeguards that are well adapted to the type of analysis we propose. All data are obtained from Datastream.[12] To avoid problems associated with Datastream errors we use the four filters proposed by Ince and Porter (2006): [13] (a) all equities not listed on the exchanges of the reference country are deleted, (b) non-common equities are deleted (e.g.

[7] The purchase of dominant stocks and short sale of dominated stocks follows the trading rule based on Shalit and Yitzhaki (1994), who show that the utility of all risk averse investors can be improved by increasing the share of the dominant asset at the expense of the dominated asset. Also, see Clark and Jokung (1999) and Clark et al. (2011) for balancing rules to generate MCSD efficient portfolios.

[8] Since a dominant (dominated) asset can dominate (be dominated by) more than one asset, the number of dominant and dominated assets can differ. However, the total amount of assets purchased must equal the total amount of assets sold.

[9] Skipping a month is aimed at eliminating microstructure distortions.

[10] A 20-year period is long-enough to identify patterns in stock prices. Similar sample periods have been used in other asset pricing studies, such as Avramov et. al. (2007) and Lesmond et. al. (2004).

[11] The first 6 months of the sample period are used for the first ranking so, the first momentum and SD portfolios are for October 1992.

[12] Datastream maintains in its database prices from stocks which have been delisted, thereby eliminating problems of survivorship bias.

[13] Ince and Porter (2006), who examine Datastream data for U.S. equities and four European markets, identify a series of problems and show that naïve use of Datastream data can have a significant impact on economic inference.

ADRs, warrants, etc.), (c) zero returns resulting from the delisting of a stock are deleted,[14] (d) extremely high returns which are reversed in the next period are deleted (these returns are very few and are due to incorrect data entries, but, left unaddressed, they can have a significant impact on results). We also use two other filters commonly employed in similar studies: i) stocks that do not trade for at least 40% of the ranking period are deleted to avoid potential price distortions related to infrequent trading, and ii) stocks with an average price of below £0.50 during the ranking period are deleted to eliminate extreme changes in returns caused by small price changes.[15] Due to these filters, the sample can change from month to month because illiquid stocks may become liquid or penny stocks may increase in value (and vice versa).[16]

To establish dominance we use the algorithm proposed by Babbel and Herce (2007). Let F and G represent the empirical cumulative distribution functions (CDFs) of two risky assets X and Y, respectively, and r indicate return. Define I_1 as

$$I_1(r) = G(r) - F(r), \qquad r_i \le r < r_{i+1}, \qquad i = 1, \dots, m, \tag{9}$$

and m is the number of their unique realized returns. For SSD we need to compute the integral of the difference in the CDFs. Thus, X SSD Y if $I_2 > 0 \ \forall \ r_i$, where I_2 is defined as

$$I_2(r) = I_2(r_{i-1}) + I_1(r_{i-1})(r - r_{i-1}) \quad \text{for } r_{i-1} \le r < r_i, \ \ i=2,\dots m, \text{ with } I_2(r_1) = 0 \tag{10}$$

For TSD, Babbel and Herce (2007) propose the definition

$$I_3(r) = \sum_{j=0}^{3} \frac{1}{j!} I_{3-j}(r_{i-1})(r - r_{i-1})^j \text{, for } r_{i-1} \le r < r_i, \tag{11}$$

with $I_k(r_1) = 0,\ i=2,3,\dots m;\ k=2,3,\dots.$

X dominates Y in the third degree if i) $I_3 > 0 \ \forall \ r_i$, ii) $I_2(r_m) > 0$ and iii) every point of the integral $I_3(r)$ lies above 0. The final condition is required because integrals higher than the second order are non-linear functions of r. Therefore, as Levy (2006) suggests, we check interior points of the integral in regions where $I_3(r)$ turns from a decreasing function to an increasing function.[17]

For each ranking period, we compute $I_2(r)$ and $I_3(r)$ for every pair of stocks in the sample. This involves the computational complication of comparing each stock in the sample with every other stock. Suppose for example that in the ranking period of month t the sample includes 700 stocks (i.e. from month t-7 to month t-2). Establishing TSD means computing equation (11) (700

[14]For delisted stocks, the reported price is always the last closing price before the delisting, resulting in zero returns after that.

[15] These cut off points for the filters were chosen to mitigate the effect of illiquidity and large percentage price changes of penny stocks while maintaining as large a sample as possible. Bhootra (2011) highlights the importance of such filters in similar empirical studies.

[16] In fact there are very few changes in the sample from one month to the next as most penny and/or illiquid stocks remain penny and/or illiquid stocks.

[17] $I_2(r)$ is the first derivative of $I_3(r)$, so the turning points are where $I_2(r)$ turns from negative to positive.

x 699) / 2 = 244,650 times to establish which stocks are dominant. To establish which stocks are dominated the equation must be run another 244,650 times. So, it is necessary to run the algorithm 489,300 times to sort out the TSD dominant and dominated stocks for one ranking period.[18]

Panel A of Table 1 reports statistics on the number of stocks for the entire sample, the SSD and the TSD stock portfolios (dominant and dominated). The average number of stocks in the sample is 665.7 which, considering the size of the U.K. stock market, is a representative sample. The average number of SSD dominant stocks per ranking period is 63.3 while the average number of TSD dominant stocks is 16.8. The respective figures for SSD and TSD dominated stocks are 28.5 and 4.2. The number of TSD dominant and dominated stocks is notably lower than those for SSD dominant and dominated stocks. In 4 ranking periods (out of 233 in the sample) only 1 stock was TSD dominated without being dominant. This, however, does not mean that the portfolios we examine are under-diversified. Our aim is to examine the returns of arbitrage portfolios, long on dominant stocks and short on dominated stocks using monthly overlapping periods, in the same way that Jegadeesh and Titman (1993) constructed their momentum portfolios. Considering that the average number of stocks (long and short) in the arbitrage TSD portfolios is 21 and that each month we assume that we hold a number of portfolios, the stochastic dominance arbitrage portfolios are well-diversified.

[INSERT TABLE 1 ABOUT HERE]

The fact that there are fewer stocks in the TSD portfolios compared to the SSD portfolios is no surprise. TSD is a less restrictive form of dominance than SSD and, consequently, more dominances are expected. This reduces the number of stocks that are exclusively dominant or dominated. For example, consider a hypothetical sample of 5 stocks (A, B, C, D and E) ranked by their past returns over some ranking period in descending order. Suppose that A and B SSD dominate D and E, while C is neither dominant nor is dominated by any stock, and there are no other SSD dominances in the sample. In our framework, the SSD dominant portfolio would consist of stocks A and B while the SSD dominated portfolio would consist of stocks D and E. Suppose now, that stock A TSD dominates all other stocks, while only stock E does not TSD dominate any other stock. In this case, the TSD dominant and dominated stock portfolios would consist only of stocks A and E respectively.

Panel B of Table 1 reports the average number of stocks which appear simultaneously in two specific portfolios. For example, each month, there are on average 15.06 stocks which are

[18] The same number of calculations must be done to calculate SSD for each of the 233 holding periods in our sample.

both SSD and TSD dominant. Some of the cells report zero overlap between two portfolios which are expected by definition. For example, there are no stocks simultaneously included in the SSD dominant and dominated portfolios or in the TSD dominant and dominated portfolios.[19] The same applies to SSD dominant - TSD dominated and SSD dominant - TSD dominated pairs. If stock A dominates stock B in the second degree, it also dominates it in the third degree. Therefore, if a stock is included in the SSD dominant portfolio, it also dominates one or more other stocks in the third degree sense and, thus, cannot be included in the TSD dominated portfolio.[20]

4. Results

4.1 Returns of the SSD and TSD arbitrage portfolios.

Table 2 reports average monthly excess returns for SSD and TSD portfolios assuming a k-month buy-and-hold strategy with initial equal weighting. All dominant stock portfolios generate positive excess returns while all dominated stock portfolios generate negative excess returns on average.

[INSERT TABLE 2 ABOUT HERE]

The TSD dominant stock portfolios generate highly statistically significant positive excess returns for the first three months into the holding period. The SSD arbitrage portfolio returns in Table 2 are statistically significant and sizable up to the 6th month. TSD arbitrage returns are considerably higher than the returns of the SSD portfolios and, although dominant stocks generate on average positive excess returns, the arbitrage returns come mainly from the low returns of the dominated stocks.

Compared with the returns of the SSD portfolios, it is obvious that the TSD arbitrage portfolios are much more profitable. For example, the average return of the TSD arbitrage portfolio during the 1st month of the holding period is 4.604% while the respective figure for the SSD arbitrage portfolio is 2.336%. A t-test for equality between these average returns is 2.15 which rejects the null at the 5% level.

The columns in Table 2 labeled "Risk Adjusted", report the alphas from a 5-factor regression of the respective SSD and TSD portfolio returns on the 1-month excess market returns, the value premium, the size premium, a liquidity premium and 6x6 momentum portfolio returns. The value and size portfolios and constructed as in Fama and French (1993), the momentum premium as in Jegadeesh and Titman (1993) employing decile portfolios and the liquidity premium is the monthly returns from a portfolio long on illiquid stocks and short on liquid stocks.

[19] A stock cannot be only dominant and only dominated at the same time.

[20] Remember that SSD and TSD dominant (dominated) portfolios include stocks which dominate (are dominated by) other stocks in the second and third degree respectively, and are not dominated by (do not dominate) any other stock in the second and third degree respectively.

For the liquidity factor we also employ decile portfolios and liquidity is established based on the average bid-ask spread over the previous year (see, for example, Eleswarapu and Reinganum, 1993)[21]. All alphas are positive and in several cases statistically significant.

[INSERT TABLE 3 ABOUT HERE]

Table 3 reports average monthly excess returns and risk adjusted returns for SSD and TSD overlapping portfolios à la Jegadeesh and Titman (1993). The overlapping portfolios are calculated as follows. The 6x3 portfolio return at time t+1 is 1/3 the return of the portfolio formed based on the ranking at t-3, 1/3 the return of the portfolio formed based on the ranking at t-2 and 1/3 the return of the portfolio formed based on the ranking at t-1; the 6x6 portfolio return at time t+1 is 1/6 times the return of the portfolios formed based on the rankings from t-6 to t-1, and so on. The monthly returns for the SSD and TSD arbitrage overlapping portfolios are quite large and highly statistically significant even 12 months into the holding period. The probability the 1 month, 6x3, 6x6, 6x9 and 6x12 TSD and SSD returns have the same mean is 1.10%, 6.73%, 12.01%, 22.93% and 63.9% respectively, based on t-tests for equality of means. This means that for the first few months after portfolio construction the TSD arbitrage portfolios generate a statistically significant higher return than the SSD portfolios. It should also be noted that the TSD and SSD premia are quite different.[22] The risk adjusted returns are statistically significant for all arbitrage portfolios, except for the SSD 6x3.

We also examine the performance of the dominant stock portfolios against the dominated stock portfolios using stochastic dominance criteria. We find that all dominant stock portfolios (Tables 2 and 3) dominate all dominated stock portfolios both in the 2nd and 3rd degree, which is further evidence for the performance of the arbitrage stock portfolios. None of the arbitrage stock portfolios reported in Tables 2 and 3 dominates any of the other arbitrage stock portfolios reported in these tables.

4.2 Can risk factors explain the SSD and TSD arbitrage returns?

4.2.1 The Fama-French four factor model

Table 4 reports statistics on the average book-to-market value and size for the SSD and the TSD stock portfolios (dominant and dominated). On average, dominated stocks have higher book-to-market values than dominant stocks. These statistics imply that the TSD and SSD premium cannot be attributed to the well-known value premium. With respect to the size effect,

[21] There are several measures of liquidity employed in the literature. However, as Chordia et. al. (2000) find, the correlation among these measures is quite high so, they can be used interchangeably.

[22] For example, the correlation coefficient between the 6x6 SSD and TSD arbitrage portfolio returns is 59.3%.

SSD dominant stocks tend to be smaller than SSD dominated stocks but TSD dominant stocks tend to be larger than TSD dominated stocks. On average, the difference in the size of the SSD dominant and dominated stocks is quite low which makes it unlikely that the SSD premium can be attributed to the size effect.[23]

[INSERT TABLE 4 ABOUT HERE]

To further examine which risk factors explain the SSD or the TSD premium, we use the Fama-French 3-factor model augmented by the momentum factor and a liquidity factor. The results are reported in Table 5. For the SSD and TSD portfolios we use the buy-and-hold returns from the 6x6 portfolios reported in Table 3.[24] The SSD arbitrage portfolio return is the dependent variable in equations (1) to (4) and the TSD arbitrage portfolio return is the dependent variable in equations (5) to (8).

In all six equations the constant is always positive and statistically significant, which means that none of the models can satisfactorily explain variations in the SSD or the TSD premia. In equations (1) to (4) the market factor is always significant but with a negative loading, suggesting that the SSD premium is countercyclical. The size factor is also significant in the full model with a negative sign. SSD and momentum arbitrage returns are correlated as is apparent in equation (4) where WML is highly significant and its inclusion in the regression raises the adjusted R^2 from 0.15 (equation 2) to 0.41. Both dominance and momentum portfolios are constructed from past return data. The main difference between the two strategies is that momentum is based on past average returns, while the dominance portfolios consider the full distribution of returns. Therefore, it is hardly surprising that the two portfolios exhibit commonalities. We investigate the similarities of the two strategies in section 4.3.

For the TSD premium the picture is different. None of the 3 factors of the Fama-French model is significant at the 5% level in any of the regressions. Only WML is highly statistically significant in equation (8) with a coefficient close to 1, indicating that there is a relationship between TSD and WML. However, the constant in equation (6) is 1.2% with a t-ratio of 2.05, which is evidence that momentum cannot fully account for the excess returns of the TSD arbitrage portfolio.[25]

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[23] We also examined to which industries the dominant and dominated stocks belong. These stocks are from various industries and we could not identify any pattern. The breakdown of the dominant and dominated stock portfolios by industry is available upon request.

[24] The results reported in Table 5 hold for the other arbitrage portfolio returns too and are available on request.

[25] As a robustness test, we also ran the regressions in Table 5 using book-to-market, size and momentum factors constructed by Gregory et. al. (2013) (the only ones available) for the UK market, which are available online at http://xfi.exeter.ac.uk/researchandpublications/portfoliosandfactors/files.php.

[INSERT TABLE 5 ABOUT HERE]

4.2.2. Additional risk factors

While the Fama-French model augmented with the momentum factor is the dominant asset pricing model in the literature, there are studies which argue that this model simply measures behavioral biases and asset mispricing (e.g. Lakonishok et. al., 1994, Daniel and Titman, 1997). So, in this section we explore the possibility of omitted risks possibly related to the SD arbitrage portfolios, which may arise in the context of our study. At the same time, we also explore if well-known cross-sectional relationships for momentum portfolios apply for SD portfolios. To examine if this is the case, we split the SSD and TSD dominant and dominated portfolios based on variables which proxy for possible risk factors on an ex ante basis. Each month, we sort the stocks in the SSD dominant and dominated portfolios from high to low, based on each of the risk factors we consider and create tercile equally weighted portfolios. We do the same thing for the TSD dominant and dominated stock portfolios but, due to the small number of stocks in them, these portfolios are only split in half. From the dominant and dominated stock portfolios in each category we create arbitrage portfolios (long on dominant stocks and short on dominated stocks). Specifically, to create the portfolios for month *t*, the proxies we use for omitted risk factors are: i) size, measured by market capitalization at the end of month *t-2*, ii) liquidity proxied by trading volume (Chordia et. al., 2001) for month *t-2* and iii) information uncertainty measures which are cash flow volatility measured as the standard deviation of the cash flows from operations in the past 5 years with a minimum of 3 years (as in Zhang, 2006), leverage, measured as the book value of debt divided by market capitalization at the end of month *t-2*, company age at the end of month *t-2* and return volatility, measured as the standard deviation of returns from month *t-7* to month *t-2*.[26]

We find that small dominant and dominated stocks generate a higher SSD and TSD arbitrage premium[27]. This effect is more pronounced in the TSD premium. However, size cannot fully explain these returns as SSD and TSD arbitrage portfolios consisting of the larger stocks in the sample, also generate abnormal returns. With respect to liquidity, we find no relationship between trading volume and SSD arbitrage returns. For TSD stocks there is a clear relationship between trading volume and returns. The low turnover arbitrage stock portfolio generates high, statistically significant returns which persist even 12 months after portfolio formation. The high

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The results using those factors are qualitatively similar to ours. These results are available upon request.

[26] So, we create a low, a medium and a high leverage SSD dominant and dominated stock portfolio, a low, a medium and a high cash flow volatility SSD dominant and dominated stock portfolio, and so on.

[27] The results from these tests are not reported here for economy of space but are available upon request.

turnover stock portfolio generates lower but statistically significant returns only for the first 9 months after portfolio formation. From the information uncertainty variables, only leverage seems to have some effect on our portfolio returns. The arbitrage returns from companies with low leverage tend to be smaller than for those with high leverage. However, low leverage portfolios still generate sizeable and statistically significant returns. Therefore, we can conclude that information uncertainty does not drive SD portfolio returns. To summarize, while we find some relationship between SD portfolio returns and some stock characteristics, none of these seems to be the driving force behind these returns.

4.2.3. Behavioral effects

A large body of the literature attributes momentum to behavioral biases, causing investors to overreact and push stock prices away from their fundamental values (e.g. Daniel et. al., 1998). If momentum is caused by overreaction, then we should observe a reversal in returns after a certain period. To test if this is the case with SD portfolios, we examine the percentage of dominant stocks that become dominated in the future and the percentage of dominated stocks that become dominant in the future. The rationale behind this analysis, is that if a dominant (dominated) stock is overbought (oversold), in the future it should under-perform (over-perform) relative to other stocks. Therefore, if overreaction is the driving force behind the SD returns we report, we expect to find that dominant stocks will eventually become dominated and dominated stocks will become dominant.

[INSERT TABLE 6 ABOUT HERE]

The relevant results of this analysis are reported in Table 6. We report only the results for SSD portfolios because we find that the percentage of stocks which are TSD dominant or dominated and switch category within 12 months is negligible. For SSD dominant (dominated) stocks, Table 6 shows that although the percentages are not really negligible, they are still very small. The percentages for both dominant and dominated stocks increase up to month 6 and then decline. These results do not support the overreaction argument. If there was overreaction at work, we would expect the figures in Table 6 to be much higher. More importantly we would expect to find that the figures increase with time. The fact that the percentage of stocks which switch category is low and remains at the same levels after month 6 into the holding period suggests that if there is overreaction at work, its effect on stock returns is limited at best.

Overall, the results in this section suggest that there are some similarities in the stock characteristics that affect momentum and SD returns, which is further evidence on the link between the two. However, we can conclude that SD returns cannot be attributed to the risk factors we consider or to overreaction.

4.3 The relationship between SSD, TSD and momentum returns

Having shown that momentum returns are correlated with SD returns but cannot explain them, in this section we investigate the relationship between SD and momentum premia more thoroughly. The results in Table 5 employ momentum returns based on decile portfolios. Our first robustness test is to employ alternative momentum specifications. To this end, we construct quantile and vingtile momentum portfolios which we use in the asset pricing regressions reported in Table 7. The quantile momentum factor is denoted as WMLQ and the vingtile momentum factor is denoted as WMLV. The results suggest that i) all momentum specifications can explain a large part of SD portfolio returns; ii) the alphas where the vingtile momentum portfolios are used are slightly lower than those employing the quantile momentum portfolios; and iii) no matter which specification is used, alphas remain positive, sizable and statistically significant in most cases.

[INSERT TABLE 7 ABOUT HERE]

As a second robustness test, we examine the returns from dominant and dominated stocks which are not part of the decile momentum portfolios. Table 8 reports monthly portfolio excess returns for momentum portfolios, measured as the difference between the portfolio return minus the respective UK 1 month T-bill rate. The ranking period is 6 months and we skip one month between the ranking and the holding periods. The stocks in the decile with the highest returns during the ranking period are the winner stocks and those in the decile with the lowest returns during the ranking period are the loser stocks. WML (winner minus loser) refers to the zero cost momentum portfolio, long on winner stocks and short on loser stocks. Panel A of Table 8 reports average monthly excess returns from a k-month buy-and-hold strategy with initial equal weighting. For example, the 2nd month return is the average excess return from the end of the 1st month to the end of the 2nd month, assuming that the portfolio has been held for 1 month and was equally weighted at formation.

[INSERT TABLE 8 ABOUT HERE]

Panel B reports winner, loser and WML portfolio excess returns for overlapping portfolios à la Jegadeesh and Titman (1993).[28] The arbitrage portfolio returns for overlapping and

[28] The 6x3 portfolio return at time t+1 is 1/3 the return of the portfolio formed based on the ranking at t-3, 1/3 the return of the portfolio formed based on the ranking at t-2 and 1/3 the return of the portfolio formed based on the ranking at t-1; the 6x6 portfolio return at time t+1 is 1/6 times the return of the portfolios formed based on the rankings from t-6 to t-1, and so on.

non-overlapping portfolios are sizable and statistically significant, which is in line with the findings of the empirical literature on momentum in general and with those reported for the UK by other studies such as Badreddine (2009). A comparison of the results in Tables 2, 3 and 8 suggest that momentum and SSD returns are very similar. In both cases, the overlapping arbitrage portfolios generate sizable and statistically significant positive excess returns.[29]

In order to assess the similarities between the momentum, SSD and TSD portfolios, we first identify the stocks which are similar in these portfolios. The winner and the loser portfolios include on average 66.57 stocks each month. On average, 26 stocks each month are SSD or TSD dominant but not winners, while 15.4 stocks each month are SSD or TSD dominated but not losers at the same time. These figures suggest that on average, 39% of the dominant stocks and 23% of the dominated stocks are not included in the momentum portfolios at any time, which means that the two types of portfolios are quite different. The correlation coefficient between the 6x6 SSD premium and the 6x6 WML premium is 56.6%, while the correlation coefficient between the 6x6 TSD and the 6x6 WML premia is 53.2% indicating a slightly stronger relationship between SSD arbitrage returns and the momentum premium than TSD arbitrage returns and the momentum premium.

The risk adjusted excess returns of the stock portfolios which include SSD dominant stocks which are not winners and SSD dominated stocks which are not losers are reported in Table 9.[30] The figures reported in the table are the alphas from a regression of the SD portfolio returns on the three Fama and French factors and a liquidity factor.[31] If we compare the arbitrage returns to those reported in Table 3 (i.e. to the SSD arbitrage portfolio returns) we can see that excluding winners and losers has no effect on statistical significance and only a marginal effect on returns. This is clear evidence that the dominance portfolios returns are not driven simply by momentum. We ran the same tests using vingtile momentum portfolios and the results are qualitatively the same.[32]

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[29] T-tests on equality of means suggest that the returns of the SSD arbitrage portfolios are not different from those of the momentum arbitrage portfolios.

[30] Because of the small number of dominated stocks in the TSD portfolio (the average number of stocks in the TSD dominated stock portfolio is 4.2 and most of these stocks are at the same time also in the loser portfolio), the same type of portfolio cannot be constructed for TSD. If we exclude from the TSD dominated stock portfolio stocks which are dominated and loser at the same time, for most months of the sample there would be no stocks in this portfolio.

[31] Since we have excluded winners and losers from the SD portfolios, we not include a momentum factor in the regressions. However, adding a momentum factor based on quantile, decile or vingtile portfolios has only a marginal effect on the size of the alphas and their statistical significance. These results are available upon request.

[32] We also used quantile momentum portfolios for the same robustness test. The SSD premium was still positive but more volatile. Using quantile momentum portfolios, excludes 40% of the sample stocks. The

Finally, we examine the performance of SSD and TSD arbitrage portfolios against momentum portfolios using stochastic dominance rules. Specifically, we examine if momentum portfolios dominate any of the SSD or TSD arbitrage portfolios reported in Table 3. For the tests we use various specifications of momentum portfolios (i.e. quantile, decile and vingtile). Our tests fail to find any dominance relations in either direction; i.e. none of the momentum portfolios dominates any of the dominance arbitrage portfolios in the 2^{nd} or 3^{rd} degree, and vice versa. We also examine if not skipping a month between the ranking and formation period for the momentum portfolios makes a difference, but it doesn't. Again we fail to find any dominance relations between the two types of arbitrage portfolios.

[INSERT TABLE 9 ABOUT HERE]

4.4 Time consistency of SSD and TSD premia

As a further robustness test we examine whether the SSD and TSD premia are consistent across time. To this end, we split the sample into two equal sub-samples and compare risk adjusted returns. The results are reported in Table 10.

Panel A reports that the returns on the SSD portfolios are positive and large for all portfolios in both sub-periods. They are statistically significant for three of the four portfolios in both periods, although the significance is slightly weaker in the period 2003-2013. The returns on the TSD portfolios in panel B are all positive, large and statistically significant for all the portfolios for both sub-periods. These results suggest that SSD and TSD arbitrage returns are robust and do not depend on a few outliers.

The period 2003-2013 generates the weakest SSD portfolio risk adjusted returns, reported in panel A. The SSD 6x3 and 6x9 portfolio returns are statistically significant during the first subperiod. For the 2003-2013 sample, SSD risk adjusted returns are positive but not statistically significant. For the TSD portfolios the results are different as there is no notable difference between the two sub-periods. TSD portfolio risk adjusted returns are statistically significant for most returns for all periods.

[INSERT TABLE 10 ABOUT HERE]

4.5 The effect of transaction costs

Lesmond et. al. (2004) show that momentum returns disappear once transaction costs have been accounted for because the arbitrage portfolios require frequent rebalancing. In this section we examine the effect of transaction costs on the SSD and TSD arbitrage portfolios. Investors face several types of costs when implementing an investment strategy which include

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stocks left in the SSD arbitrage portfolios were few so, the higher volatility of the premium could be the result of low diversification in the arbitrage portfolios.

commissions, the bid-ask spread, taxes and price impact effects (Lesmond et. al., 2004). If the strategy involves taking short positions, then to the above list shorting costs must be added.[33] For the UK, shorting costs and price impact effects are not easily observed due to lack of data. However, there are available data on the bid-ask spread, commissions and taxes. For the bid-ask spread we follow Bhardwaj and Brooks (1992) and Lesmond (2007) and employ the following specification:

$$Spread = \frac{1}{T}\sum_{t=1}^{T}\frac{Ask_{i,t} - Bid_{i,t}}{(Ask_{i,t} + Bid_{i,t})/2} \tag{12}$$

where $Ask_{i,t}$ and $Bid_{i,t}$ are the ask and bid prices respectively for stock i at day t, and T is the number of observations from which we measure the bid-ask spread. The relevant data are available from Datastream. The spread for stock i is calculated from daily data for that stock from the 12 month period prior to the portfolio formation month.[34]

For the level of commissions, we use the estimates of the Survey of London Stock Exchange Transactions 2000 (2000) where it was reported that the commissions paid in the UK by intermediaries, institutions, corporate and private clients were 0.13%, 0.15%, 0.25% and 0.67% respectively.[35] For the cost of commissions paid we use the average of these figures which is 0.3% per transaction. Finally, we include a cost of 0.5% for stamp duty. The roundtrip cost of investing in share i at time t is:

$$Cost_{i,t} = Spread_{i,t} + (2\ x\ commission) + stamp\ duty \tag{13}$$

Using formula (13), we find an average roundtrip cost of 9.71% for the stocks in our sample. Although this figure seems rather high, it is in fact in line with other UK studies; for example, Soares and Stark (2009) use the exact same formula with a 0.13% commission cost and find that the average roundtrip cost for the UK is 11.3% for stocks with low accruals and 8.1% for stocks with high accruals. We should note that 9.71% is the average cost of all stocks in our sample; dominant, dominated and others. The average roundtrip cost for the dominant and dominated stocks in our sample is 6.01%, which means that most of the SD stocks are rather liquid.

Table 11 reports returns for overlapping TSD and SSD arbitrage portfolios including transaction costs. The 6x3 portfolios generate negative returns. From month 6 onwards into the holding period, returns become positive and for the 6x12 portfolios, they are statistically significant at the 10% level. In other words, both SSD and TSD portfolios generate statistically

[33] For a study on the effect of short sales constraints on momentum profits, see: Ali and Trombley (2006).
[34] For a few of the stocks in the sample this information is not available. For these stocks we use the average spread observed in the sample.
[35] See also: Agyei-Ampomah (2007) and Soares and Stark (2009).

and economically significant returns. Considering that roundtrip transaction costs are about 6% for dominant and dominated stocks, it may seem puzzling how these portfolios can still generate economically significant returns. There are two reasons for this; firstly, transactions costs per stock and period in our sample are much dispersed. The transaction costs for the dominant and dominated stocks for the months we buy them and sell them respectively, are in many cases lower than the average. The second reason transaction costs do not eliminate the profitability of the 6x9 and 6x12 portfolios is because the portfolios do not require frequent rebalancing.

[INSERT TABLE 11 ABOUT HERE]

The bottom row of Table 11 reports returns for SSD arbitrage portfolios where we have excluded winner stocks from the SSD dominant portfolios and loser stocks from the SSD dominated portfolios. The 6x9 and 6x12 portfolios still generate statistically significant positive returns, which is further evidence that the effect of dominance on stock returns is quite different from the momentum effect. The 6x3 portfolio generates negative returns due to the high transaction costs. However, all the other portfolios generate positive returns which for the 6x12 portfolios are statistically significant at the 5% level and for the 6x9 portfolio at the 10% level. The bottom line of the results reported in Table 11 is that transaction costs do not severely erode the profitability of the TSD and SSD arbitrage portfolios.

4.6 Accounting for weak SD relations in our portfolios

The last point we address is the potential effect of weak dominance relations in our dominant or dominated stocks. To control for this in the SSD portfolios we proceed as follows. Each month, for each pair of stocks, we count the number of times that I2 increases and decreases (see equation 10). Then, for each month, we eliminate the 5% of dominances with the highest number of decreases in I2. For the TSD portfolios we follow the same procedure. We count the number of times that I3 increases and decreases (see equation 11) and eliminate the 5% of dominances with the highest number of decreases.

To understand how this controls for weak dominance in SSD portfolios, consider the algorithm for I2 in equation 10. I2 decreases only if I1, which measures the difference in the CDFs of a pair of stocks, is negative. Dominance is established if I2 is always positive. However, it could be that due to sampling error if one or a few of the initial values of I1 is very high but many or most of the following values are negative. In this case, although I2 will be decreasing, it could possibly remain positive. The dominance, however, would be called into question because the removal of the outliers that produce high values of I2 would make the following I2s become negative, thereby eliminating the dominance. Eliminating the SSDs with the highest number of negative I2s controls for this source of potential misclassification.

The same type of reasoning goes for the TSD portfolios. From equation 11, I3 decreases only if I2 is negative. Dominance is established if I3 is always positive. As with SSD, TSD could be called into question if I3 remains positive due to a couple of outliers. Eliminating the TSDs with the highest number of negative I3s controls for this source of potential misclassification.

After proceeding as described above to remove the potential cases of misclassification from the sample of dominant and dominated portfolios, we re-calculated tables 2, 3 and 13. The results, not reported here but available on request, are qualitatively and quantitatively very similar. In fact, in some cases, the arbitrage returns obtained from the trimmed sample are slightly lower than the ones reported in the paper, which suggests that the weak dominance effect is not an issue. T-tests of equality of means show that the returns before and after trimming are statistically the same.

6. Conclusions

In this paper we examine if ex-post dominance relations can be employed to generate abnormal returns. An arbitrage portfolio long on SSD dominant stocks and short on SSD dominated stocks generates a relatively large, statistically significant premium. An arbitrage portfolio long on TSD dominant stocks and short on TSD dominated stocks generates a considerably higher statistically significant premium. These results are robust with respect to a range of conventional risk factors that include the Fama and French 3-factor model augmented by a momentum and a liquidity factor, as well as other risk factors such as cash flow volatility, leverage, company age, and return volatility. They are also robust with respect to the behavioral biases of over/underreaction as well as to sample specificities, transaction costs and misclassification due to data or statistical discrepancies.

Where momentum is concerned, we find an overlap in the composition of winner and dominant stock portfolios, and in the composition of loser and dominated stock portfolios. Removing winner stocks from the dominant stock portfolios and loser stocks from the dominated stock portfolios has only a marginal effect and the remaining dominant and dominated stocks continue to generate arbitrage premia of the same magnitude and significance levels as before.

The results of this paper suggest that ex-post dominance relations can be used to generate abnormal returns. Our strategy is similar to the well-known momentum strategy. However, we have shown that the two also have important differences. We propose that the findings of this paper can be used to improve momentum-type strategies. Portfolios built based on TSD, in particular, generate returns which are considerably higher than momentum or SSD portfolio returns and cannot be attributed to any of the risk factors commonly used in the literature. TSD relations identify stocks which are appealing to investors with decreasing absolute risk aversion.

This type of risk preference is probably the most intuitively appealing, thereby suggesting that our results could be due to the fact that investors prefer stocks which have recently demonstrated such behavior while they avoid stocks which have recently demonstrated the opposite behavior. Our results clearly suggest that using dominance relations as an additional filter for long and short positions can prove profitable.

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Table 1 Statistics on the number of stocks in the dominant/dominated stock portfolios

Panel A. Basic statistics on the number of stocks in each portfolio

	Average	Maximum	Minimum	Median
Sample	665.7	899	419	656
SSD Dominant	63.3	196	6	47
SSD Dominated	28.5	148	1	15
TSD Dominant	16.8	40	2	16
TSD Dominated	4.2	13	1	4

Panel B. Average number of common stocks in each pair of portfolios

	SSD Dominant	SSD Dominated
TSD Dominant	15.06	
TSD Dominated		3.57

Panel A reports basic statistics on the number of stocks in the sample as well as on the SSD and TSD dominant and dominated stock portfolios. SSD and TSD stand for second degree dominance and third degree dominance respectively. Panel B reports the average number of stocks that appear in two stock portfolios at the same time. For example, each month, there are on average 15.06 stocks which are both SSD and TSD dominant. The sample period is 03/1992 to 02/2013.

Table 2. Monthly average excess and risk adjusted returns of SSD and TSD portfolios 1 to 6 months into the holding period

Month	SSD Dominant	SSD Dominated	SSD Arbitrage	SSD Arbitrage Risk Adjusted	TSD Dominant	TSD Dominated	TSD Arbitrage	TSD Arbitrage Risk Adjusted
1st	0.883*	-1.453	2.336***	0.931	1.413***	-3.19***	4.604***	2.732***
	(1.95)	(-1.57)	(2.82)	(1.22)	(2.92)	(-2.73)	(4.02)	(2.64)
2nd	0.858**	-1.231	2.089**	0.252	1.282**	-1.058	2.340**	0.731
	(2.05)	(-1.30)	(2.46)	(0.81)	(2.20)	(-0.96)	(2.37)	(1.28)
3rd	0.920**	-0.881	1.801**	1.027**	1.269**	-1.563	2.832**	1.544**
	(2.11)	(-0.93)	(2.32)	(2.02)	(2.42)	(-1.15)	(2.44)	(2.07)
4th	0.658	-0.811	1.469*	0.528	0.991*	-1.304	2.295**	0.247
	(1.56)	(-0.85)	(1.88)	(1.12)	(1.77)	(-1.13)	(2.05)	(0.72)
5th	0.836**	-1.095	1.931***	0.918**	0.891	-1.550	2.441**	0.495
	(1.99)	(-1.36)	(3.30)	(2.28)	(1.49)	(-1.38)	(2.22)	(0.88)
6th	0.863**	-1.315	2.178***	0.505	1.252*	-1.962**	3.214***	1.437**
	(2.14)	(-1.44)	(2.80)	(1.15)	(1.76)	(-2.14)	(3.59)	(2.00)

The table reports average monthly buy-and-hold excess returns for portfolios of dominant and dominated stocks in the second (SSD) and third (TSD) degree and arbitrage portfolios 1 to 6 months into the holding period. For example, the 2nd month excess return is the average excess return from the end of the 1st month to the end of the 2nd month, assuming that the portfolio has been held for 1 month and was equally weighted at formation. Portfolios returns are in excess of the respective UK 1 month T-bill rate. The ranking period is 6 months and we skip one month between the ranking and the holding period. The SSD arbitrage portfolio is long on SSD dominant stocks and short on SSD dominated stocks while the TSD arbitrage portfolio is long on TSD dominant stocks and short on TSD dominated stocks. The Arbitrage Risk Adjusted columns, report the alphas from a 5-factor regression, where the dependent variable is the respective SSD or TSD arbitrage portfolio returns and the 5 factors are the 1-month excess market returns, the value premium, the size premium, the momentum factor and a liquidity factor. Momentum 6x6 returns are generated from the same sample as SSD and TSD portfolios. Winner stocks are stocks in the decile with the highest returns during the ranking period and loser stocks are stocks in the decile with the lowest returns during the ranking period. The size premium is calculated from the annually rebalanced small-minus-big arbitrage portfolio and the value premium from the annually rebalanced high book-to-market minus low book-to-market portfolio, as in Fama and French (1993). For the excess market return, the proxy for the market portfolio is the FTSE All Share index and the risk free rate is the UK 1 month T-bill rate. The liquidity premium is the returns from a portfolio long on illiquid stocks and short on liquid stocks. Illiquid stocks are stocks in the decile with the highest bid-ask spread and liquid stocks are stocks in the decile with the lowest bid-ask spread over the previous year. The sample period is 03/1992 to 02/2013. Figures in parentheses are t-ratios. Standard errors are adjusted for heteroscedasticity and serial correlation using the Newey-West estimator. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 3. Monthly average excess returns of SSD and TSD overlapping portfolios 3 to 12 months into the holding period

	SSD Dominant	SSD Dominated	SSD Arbitrage	SSD Arbitrage Risk Adjusted	TSD Dominant	TSD Dominated	TSD Arbitrage	TSD Arbitrage Risk Adjusted
6x3	0.713*	-1.500*	2.213***	0.737	1.115**	-2.337**	3.452***	1.669**
	(1.66)	(-1.71)	(2.96)	(1.54)	(2.21)	(2.29)	(3.89)	(2.20)
6x6	0.705*	-1.212	1.917***	0.693**	1.041*	-1.982**	3.023***	1.198**
	(1.70)	(-1.46)	(2.99)	(1.99)	(1.90)	(2.14)	(3.77)	(2.05)
6x9	0.726*	-1.074	1.800***	0.758**	0.966*	-1.567*	2.533***	0.979*
	(1.76)	(-1.44)	(3.35)	(2.21)	(1.83)	(-1.90)	(3.66)	(1.75)
6x12	0.638	-0.649	1.287**	0.680**	0.709	-1.094	1.803***	0.826*
	(1.55)	(-0.86)	(2.48)	(1.98)	(1.37)	(-1.39)	(3.11)	(1.68)

The table reports average monthly buy-and-hold excess returns for the second (SSD) and third (TSD) degree dominant, dominated and arbitrage portfolios 3 to 12 months into the holding period, assuming overlapping portfolios à la Jegadeesh and Titman (1993). Portfolios are equally weighted at formation. Portfolios returns are in excess of the respective UK 1 month T-bill rate. The ranking period is 6 months and we skip one month between the ranking and the holding period. The SSD arbitrage portfolio is long on SSD dominant stocks and short on SSD dominated stocks and the TSD arbitrage portfolio is long on TSD dominant stocks and short on TSD dominated stocks. The Arbitrage Risk Adjusted columns, report the alphas from a 5-factor regression, where the dependent variable is the respective SSD or TSD arbitrage portfolio returns and the 5 factors are the 1-month excess market returns, the value premium, the size premium, the momentum factor and a liquidity factor. For a description of the factors used, see Table 2. The sample period is 03/1992 to 02/2013. Figures in parentheses are t-ratios. Standard errors are adjusted for heteroscedasticity and serial correlation using the Newey-West estimator. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 4 Statistics on the average book-to-market value and market capitalization of the SSD and TSD dominant and dominated stock portfolios

Panel A. Statistics on the average book-to-market value of the SSD and TSD dominant and dominated stock portfolios.

	Average	Maximum	Minimum	Median
SSD Dominant	0.50	1.73	0.10	0.48
SSD Dominated	1.16	9.09	0.11	0.63
TSD Dominant	0.41	2.46	0.10	0.38
TSD Dominated	2.45	25.00	0.07	0.97

Panel B. Statistics on the average market capitalization of the SSD and TSD dominant and dominated stock portfolios (in million of ₤UK).

	Average	Maximum	Minimum	Median
SSD Dominant	689.9	8521.1	83.2	390.0
SSD Dominated	990.5	8715.2	0.8	216.5
TSD Dominant	788.0	9150.9	47.8	478.0
TSD Dominated	70.3	1745.5	0.8	45.7

The table reports statistics on the average book-to-market value (Panel A) and market capitalization (Panel B) of the SSD and TSD dominant and dominated stock portfolios.

Table 5 Asset pricing regressions for SSD and TSD arbitrage portfolio returns

	(1) $SSD6x6_t$	(2) $SSD6x6_t$	(3) $SSD6x6_t$	(4) $SSD6x6_t$	(5) $TSD6x6_t$	(6) $TSD6x6_t$	(7) $TSD6x6_t$	(8) $TSD6x6_t$
Constant	2.14%***	2.11%***	2.02%***	0.69%**	3.12%***	3.13%***	2.97%***	1.20%**
	(3.58)	(3.54)	(3.09)	(1.99)	(4.00)	(3.91)	(3.38)	(2.05)
$(R_M\text{-}R_f)_t$	-0.69***	-0.68***	-0.65***	-0.455**	-0.293	-0.270	-0.215	0.047
	(-3.32)	(-3.34)	(-3.31)	(-2.33)	(-1.37)	(-1.24)	(-1.06)	(0.30)
SMB_t		-0.296	-0.350	-0.45***		-0.039	-0.134	-0.263
		(0.11)	(-1.51)	(-3.39)		(-0.13)	(-0.38)	(-1.50)
HML_t		-0.283**	-0.264**	-0.097		-0.187	-0.154	0.069
		(-2.03)	(-2.08)	(-1.61)		(-1.08)	(-1.03)	(0.54)
LIQ_t			0.091	-0.026			0.160	0.003
			(0.54)	(-0.19)			(0.74)	(0.03)
WML_t				0.760***				1.016***
				(4.61)				(6.86)
R^2-adj.	0.11	0.15	0.15	0.41	0.01	0.01	0.01	0.28

SSD and TSD are the second degree stochastic dominance and third degree stochastic dominance returns respectively. Both use a 6 month ranking period and we skip a month between the ranking and the holding period. SSD and TSD returns are buy-and-hold returns from the 6x6 portfolios reported in Table 3. Momentum 6x6 returns (WML) are generated from the same sample as SSD and TSD portfolios. Winner stocks are stocks in the decile with the highest returns during the ranking period and loser stocks are stocks in the decile with the lowest returns during the ranking period. SMB is the annually rebalanced small-minus-big arbitrage portfolio and HML is the annually rebalanced high book-to-market minus low book-to-market portfolio, as in Fama and French (1993). R_M-R_f is the excess return of the market portfolio, where the proxy for the market portfolio is the FTSE All Share index and the risk free rate is the UK 1 month T-bill rate. LIQ is the returns from a portfolio long on illiquid stocks and short on liquid stocks. Illiquid stocks are stocks in the decile with the highest bid-ask spread and liquid stocks are stocks in the decile with the lowest bid-ask spread. For the regressions we employ monthly returns for the period 03/1992 to 02/2013. Figures in parentheses are t-ratios. Standard errors are adjusted for heteroscedasticity and serial correlation using the Newey-West estimator. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 6 SSD dominant stocks which become dominated and vice versa

Panel A. Percentage of SSD dominant stocks which become dominated after n months

	1 month	3 months	6 months	9 months	12 months
Average	0.54%	1.49%	2.57%	2.56%	2.55%
Maximum	7.37%	18.00%	22.00%	15.63%	15.79%
Minimum	0.00%	0.00%	0.00%	0.00%	0.00%

Panel B. Percentage of SSD dominated stocks which become dominant after n months

	1 month	3 months	6 months	9 months	12 months
Average	1.60%	3.35%	6.23%	5.19%	4.30%
Maximum	41.18%	46.67%	93.75%	90.00%	65.00%
Minimum	0.00%	0.00%	0.00%	0.00%	0.00%

The table reports the percentage of SSD dominant stocks which become dominated after n months into the holding period, and vice versa. The sample covers the period 03/1992 to 02/2013.

Table 7 Asset pricing regressions using quantile and vingtile momentum portfolios

The dependent variable is arbitrage portfolio returns based on 2nd degree stochastic dominance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$SSD6x3_t$	$SSD6x6_t$	$SSD6x9_t$	$SSD6x12_t$	$SSD6x3_t$	$SSD6x6_t$	$SSD6x9_t$	$SSD6x12_t$
Constant	0.72%	0.69%*	0.75%**	0.63%*	0.51%	0.45%	0.58%*	0.56%*
	(1.35)	(1.68)	(1.99)	(1.66)	(1.22)	(0.92)	(1.71)	(1.66)
$(R_M\text{-}R_f)_t$	-0.346	-0.370*	-0.303**	-0.422*	-0.462*	-0.455**	-0.381**	-0.483**
	(-1.45)	(-1.94)	(-1.99)	(-1.89)	(-1.93)	(-2.42)	(-2.52)	(-2.24)
SMB_t	-0.327**	-0.363***	-0.307***	-0.369***	-0.383**	-0.412***	-0.347***	-0.396***
	(-2.04)	(-2.68)	(-3.21)	(-3.27)	(-2.08)	(-3.40)	(-3.93)	(-3.49)
HML_t	-0.148	-0.105	-0.067	-0.088	-0.144	-0.095	-0.061	-0.089
	(-1.43)	(-1.29)	(-1.02)	(-1.34)	(-1.38)	(-1.16)	(-0.90)	(-1.25)
LIQ_t	0.025	-0.0001	0.017	-0.054	0.001	-0.025	-0.001	-0.064
	(0.18)	(-0.00)	(0.16)	(-0.42)	(0.01)	(-0.18)	(-0.01)	(-0.48)
$WMLQ_t$	1.14***	0.950***	0.799***	0.564***				
	(5.07)	(5.29)	(5.93)	(2.94)				
$WMLV_t$					0.810***	0.705***	0.579***	0.388**
					(4.77)	(5.39)	(5.76)	(2.58)
R^2-adj.	0.40	0.41	0.41	0.32	0.41	0.45	0.43	0.32

The dependent variable is arbitrage portfolio returns based on 3rd degree stochastic dominance

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

	$TSD6x3_t$	$TSD6x6_t$	$TSD6x9_t$	$TSD6x12_t$	$TSD6x3_t$	$TSD6x6_t$	$TSD6x9_t$	$TSD6x12_t$
Constant	1.80%**	1.37%*	1.10%*	0.89%	1.25%**	0.81*	0.67%	0.61%
	(2.22)	(1.72)	(1.69)	(1.44)	(2.05)	(1.77)	(1.11)	(1.04)
$(R_M-R_f)_t$	0.033	0.129	0.132	0.038	-0.059	0.055	0.071	-0.005
	(0.14)	(0.73)	(0.87)	(0.20)	(-0.25)	(0.37)	(0.54)	(-0.03)
SMB_t	-0.043	-0.149	-0.176	-0.207	-0.118	-0.219	-0.230	-0.243
	(-0.21)	(-0.81)	(-1.11)	(-1.22)	(-0.59)	(-1.33)	(-1.56)	(-1.45)
HML_t	-0.004	0.037	0.079	0.014	0.033	0.079	0.110	0.034
	(-0.02)	(0.29)	(0.68)	(0.13)	(0.21)	(0.66)	(1.02)	(0.34)
LIQ_t	-0.124	0.049	0.154	0.022	-0.174	-0.001	0.116	-0.003
	(-1.01)	(0.42)	(1.51)	(0.18)	(-1.27)	(-0.01)	(1.16)	(-0.03)
$WMLQ_t$	1.294***	1.149***	0.918***	0.625***				
	(5.93)	(5.34)	(5.23)	(3.55)				
$WMLV_t$					1.050***	0.972***	0.767***	0.517***
					(6.89)	(8.46)	(7.92)	(4.12)
R^2-adj.	0.20	0.23	0.22	0.12	0.27	0.34	0.31	0.17

SSD and TSD are the second degree stochastic dominance and third degree stochastic dominance returns respectively. Both use a 6 month ranking period and we skip a month between the ranking and the holding period. SSD and TSD returns are buy-and-hold returns from the 6x6 portfolios reported in Table 3. Momentum 6x6 returns, WMLQ and WMLV are generated from the same sample as SSD and TSD portfolios. Winner stocks are stocks in the quantile with the highest returns during the ranking period and loser stocks are stocks in the quantile with the lowest returns during the ranking period for WMLQ, while winner stocks are stocks in the vingntile with the highest returns during the ranking period and loser stocks are stocks in the vingtile with the lowest returns during the ranking period for WMLV. SMB is the annually rebalanced small-minus-big arbitrage portfolio and HML is the annually rebalanced high book-to-market minus low book-to-market portfolio, as in Fama and French (1993). R_M-R_f is the excess return of the market portfolio, where the proxy for the market portfolio is the FTSE All Share index and the risk free rate is the UK 1 month T-bill rate. LIQ is the returns from a portfolio long on illiquid stocks and short on liquid stocks. Illiquid stocks are stocks in the decile with the highest bid-ask spread and liquid stocks are stocks in the decile with the lowest bid-ask spread. For the regressions we employ monthly returns for the period 03/1992 to 02/2013. Figures in parentheses are t-ratios. Standard errors are adjusted for heteroscedasticity and serial correlation using the Newey-West estimator. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively

Table 8 Monthly excess returns of decile momentum portfolios

Panel A. Average monthly excess returns (in %) from a k-month buy-and-hold strategy with initial equal weighting

Month	1^{st}	2^{nd}	3^{rd}	4^{th}	5^{th}	6^{th}
Winners	1.303**	1.060*	0.839	0.589	0.699	0.794
	(2.23)	(1.91)	(1.44)	(1.05)	(1.23)	(1.41)
Losers	-0.610	-1.035	-0.778	-0.809	-0.776	-0.635
	(-0.79)	(-1.43)	(-1.11)	(-1.19)	(-1.15)	(-1.04)
WML	1.913***	2.095***	1.617***	1.398***	1.475***	1.429***
	(2.85)	(3.62)	(2.93)	(2.76)	(2.73)	(2.80)

Panel B. Average monthly excess returns (in %) from a k-month buy-and-hold strategy with initial equal weighting for overlapping portfolios

Portfolio	6x3	6x6	6x9	6x12
Winners	0.951	0.810	0.732	0.564
	(1.61)	(1.39)	(1.30)	(1.03)
Losers	-1.005	-0.900	-0.752	-0.502
	(-1.34)	(-1.28)	(-1.16)	(-0.82)
WML	1.956***	1.710***	1.484***	1.066***
	(3.21)	(3.17)	(3.16)	(2.69)

Panel A reports average monthly buy-and-hold excess returns for the winner, loser and winner-minus-loser (WML) portfolios 1 to 6 months into the holding period. For example, the 2nd month excess return is the average excess return from the end of the 1st month to the end of the 2nd month, assuming that the portfolio has been held for 1 month and was equally weighted at formation. Panel B reports average monthly buy-and-hold excess returns for the winner, loser and WML portfolios 3 to 12 months into the holding period, assuming overlapping portfolios à la Jegadeesh and Titman (1993). Portfolio returns are in excess of the respective UK 1 month T-bill rate. The ranking period is 6 months and we skip one month between the ranking and the holding period. The WML portfolio is long on winner stocks and short on loser stocks. The sample period is 03/1992 to 02/2013. Figures in parentheses are t-ratios. Standard errors are adjusted for heteroscedasticity and serial correlation using the Newey-West estimator. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 9 Monthly average excess risk adjusted returns (in %) of Second degree Stochastic Dominance stock portfolios excluding decile winner and loser stocks

Portfolio	6x3	6x6	6x9	6x12
SSD Dominant excluding Winners	0.239 (1.05)	0.343* (1.94)	0.347** (2.14)	0.290* (1.85)
SSD Dominated excluding Losers	-1.791*** (-2.99)	-1.282** (-2.45)	-1.308*** (-2.88)	-1.206*** (-2.76)
SSD Arbitrage (excluding winners and losers)	2.029*** (3.07)	1.625*** (2.86)	1.654*** (3.44)	1.495*** (3.27)

The table reports alphas from a four-factor regression model for three portfolios 3 to 12 months into the holding period, assuming overlapping portfolios à la Jegadeesh and Titman (1993). Portfolios returns are in excess of the respective UK 1 month T-bill rate. The ranking period is 6 months and we skip one month between the ranking and the holding period. The SSD Dominant - Winners portfolios include stocks which are SSD dominant but not winners for the same month. The SSD Dominated - Losers portfolios include stocks which are SSD dominated but not losers for the same month. The SSD arbitrage portfolio is long on SSD Dominant - Winners stocks and short on SSD Dominated - Losers stocks. The risk factors are the excess market return, the size, value and liquidity premium. For a definition of the factors, see Table 5. The sample period for overlapping portfolios is 03/1992 to 02/2013. Figures in parentheses are t-ratios. Standard errors are adjusted for heteroscedasticity and serial correlation using the Newey-West estimator. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 10 Monthly average risk adjusted arbitrage returns (in %) for Second and Third degree Stochastic Dominance portfolios for sub-samples

Panel A. SSD arbitrage returns

Ranking period sub-sample	1992 - 2002	2003 - 2012
SSD 6x3	3.053*** (2.74)	1.530 (1.57)
SSD 6x6	2.413** (2.42)	1.516* (1.86)
SSD 6x9	2.115*** (2.64)	1.545** (2.15)
SSD 6x12	1.179 (1.41)	1.374** (2.07)
Panel B. TSD arbitrage returns		
TSD 6x3	2.955*** (2.65)	3.854*** (2.95)
TSD 6x6	3.166*** (2.98)	2.907** (2.50)
TSD 6x9	2.237** (2.44)	2.773*** (2.77)
TSD 6x12	1.186* (1.70)	2.304*** (2.67)

The table reports average monthly buy-and-hold returns for the second and third degree stochastic dominance 6x3, 6x6, 6x9 and 6x12 arbitrage portfolios, assuming overlapping portfolios à la Jegadeesh and Titman (1993) for 2 sub-samples. The ranking period is 6 months, skipping one month between the ranking and the holding period. The SSD and TSD portfolios are long on dominant stocks and short on dominated stocks in the second and third degree respectively. The sample period is 03/1992 to 02/2013. Figures in parentheses are t-ratios. Standard errors are adjusted for heteroscedasticity and serial correlation using the Newey-West estimator. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Panel A. SSD arbitrage returns		
Ranking period sub-sample	1992 - 2002	2003 - 2013
SSD 6x3	1.128* (1.77)	0.02 (0.57)
SSD 6x6	0.765 (1.54)	0.187 (0.94)
SSD 6x9	0.812* (1.65)	0.354 (1.15)
SSD 6x12	0.672 (1.41)	0.257 (1.01)
Panel B. TSD arbitrage returns		
TSD 6x3	1.246** (1.96)	2.127** (2.145)
TSD 6x6	1.298** (1.98)	1.288* (1.90)
TSD 6x9	0.903* (1.81)	1.195* (1.81)
TSD 6x12	0.735 (1.41)	0.778 (1.57)

The table reports alphas from a five-factor regression model where the dependent variable is the buy-and-hold monthly returns of the 2nd and 3rd degree stochastic dominance 6x3, 6x6, 6x9 and 6x12 arbitrage portfolios, assuming overlapping portfolios à la Jegadeesh and Titman (1993) for 2 sub-samples. The risk factors are the excess market return, the size, value and liquidity premium, and the 6x6 momentum premium. For a definition of the factors, see Table 5. For the dominance portfolios, the ranking period is 6 months, skipping one month between the ranking and the holding period. The SSD and TSD portfolios are long on dominant stocks and short on dominated stocks in the second and third degree respectively. The sample period is 03/1992 to 02/2013. Figures in parentheses are t-ratios. Standard errors are adjusted for heteroscedasticity and serial correlation using the Newey-West estimator. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively.

Table 11 Arbitrage portfolio returns including transaction costs

	6 x 3	6 x 6	6 x 9	6 x 12
TSD	-1.171	0.712	0.992*	0.648*
	(-1.35)	(0.89)	(1.74)	(1.65)
SSD	-1.542**	0.041	0.549	0.348*
	(-2.01)	(0.06)	(1.61)	(1.67)
SSD excluding	-1.336*	0.366	0.798*	0.864**
WML stocks	(-1.99)	(0.57)	(1.72)	(1.99)

The table reports average monthly returns one month after the ranking period for overlapping arbitrage portfolios à la Jegadeesh and Titman (1993) including transaction costs. The 6x1 portfolios assume monthly rebalancing so they are not overlapping portfolios. The sample period is 03/1992 to 02/2013. TSD is an arbitrage portfolio long on 3rd degree dominant stocks and short on 3rd degree dominated stocks. SSD is an arbitrage portfolio long on 2nd degree dominant stocks and short on 2nd degree dominated stocks. WML is an arbitrage portfolio long on winner stocks and short on loser stocks. The bottom row reports returns for the SSD portfolios where we have excluded stocks which are SSD dominant and winners or SSD dominated and losers at the same time. Figures in brackets are t-ratios adjusted for heteroskedasticity and serial correlation using the Newey-West standard errors. ***, ** and * indicate significance at the 1%, 5% and 10% level respectively. Transaction costs are calculated as:
$Cost_{i,t} = Spread_{i,t} + (2 \text{ x } commission) + stamp\ duty$, where the spread is calculated from equation (12), commission is 0.3% per transaction and stamp duty is 0.5%.