How do short selling costs and restrictions affect the profitability of stock anomalies?

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Abstract

Short selling frictions cannot explain the persistence of seven prominent stock anomalies. Long-only investing is robust and profitable and can be further enhanced by using a synthetic short. Moreover, portfolios restricted to stocks that are easy to short sell continue to have large and significant short anomaly alphas. The paper derives cost bounds for switching between implementation methods and shows that the cost associated with short anomaly positions is small relative to their profitability contribution using a proprietary database of borrowing fees. Overall, the empirical evidence does not support the implications of arbitrage asymmetry that mispricing is concentrated in short positions where it is too costly to exploit.

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1. Introduction

Historical tests of the CAPM have given rise to an abundance of anomalously priced characteristics in the cross-section of stock returns (Cochrane, 2011). These characteristics can also be used as return predicting signals in the construction of profitable rule-based active investment strategies. Their success in empirical work has drawn the attention of practitioners and motivated a proliferation of anomaly replicating funds and smart beta indexes.

Focus in academic work has been placed on the performance of zero-cost long-short portfolios. In practice, investment vehicles that provide anomaly exposure tend to be long-only. Evidence on the impact of short selling frictions on anomaly profitability is scarce. The goal of this paper is to fill this gap and explore the effect of short selling costs and short selling restrictions on the viability of anomaly investing.

From the point of view of practitioners, the impact of short selling frictions is relevant as it can help determine the optimal approach to anomaly investing. Should strategies be executed long-only or long-short? Alternatively, can shorting the market, rather than short selling individual securities, be used to improve between anomaly fit and the performance of anomaly combinations?

From the point of view of academics, the impact of short selling frictions is relevant because mispricing explanations to anomalies require some form of limits to arbitrage. Intuitively, mispricing can persist if savvy investors are unable to profitably execute offsetting trades following a price distorting demand shock. In the specific case of short-selling, investors may not be able to exploit security *overpricing* because short-selling is prohibited or costly. This results in an asymmetry in arbitrage as buying is easy and short selling can be difficult (Stambaugh, Yu & Yuan, 2015).

An explanation of anomalies grounded on arbitrage asymmetry implies two key hypotheses: (1) anomaly profitability should be concentrated in short positions and (2) capturing this profitability should be too costly. The paper finds evidence against both claims for seven prominent stocks anomalies. Extensive mispricing exists in long positions and short selling costs are avoidable and low relative to short position profitability. In other words, short selling frictions cannot account for the persistence of anomalies. The evidence is as follows.

Time series alphas are large and statistically significant in *long-only* anomaly portfolios. Moreover, the inclusion of long-only anomalies to the investment universe leads to an economically large improvement in risk-adjusted performance. Sharpe ratios go up by 32% out-of-sample and 60% in-sample relative to a traditional passive investment in the market. The improvement is significant at the 1% level. The significant profitability in long-positions is evidence against the first implication of arbitrage asymmetry that anomaly profitability should be concentrated exclusively in short positions. From the point of view of investors, the result implies that improvements in performance can be achieved even without short selling.

Is it necessary to short sell individual securities to exploit security overpricing and to capture negative alphas? If short selling individual securities is impossible, how can we further improve upon long-only investing? In the presence of all-encompassing prohibitive shorting frictions on individual securities, the paper proposes the use of a synthetic-short strategy. The synthetic bet goes long the highest alpha decile and an intermediate portfolio whilst shorting the market. The synthetic-short approach aims to achieve two objectives. First, it removes overexposure to the equity premium which otherwise dominates long-only investing. Second, the synthetic-short approach exploits negative alphas in overvalued securities. Ideally, investors want to buy positive alpha whilst short selling negative alpha securities. In practice investors can often only easily short sell the market. In other words, investors can only easily short securities in their value-weighted proportions. A long position in a positive alpha decile combined with a market short implies a net short position on all nine remaining decile portfolios. Taking a short position on the lowest negative alpha decile portfolio is beneficial. This is the standard approach in the unrestricted long-short setting. However, short positions in intermediate portfolios can be suboptimal. In properly priced intermediate portfolios without an alpha, short positions are just redundant bets that needlessly waste capital. More problematically however, intermediate portfolios can also have a positive alpha which can be harmful to strategy profitability. To reduce this risk, the synthetic-short strategy includes a positive weight in the second highest alpha portfolio. The results show that using a synthetic-short improves Sharpe ratios by 40% out-of-sample and 80% in-sample relative to long-only investing. Improvements are statistically significant at the 2% level. The findings suggest that long-only investing can be extensively improved by using only a market short. The evidence goes against the second hypothesis as it suggests that short position profitability can be partly exploited using a cheap execution method such as a market short.

Short selling *individual securities* in the short leg of anomalies is profitable in the absence of shorting costs. Short alphas capture 63% of average long-short profitability. In addition, portfolio analysis shows that short selling individual securities improves the Sharpe ratio by 64% out of sample and 24% in-sample relative to the synthetic-short approach. Improvements are statistically significant at the 2% level (4% in-sample). The finding suggests that short selling individual securities is profitable in the absence of shorting costs.

Overall the results suggest that short selling restriction on either individual securities or the market can severely reduce the profitability of anomalies. However, they do not completely annul their investment potential. But how high are short selling costs and can they be easily reduced?

For investors that do not face regulatory or self-imposed short selling restrictions, it is important to get a sense of the magnitude of short selling costs on individual securities relative to their profitability contribution. Towards this goal, the paper uses a proprietary cross-sectional database of borrowing fees to estimate short selling costs. The value weighted borrowing cost is 46 basis points (BPS) annually which is close to the general collateral (GC) rate of 35 BPS in the data. In contrast, the equally weighted borrowing fee is 416 BPS. This is nine times larger. Even though 37.3% of stocks in the data are on special (not on GC and expensive to borrow), they account for only 2.9% of market capitalization. The evidence suggests that high borrowing costs are concentrated in small caps.

The borrowing costs of anomaly short positions are small relative to their alphas. On average, borrowing costs are only 15.4% of the average short anomaly alpha. The highest borrowing costs are for the unprofitable (116 BPS annually) and looser portfolio (110 BPS annual). However, their short selling cost is only a fraction of their gross short alpha which is 504 BPS for profitability and 1124 BPS for momentum. For the remaining five anomalies, costs are below 65 BPS. In fact, size, value, investments and accruals have a higher shorting cost for stocks that fall in the long position than for stocks in the short position. Overall, the results suggest that short selling costs are small relative to anomaly profitability. This goes against the second hypothesis of arbitrage asymmetry which suggests that exploiting short position profitability is too costly.

The approach to anomaly construction can have a large impact on borrowing cost estimates. Throughout the analysis, the paper relies on value weighted portfolios with NYSE break points for anomaly construction. This method is common in the literature and aims to reduce the impact of small stocks. However, researchers often use equally weighted sorts without NYSE break points to make statements about the population of equities without placing special emphasis on firms with large market capitalization. Conclusions change extensively with this alternative approach to anomaly construction. The average borrowing cost associated with equally weighted anomaly sorts is 974 BPS which is fourteen times larger than its value weighted counterpart. The difference arises due to the large cross-sectional differences in borrowing costs between small and large market capitalization stocks.

Equally weighted anomalies also have higher alphas but *only in long* positions. In other words, short selling costs can be easily and extensively reduced using value weights and NYSE breakpoints without forgoing any short position profitability. Empirical investigations of shorting costs that rely on methods which emphasize small market capitalization stocks can severely overstate the relevance of shorting costs in practice. Moreover, investment strategies that make extensive use of small stocks for short positions can have prohibitive short selling costs. However, costs for strategies that are based on large caps seem to be low relative to profitability.

The analysis relies on cross-sectional differences between borrowing costs. However, costs can also vary considerably over time and more importantly, between lender borrower relationships (Kolasinski, Reed & Ringgenberg, 2013). The market for borrowing securities is decentralized and opaque. Prices are not centrally determined, competitive or publicly observable. Therefore, the conditions available to one borrower may not be applicable to another. Nevertheless, short selling costs can be known in advance. Interested arbitrageurs can estimate their own concurrent shorting costs before committing to an anomaly execution approach. Towards this goal, the paper estimates the bound at which investors should switch between execution methods. Based on their concurrent shorting costs, investors can dynamically decide whether to execute long with a synthetic-short or a security-short. The results show that investors can no longer be confident that a security-short approach will outperform synthetic-short execution when short selling costs for a portfolio of anomalies exceeds 125 basis points annually. Constructing a synthetic short becomes more profitable than a security-short when borrowing costs for individual securities exceed 300 basis points annually. The bounds for switching to a synthetic-short are an order of magnitude larger from the estimated average value weighted anomaly borrowing cost of 68 BPS.

To sum up, there is significant profitability in the long leg of anomalies and additional improvements in performance can be achieved through a synthetic-short. Short selling costs on individual equities are small relative to their profitability contribution if investors do not extensively rely on small market capitalization firms in portfolio construction. Overall, the evidence does not support the view that short selling frictions can account for the persistence of anomalies.

The paper has three key contributions: (1) it develops the synthetic-short approach which successfully improves upon long-only investing, (2) it derives cost bounds for different methods of anomaly execution and compares them to cost estimates derived from borrowing cost data, and (3) shows the effect of anomaly construction choices on the magnitude of borrowing costs.

2. Short selling and anomalies

2.1. Understanding the market for short selling

Before a stock can be sold short, it must be borrowed. The US market for lending and borrowing stocks is decentralized and opaque. Deals are often made between brokers and institutions and prices are not centrally determined or publicly observable. Resultantly, proprietary datasets from security lenders are routinely used as sources of information in the literature (D'Avolio, 2002; Jones & Lamont, 2002; Cohen, Diether & Malloy, 2007). Alternatively, various proxies for shorting demand (e.g. short interest) and shorting supply (e.g. institutional ownership) are often employed for analysis (Nagel, 2005).

Short sellers are a diverse group. From market makers and option traders to long-short hedge funds. When it comes to mutual funds, only a third can short sell by their charters and only 2% do so in practice (Almazan, Brown, Carlson, & Chapman, 2004). Practitioners often cite regulatory, cultural and client-imposed constraints as common motivators for an underlying reluctance to short sell. Since short sellers do not obtain the proceeds from a sale, there is little benefits from short selling in terms of liquidity. Rather, short sellers are more likely to be motivated by superior information (Diamond & Verrechia, 1987) and hedging needs (Bohemer, Jones & Zhang, 2008).

Lenders are usually custodian banks that clear and hold positions for large asset owners, such as pension funds and mutual funds. Custodian banks enter into revenue sharing contracts with beneficial owners as compensation for their services (Reed, 2013). Stock lending programs are an important source of revenue for institutional investors. Estimates suggest institutional lending revenue is $800 million annually (Aggarwal, Saffi, & Sturgess, 2015).

The US market for short selling has become relatively more active recently. The market started slowly, with total short interest as percent of NYSE shares outstanding period being less than 1% in the 1929-1931 (Meeker, 1932). More recent data (2000-2004) suggests that short selling is up to 13% of NYSE share volume (Bohemer, Jones & Zhang, 2008). Estimates of equity loans from 2010 suggest that 15% of stocks available for lending are utilized (Prado, Saffi & Strugess, 2016). However, not all stocks borrowed are used for short selling; they may also be used for voting or tax-arbitrage (Christoffersen, Getzy, Musto & Reed, 2005).

2.2. The mechanics of the short sale

Loans are often intermediated by brokers in order to reduce search costs and enable ease in collateral management. Upon receiving a request to borrow shares, the broker seeks out a willing lender who agrees (but does not commit) to deliver shares in three days. Large institutions can circumvent the process and negotiate directly.

The obligations of share borrowers are simple. Dividends need to be transferred to back to the lender. However, share borrowers do attain the right to vote on shareholder meetings. Consequently, lending involves a trade-off between obtaining the lending fee and the right to express dissent though voting[1].

Short sellers must post collateral for borrowed shares. For US equities, collateral is set at 102% of the value of the stock. Lenders can use posted collateral to close a position if borrowers fail to deliver shares three days after a recall. Cash is used as collateral for 98% of the cases and T-bills for the rest (D'Avolio, 2002). When collateral takes the form of a security, fees are directly arranged by the parties.

The rebate rate is the interest rate that borrowers receive on their collateral. The difference between the rebate rate and the prevailing market rate is the borrowing cost (also known as the loan fee). Intuitively, the market rate is the opportunity cost; it captures the income that the short seller could have obtained if he used his money to invest in a safe market instrument such as the Federal Funds Rate. Therefore, the borrow fee, which is the difference between the market and rebate rate, is the cost of short selling.

Stocks that are hard to borrow are on 'special' and have higher borrow fees. In contrast, stocks with a baseline fee are on 'general collateral' (GC). Together, GC and specialness equilibrate supply and demand in the market for stock borrowing. Theoretically, borrowing costs would be zero if every asset owner was willing to lend shares in a perfectly competitive market. For positive short selling costs to arise, some investors must hold (overpriced) stocks that they are not willing to lend (Dufee, 1996; Krishnamurty, 2002).

Retail investors who want to short sell receive zero interest on their collateral which usually accrues to the broker. In addition, stocks on special are usually traded by large proprietary trading desks; brokers tend to deny short sales for stocks on special to small investors (Reed, 2013). Resultantly, retail investors or small players are disadvantaged in this marketplace.

Loans are typically on a continuous basis (open-term); this implies that every day they can be renegotiated or terminated by either party. The variability of costs adds some dynamic risk to short selling as investors need to be mindful of fee variance (Engelberg, Reed & Ringgenberg, 2016). The value of collateral is marked to market daily which ameliorates counterparty risk. In case of unfavourable price movements, short sellers are asked to update collateral (Mitchel, Pulvino & Stafford, 2001; Jones & Lamont, 2001). Investors without liquid assets to post collateral may need to close a position early. Moreover, under a call to terminate from a counterparty, borrowers will need to either close the position permanently or find another willing lender. Borrowers have three days to return recalled borrowed shares and the average time to re-establish a short is estimated at 23 trading days (D'Avolio, 2002). Due to reputation effects however,

[1] In practice, institutional investors often restrict share lending and recall loaned shares in firms with poor performance and weak governance in order to vote (Aggarwal, Saffi & Sturrgess, 2015). This tend to raise borrowing fees around voting record dates.

recall rates tend to be quite low (2% per month) (D'Avolio, 2002). As with most financial contracts, there is some flexibility in the design. Recall risk can be ameliorated with the use of a fixed term loan which cannot be renegotiated before an agreed upon date. Nevertheless, term loans tend to be infrequent in practice, arguably, due to the low incidence of recalls.

Return swaps or options are an alternative to short selling. Studies show that the use of options increases when short selling is constrained (Evans, Geczy, Musto & Reed, 2008; Battalio & Schultz, 2011). However, sellers tend to transfer short selling costs and risks to the derivative buyer. For example, short sale constraints tend to be reflected in option pricing (Ofek, Richardson & Whitelaw, 2004). This is intuitive as sellers would want to have the choice to hedge positions cheaply. In fact, derivative contracts often contain fee provisions in case of a rise in the underlying loan fees. In a sense, loan prices, derivative conditions and spot prices are jointly determined (D'Avolio, 2002).

2.3. Theoretical links between short selling and mispricing

There is a flourishing literature on the theoretical link between short selling and scrutiny prices. Given that anomalies came about as tests of the CAMP, it is important to first note that short selling frictions do not change the predictions of the CAPM. As an equilibrium model, the CAPM predicts that all homogeneous investors hold the market portfolio. Given that short positions cannot be part of this equilibrium, short selling frictions are immaterial for the model's predictions (Elton, Gruber, Brown & Goetzmann, 2009, Ch. 14). Intuitively, the representative investor cannot be short on average just like he cannot be a net lender.

Under investor *heterogeneity* however, overpricing can occur as a combination of differences in opinion and short selling restrictions. The mechanism is simple, short sale constraints prevent negative opinions from being incorporated into prices (Miller, 1977). Reasoning more generally, short leg overpricing can remain persistently strong and reflect the views of primarily optimistic (or irrational) investors if savvy arbitrageurs are unable to profitably execute offsetting trades due to short selling costs. This can lead to prices being biased by the view of optimists. Relying on similar forms of reasoning, theoretical models often use short selling constraints to sustain differences between prices and fundamentals (Duffie, Garleanu & Pedersen, 2002).

Limits to arbitrage, such as short selling costs, are a fundamental building block of mispricing explanations of anomalies. If investors experience a demand shock that pushes prices away from fundamental values, arbitrageurs will not be able to correct security prices if they face difficulties trading. The demand shock causing price divergence is often modelled in the literature as the result of irrational investor behaviour. Limits to arbitrage is therefore a key ingredient to behavioural explanations (Barveris & Thaler, 2003). Since demand shocks can also arise for a variety of different reasons, such as institutional frictions relating to contracting and agency (Gromb & Vayanos, 2010), the relevance of short selling frictions for asset pricing is even more comprehensive.

2.4. Arbitrage asymmetry

Exploiting mispricing in an undervalued security is easy as arbitrageurs can simply make a purchase. In the process, they will cause price pressure until mispricing corrects. However, if short selling frictions are extensive, arbitrageurs will face difficulty profiting from security overpricing. This causes an asymmetry in arbitrage. For anomalies to be explained by arbitrage asymmetry we need to confirm two hypotheses: (1) anomaly profitability is concentrated in short position and (2) it is too costly to profitably exploit.

We need both hypothesis to be confirmed by the data to be able to claim that the persistence of anomalies is explained exclusively by short selling frictions. If only the second hypothesis holds, then arbitrage asymmetry explains the profitability of short positions and we would need to develop a completely different explanation for the profitability of long positions.

The details matter. We are not interested if short selling costs are higher than long-short profitability; even though this is often done in the literature. When long-only investing works, investors can always simply choose not to short sell. Consequently, we need to investigate two implications of arbitrage asymmetry: (1) is there profitability in long positions and (2) how high are costs in short positions relative to their profitability. Finally, we need to understand if there are methods to avoid high short selling costs that do not result in a commensurate drop in profitability.

It is important to note that short selling frictions only have the potential to explain the persistence of anomalies. They cannot account for anomaly existence. In other words, short selling frictions can suggest that trading against model mispricing may be unprofitable for an array of investors, but they do not explain why there is model mispricing in the first place. To motivate why anomalies arise in the first place we would need to model the pricing process of the representative investor.

2.5. Anomalies and short selling: the assumptions for frictionless anomaly trading

Papers examining anomaly performance in frictionless markets are implicitly making two assumptions: (1) the size of the collateral posted on borrowed assets is equivalent to their value and (2) the rate paid on borrowed cash is equivalent to the rate received on collateral. These two assumptions are required for long-short anomaly investments to require no initial money outlay and to have no short selling cost.

How would the zero-cost trade work under these two assumptions? First, you borrow 100$ dollars from the market at the borrow rate (R) and post them as collateral on the short position. On this collateral you receive an interest rate (r) from the counterparty. This makes you effectively a lender of cash to the security lender; at the same time, you are a borrower from the market. Once you have the asset, you can sell it on the market and obtain 100$ for its sale (assumption 1) . Finally, you can use the 100$ from the short sale to buy the long asset. In the final portfolio, you get a rebate rate (r) on your cash collateral and you pay the borrow rate on your cash borrowings (R). These two rates cancel out (assumption 2) and portfolio performance is determined by the difference between the long and short stock position.

Both assumptions are violated in practice. The market rate is different from the rebate rate. This difference is effectively the short selling cost. Second, the size of the collateral for short positions is higher than the value of the asset (102% for US equities). Consequently, taking a long-short anomaly bet though physical short selling cannot be without an initial money outlay[2] or a short selling cost. This raises the question as to how high are short selling costs in practice and whether they can explain the profitability of short positions in well-known anomalies?

2.6. Short selling costs: what do we know?

Early evidence on the magnitude of short selling costs comes from Jones & Lamont (2001). Using data on 80 actively traded NYSE stocks in the 1926-1933 period, they find substantial time series and cross-sectional variation in short selling costs. In their sample, most large-cap stocks are inexpensive to short. In addition, expensive to short stocks have lower subsequent returns.

Using data from an institutional lender in a sample covering the 2000-2001 period, D'Avolio (2002) finds that the cost of borrowing a value-weighted loan portfolio is 25 basis points annually. Around 16% of CRSP stocks in his sample can't be borrowed but they account for less than 1% of the market capitalization. Stocks on special represent 9% of the sample and cost around 4.3% annually; they also tend to be small with low institutional ownership. The remaining stocks have loan fees of around 20 basis points annually. For most stocks, there is excess lendable supply (D'Avolio, 2002). D'Avolio argues that shorting fees are not high enough to explain return anomalies or an underlying reluctance to short sell.

An early attempt to estimate the shorting cost of anomalies was made by Geczy, Musto & Reed (2002). Using a year of equity loans data, they find that the short selling costs of big, growth and low momentum firms are small relative to the documented excess returns of the strategies.

Nagel (2004) uses institutional ownership as a proxy for short selling constraints. Consistent with the view that short selling constraints reduce price efficiency and anomaly performance, Nagel (2004) finds that lower instructional ownership implies more overpricing of short leg securities in equally weighted sorts.

Cohen, Diether & Malloy (2007) use proprietary lending data from a large institution and find an average loan fee of 4% for small stocks and 0.4% for large stocks for the 1999–2003 period. The median holding time for a stock loan position is 3 weeks in their sample. Cohen, Diether & Malloy (2007) find that outward demand shifts, which signal an increase in the amount of negative information coming to the borrowing market, lead to negative future stock returns.

Boehmer, Jones & Zhang (2008) construct a proprietary NYSE panel data of short sales and find that short selling constraints are not widespread. In their 2000-2004 sample, they find that heavily shorted stocks outperform stocks low levels of levels of shorting over a 20-day period.

Drechsler & Drechsler (2014) argue that anomalies disappear for stocks with low lending fees. Their result is contrary to findings by Getczy, Musto & Reed (2002) but in line with the results of Nagel (2004) who finds that (proxied) short selling constraints are associated with more short position overpricing.

Chu, Hirshleifer & Ma (2016) use regulation SHO as a natural experiment to examine the impact of limits to arbitrage on ten stocks anomalies. The examined regulation relaxed constraints on *short selling*

[2] We can also view the addition collateral as a cost and assume that the long position is scaled down to account for the higher collateral requirement.

execution for a random pilot of NYSE/AMEX stocks. They find that profitability fell by 77 basis points per month for anomaly short positions following the adoption of the regulation. The authors argue that their estimates capture the causal effect of limits to arbitrage. They interpret the findings as being more consistent with mispricing explanations to anomalies.

Overall, short selling investigations give ambiguous evidence on the potential relevance of borrowing costs for anomalies. On the one hand, studies find low average borrowing fees (Jones & Lamont, 2001; D'Avolio, 2002; Cohen, Diether & Malloy, 2007), low shorting costs to anomalies (Getczy, Musto & Reed, 2002) and weak short selling constraints (Boehmer, Jones & Zhang, 2008). On the other hand, some authors argue that shorting costs are high for anomalies (Drechsler & Drechsler, 2014), that price inefficiency is high when short selling costs are high (Nagel, 2004) and that removing constraints on shorting execution reduces short anomaly profitability (Chu, Hirshleifer & Ma, 2016).

When it comes to the magnitude of short selling costs for anomalies, this paper argues that the results in the literature are not necessarily inconsistent as choices in anomaly construction can have a large impact on the results. This paper shows that strategies relying on small stocks (by using equal weights without NYSE break points for example) have much larger borrowing cost. The difference across construction methods is so large that it can extensively alters the conclusions of the analysis.

2.7. Transaction costs

Investigations of trading and short selling costs tend to be undertaken separately in the literature as they tackle different issues. Frazzini, Israel & Moskowitz (2012) show that the price impact of short selling is not (statistically) different from the price impact of selling long. Israel & Moskowitz (2012) find little evidence that variation in the size, value and momentum premiums can be explained by variation in trading costs. More recently, Novy-Marx & Velikov (2015) study an array of anomalies and find positive net spreads after incorporating simple transaction cost mitigation techniques into the strategies. Recent research also suggests that despite the incredible growth rates experienced by smart beta ETFs over the past few years, well-known active strategies can still accommodate extensive supplementary growth before the market impact of large fund turnover can annul smart beta profitability (Novy-Marx & Velikov, 2016; Ratcliffe, Miranda, & Ang, 2016). In short, studies do not support the view that transaction costs can account for anomalies or that they are larger for short position relative to long positions.

3. Anomaly construction and short selling data

3.1. Anomaly construction

The paper constructs seven anomalies using CRSP and COMPUSTAT data on US common stocks listed on NYSE, AMEX, and NASDAQ from 07/1963 until 12/2016. Data before the examined time frame is not used as it can be biased towards large successful firms (Fama & French, 1992). To avoid forward looking bias, fundamental data from the previous fiscal year is conservatively assumed to be available at the end of June. Firms without market capitalization at the period of portfolio formation are excluded. Delisting returns are included whenever available in CRSP to minimize potential biases (see Shumway (1997) for an extensive discussion of delisting returns).

Baseline anomalies are constructed using value weighted decile sorts with NYSE break points (equal number of NYSE firms across portfolios). Equally weighted sorts require additional trading each month following return realizations in order to rebalance back to equal weights. Equally weighted sorts also overweight small stocks by construction. As a result, they have two to three times the transaction costs of value weighted portfolios (Novy-Marx & Velikov, 2015). Similar problems will occur if we do not use NYSE break points or if we assigning weights based on the strength of the signal; top and bottom portfolios will end up being overpopulated with small firms as they tend to have extreme values of the characteristics. Intuitively, a small firm is more likely to have extreme characteristics, such as a low profitability or investments, relative to a large firm which can be diversified over projects, regions and divisions.

Seven anomalies are reconstructed: size, value, profitability, investment, momentum, accruals and net issuance. These anomalies also appear in Fama & French (2008). Anomaly portfolio rebalancing is annual except for momentum which is rebalanced monthly. Stocks are excluded if they lack the information to be included in a sort.

Size (SMB) is constructed following Fama & French (1993) whereby portfolios are constructed at the end of June using market capitalization as the sorting signal. The 'me' signal is the log of market capitalization recorded in million. The size anomaly goes long on low market capitalization firms and short on high market capitalization firms.

Value (BTM) follows Fama & French (1993). The signal is formed by dividing book equity with market equity whereby negative book to market firms are excluded. Value goes long on high book to market firms and short on low book to market firms. I do not take the log of the ratio to improve the signal's interpretability.

Operating profitability (OP) follows Fama & French (2015). The operating profitability (OP) signal is constructed as revenues minus cost of goods sold, interest expense, and selling, general, and administrative expenses divided by book equity. The operating profitability anomaly goes long high profitability firms and short low profitability firms.

Investments (INV) follows Fama & French (2015). The investments signal is constructed as the change in total assets between two fiscal years divided by the earlier fiscal year. The investments anomaly goes long firms with low investments and short firms with high investments.

Momentum (WML) is constructed using cumulative returns between t-2 and t-12 as the sorting signal (with portfolio formation at t-1) and monthly rebalancing following Jagadeesh and Titman (1993). The momentum anomaly goes long on high cumulative return firms and short on low cumulative return firms.

Accruals (ACC) follows Sloan (1996). The accruals signal is constructed as:

$$Accruals = \frac{(dACT - dCHE - dLCT + dDLC + dTXP - DP)}{\frac{(AT + AT_{-12})}{2}}$$

Where *d*ACT is the annual change in total current assets, dCHE is the annual change in total cash and short-term investments, *d*LCT is the annual change in current liabilities, *d*DLC is the annual change in debt in current liabilities, *d*TXP is the annual change in income taxes payable, *d*DP is the annual change in depreciation and amortization, and (AT+AT−12)/2 is average total assets over the last two years. Companies that do not have information for all variables needed for constructing the signal (except income taxes payable) are excluded. The accruals anomaly goes long on low accruals firms and short high accrual firms.

Net issuance (NI) follows Fama & French (2008). The net issuance signal is constructed as the log ratio of split adjusted shares outstanding over the two previous consecutive years. Portfolios exclude firms with no change in net issuance. The net issuance signal is the difference between the highest issuance portfolio and a separate negative issuance portfolio.

The market (MKT) is constructed as the value weighted return in excess of the Treasury bill rate of all US common stocks in NYSE, AMEX, and NASDAQ that have valid data in CRSP. Long-only anomalies (LSMB, LBTM, LWML, LOP, LINV, LAC, LNI) are constructed by only taking the long position in each anomaly. Short-only anomalies (SSMB, SBTM, SWML, SOP, SINV, SAC, SNI) are constructed by taking only the short position in each anomaly. Table 1 shows descriptive statistics of the signals in the data. All signals display considerable cross-sectional variation.

3.2. Short selling data

To estimate short selling costs, the paper uses a proprietary cross-sectional database (20/04/2017) from a large financial institution containing the borrowing fee on 7435 equities. The data is particularly useful for understanding cross-sectional differences in characteristics between cheap and expensive securities. The data captures borrowing cost quotes between two large financial institutions. It shows the type of fees that a large arbitrageur will face in normal times. In most investigations of the lending market, data comes from proprietary lending databases. Due to intermediation costs, the borrowing and lending fee need not be equivalent. A database containing borrowing fees is therefore more suitable to the examination of short selling costs. The reference value for borrow cost calculation is the overnight bank funding rate (OBFR; 91 BPS). The general collateral rate is 35 BPS below the OBFR reference value. The database also contains information on the number of stocks available for borrowing. Short selling data is matched with accounting data from previous fiscal year (December). Cost data is available for 96% of securities with market capitalization information in CRSP/COMPUSTAT. Securities without market capitalization information are excluded.

Table 2 summarizes information in the short selling database. Around 17.8% of the shares outstanding are available for borrowing. Most of them are stocks on GC where 17.2% of total shares outstanding are available for borrowing. Using market values rather than shares outstanding gives a similar picture; 19.4% of market capitalization is available for shorting. The result suggests that the data provider is a large player in the market.

The most important result is the difference between the value weighted and equally weighted average of borrowing cost. The value weighted borrowing cost is only 46 basis points (BPS) which is close to the GC rate of 35 BPS. In comparison, the equally weighted borrowing cost is 416 BPS. This is nine times larger![3] Figure 1 illustrates the issue. Most securities above the median market cap (vertical line in Figure 1) are on GC while extreme values for borrowing costs are common for small caps. In fact, the smallest stocks are almost never on GC. The average cost of stocks above the median market capitalization is 70 basis points (Figure 1 difference between intercept and above median market capitalization dummy).

The mean value of stocks on special is 1060 BPS. Even though 37.3% of stocks in the sample are on special, they represent only 2.9% of total market capitalization. The most important result it is that high borrowing costs are concentrated in small market capitalization firms.

Portfolio sorts are the same as non-parametric cross-sectional regressions (Cochrane, 2011) and they are particularly well suited to give a clear picture of how characteristics vary across different levels of short selling costs. Table 3 shows the variation of characteristics across ten portfolios sorted on borrowing costs. As expected, portfolios with high borrowing costs are small market capitalization firms with relatively fewer lendable shares relative to outstanding. Accruals and investments do not seem related to borrowing fees. Moreover, value stocks seem to be associated with higher short selling costs than growth stocks. On the other hand, unprofitable loser firms that invest extensively and issue shares are associated with high short selling costs. Nevertheless, we also need to keep in mind that results can be driven by market capitalization as small firms tend to have both high fees and extreme values of the characteristics.

The important thing to note from Panel B in Table 3 is that stocks above the median market capitalization have low equally weighted borrowing fees. The finding that large stocks are inexpensive to short is consistent with preceding investigations that use proprietary data (Jones & Lamont, 2001; D'Avolio, 2002). This is intuitive as non-lending investors are less likely to absorb the entire share issue in larger companies. Short selling costs for small stocks may also be unreliable as a large arbitrageur can move the market.

The intuition and empirical findings suggest that size is a good proxy for short selling costs. Using this proxy we can extend the analysis for the full sample period. Resultantly, the paper will form portfolios that exclude firms below the median market capitalization as a mechanism for excluding hard to borrow securities.

[3] The equally weighted mean borrowing fee is close its full sample counterpart which does not exclude firms that are not in CRSP.

Time series average of characteristics (07/1963 - 12/2016)							
	me	mom	bm	prof	inv	acc	ni
High signal portfolio (vw)	9.87	1.91	2.25	0.85	0.76	0.10	0.32
Average (ew)	4.49	1.14	0.94	0.17	0.17	-0.03	0.04
Low signal portfolio (vw)	3.61	0.64	0.19	-0.29	-0.15	-0.14	-0.02
Time series average of cross sectional dispersion							
CS dispersion	1.93	0.57	1.26	8.61	0.98	0.11	0.14

Table 1: Characteristics. Shows the average and dispersion of anomaly signals for the 07/1963-12/2016 period. me is the signal for size (in million and log). Mom is the cumulative momentum signal for momentum. bm is the book to market signal for value. prof is the signal for profitability. inv is the signal for investment. acc is the signal for accruals. ni is the signal for net issuance. Average (ew) is the time series average of the equally weighted cross-sectional average of the characteristic. High signal portfolio (vw) is the time series average of the value weighted cross-sectional average in the decile sorted portfolio with the highest value of the characteristic. Low signal portfolio (vw) is the time series average of the value weighted cross-sectional average in the decile sorted portfolio with the lowest value of the characteristic. CS dispersion is the time series average of the cross-sectional standard deviation of characteristics.

Borrow Costs			
Number of stocks	3497	Max	-0.35%
GC	-0.35%	10th percentile	-8.37%
VW Mean	**-0.46%**	1st percentile	-87.6%
Mean	**-4.16%**	Min	-99.9%
Median	-0.35%	S.D.	13.2%
Mean (Specials)	-10.6%	% on Special	37.3%
Available			
Shares		$	
Available/Outstanding	17.8%	Available/Market	19.4%
Available GC/Outstanding	17.2%	Available GC/Market	19.3%
		Capitalization Special/Market	2.9%

Table 2: Borrowing costs and share availability. Shows summary statistics for borrowing costs and the shares available for borrowing. Borrowing costs are annual. Firms without market capitalization in CRSP are excluded. VW Mean is the value weighted mean of borrow costs. % on special is the number of stocks that are not on general collateral (GC) relative to total. Available/Outstanding is the average total number of shares available for borrowing relative to total number of shares outstanding. Available GC/Outstanding is average the total number of shares on general collateral relative to total shares outstanding. Capitalization Special/Market is the total market capitalization of stocks on special relative to the total market capitalization of stocks in the sample.

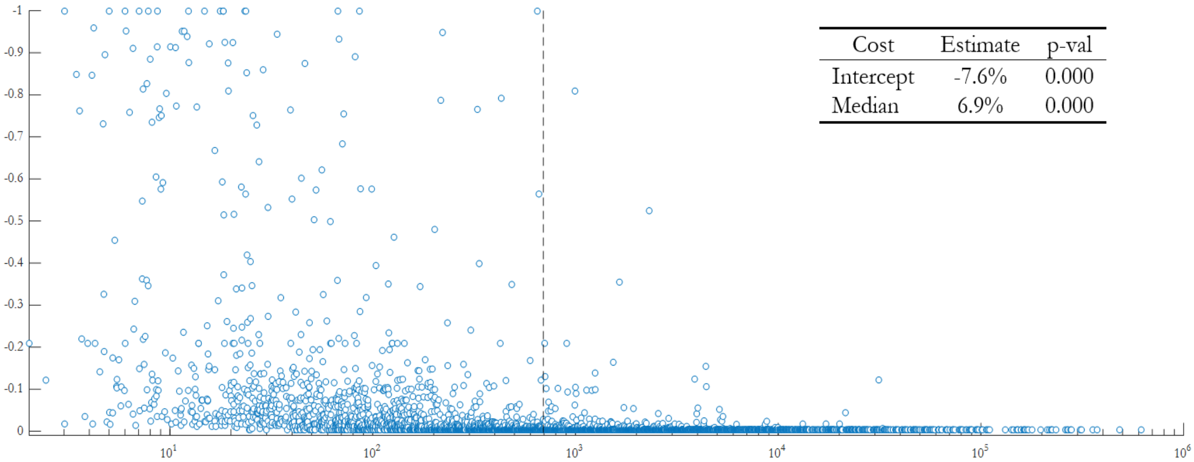

Figure 1: Borrowing costs and market capitalization. Shows borrowing costs (y axis) on market capitalization (x axis-log scale recorded in million). Dotted vertical line is the median of market capitalization. Median is a dummy variable that takes the value 1 when a stock is above the median market capitalization.

Panel A-Sort on cost										
Decile	Securities	Cost	Mc	A/O	Bm	Mom	Prof	Inv	Acc	Ni
1	350	**-31.78%**	**247**	**2%**	**1.07**	**0.87**	**-1.32**	0.18	-0.04	**0.18**
2	349	-5.07%	269	4%	1.06	0.99	-0.18	0.17	-0.04	0.08
3	350	-1.85%	576	6%	1.17	1.05	0.59	0.11	-0.05	0.07
4	350	-0.80%	858	10%	0.75	1.09	0.05	0.17	-0.04	0.04
5	350	-0.35%	749	16%	0.82	1.26	0.21	0.07	-0.05	0.02
6	349	-0.35%	1521	21%	0.61	1.20	0.22	0.15	-0.05	0.03
7	350	-0.35%	2122	24%	0.62	1.25	0.24	0.13	-0.05	0.02
8	350	-0.35%	3537	27%	0.64	1.20	0.30	0.08	-0.05	0.01
9	349	-0.35%	7230	28%	0.65	1.23	0.30	0.13	-0.05	0.02
10	350	-0.35%	46733	23%	0.61	1.21	0.35	0.06	-0.05	0.00
μ	3497	-4.16%	6401	16.1%	0.79	1.14	0.10	0.12	-0.05	0.04
p-val (10=1)		0.00	0.00	0.00	0.00	0.00	0.00	0.33	0.48	0.00

Panel B-Sort on market capitalization										
Decile	Securities	Mc	Cost	A/O	Bm	Mom	Prof	Inv	Acc	Ni
1	350	286	-21.85%	1%	**1.71**	**0.99**	**-0.63**	0.08	-0.05	**0.11**
2	349	400	-10.90%	4%	0.96	1.01	0.43	0.18	-0.06	0.09
3	350	346	-3.40%	8%	0.80	1.05	-0.27	0.14	-0.03	0.07
4	350	619	-2.37%	12%	0.77	1.11	-0.05	0.17	-0.04	0.05
5	350	950	-0.92%	16%	0.70	1.14	0.09	0.09	-0.05	0.03
6	349	1567	-0.58%	21%	0.58	1.18	0.19	0.19	-0.05	0.05
7	350	2168	-0.44%	24%	0.62	1.24	0.19	0.11	-0.05	0.02
8	350	3533	-0.38%	27%	0.64	1.20	0.29	0.10	-0.05	0.01
9	349	7146	-0.37%	28%	0.66	1.22	0.29	0.13	-0.05	0.02
10	350	46806	-0.35%	22%	0.61	1.21	0.35	0.06	-0.05	0.00
μ	3497	6401	-4.16%	16.1%	0.79	1.14	0.10	0.12	-0.05	0.04
p-val (10=1)		0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.95	0.00

Table 3. Borrow costs and characteristics. Shows the equally weighted average of characteristics in ten portfolios sorted on borrow costs with market capitalization as a secondary sort (when borrow costs are equivalent) in Panel A and sorted on market capitalization in panel B. Includes stocks for which anomalies are constructed. Cost is the annual borrowing cost. A/O is average of the firm values of shares available for borrowing relative to shares outstanding. Mc is market capitalization recorded in million. Bm is the book to market ratio. Mom is cumulative momentum. Op is operating profitability. Inv is investments. Acc is accruals. Ni is net share issuance.

3.3. Portfolio performance

Table 4 shows summary statistics for long-short portfolios. Net issuance and momentum have the highest risk-adjusted performance with an M2 of 11.2 % and 10.5% respectively. On the other side of the spectrum are size (SMB) and operating profitability (OP) with the lowest risk adjusted performance as stand-alone investments. In fact, their raw excess returns are not statistically significant. On average, anomaly skewness is positive. Excess kurtosis on the other hand, is an issue for all the strategies. The maximum drawdown measure indicates that extreme crashes are especially problematic for size and momentum.

Table 14 in the appendix shows portfolio statistics for taking a long position in the short side of anomalies. As expected, the Sharpe ratio of the short side of anomalies is much lower than that of the long side of anomalies. Furthermore, the short side of anomalies experiences even higher drawdowns on average that the long side. The drawdown of 99% for low momentum really stands out. High drawdowns suggest that undiversified counterparties to individual anomaly bets face considerable crash risk.

Table 5 shows that the average correlation between long-short strategies is very low. The highest individual correlation are value-investments (0.51) and operating profitability-net issuance (0.38). On average, the equity premium is the least correlated strategy. The result can be expected given the historical development of anomalies as tests of the CAPM whereby researchers discover anomalies using the equity premium as an aggregate wealth proxy.

The average correlation among stock strategies rises considerably in the long-only setting (Table 6). Surprisingly, the market reverses its role and becomes the most correlated strategy. Individual correlations between the market and operating profitability, investments, accruals and net issuance are all above 0.9. This severely limits the diversification potential of long-only strategies. Intuitively, whenever you invest in a stock, whether that stock is a value stock or a low issuance stock, you are also investing in the stock market. Therefore, the equity premium is implicitly included in all long only anomalies. Correlations among short strategies are even higher than their long-only counterparts. Again, the market has the highest average correlation among short strategies.

Finally, the diagonal in Table 6 shows the correlation between the long and short leg of the same anomaly. High correlations are desirable in this case. A perfect correlation would imply arbitrage; the long and short portfolio would move together whilst simultaneously providing different average returns. Net issuance has the highest correlation between the long and short leg. This can in part explain net issuance's low variance and drawdown. On the other hand, low and high momentum portfolios have a relatively low correlation. Given that the performance of the long and short momentum portfolios can significantly diverge, the strategy has a high standard deviation and a large maximum drawdown.

4. Anomaly alpha and short selling costs

4.1. Alphas

Anomaly alphas with respect to the equity premium are positive and statistically significant for six out of the seven examined anomalies[4] (Table 7). An exception is size, which has an economically small and a statistically insignificant alpha. The average alpha t-statistic across anomalies is 3.68. Five of the anomalies have a long-short alpha t-statistic larger than 3.

When it comes to the alphas of long-only anomalies, we see a significant decrease in both economic and statistical significance. Average alpha falls by more than half for long-only portfolios. Book to market, momentum, investments and net issuance have statistically significant long-only alphas. Surprisingly, value's long-only alpha is more significant than its long-short counterpart. While average alphas fall by more than half in the long-only setting, the average t-statistics of alphas has a much smaller decline. This occurs as the market model is a much better fit in the long-only setting (an average R2 of 77% compared to 6% for the long-short setting) which reduces the standard errors of anomaly alphas and raises their statistical significance.

Time series regressions reveal that 63% of long-short profitability comes from the short side. Five from the seven examined anomalies have statistically significant negative alphas. Statistical significance is even higher than in the long-short setting for accruals and operating profitability.

Momentum, investments and net issuance have significant alphas from both the long and short position. Book to market seems to be the only anomaly deriving its alpha primarily from the long side. On the other hand, operating profitability and accruals get their alpha primarily from the short position. Finally, size portfolios are well explained by the market model and do not have significant alphas.

[4] A t-statistic threshold of 2 is more appropriate as the data-mining adjusted hurdle of 3 refers to new discoveries (Harvey, Liu & Zhu, 2016).

	MKT	SMB	BTM	WML	OP	INV	ACC	NI	μ
R	0.50%	0.28%	0.38%	1.34%	0.30%	0.38%	0.31%	0.55%	0.51%
t-stat	*2.84*	*1.46*	*2.26*	*4.87*	*1.69*	*2.86*	*2.44*	*5.12*	2.96
σ	4.44%	4.81%	4.22%	6.93%	4.44%	3.30%	3.23%	2.69%	4.23%
Sharpe	0.12	0.06	0.09	0.18	0.07	0.12	0.10	0.20	0.12
M2	6.3%	3.2%	5.0%	10.5%	3.9%	6.4%	5.5%	11.2%	6.5%
Skew	**-0.53**	0.74	0.49	-1.46	0.37	0.35	0.19	0.07	**0.11**
t-stat	*-5.43*	*7.63*	*5.11*	*-15.11*	*3.82*	*3.62*	*1.93*	*0.75*	1.11
Ex. Kurt.	1.94	4.41	1.76	7.81	4.20	1.83	1.74	0.75	3.21
t-stat	10.05	22.79	9.10	40.39	21.71	9.44	8.98	3.90	16.62
Max	16%	32%	21%	23%	26%	17%	13%	10%	20%
Min	-23%	-21%	-15%	-46%	-23%	-13%	-12%	-9%	-20%
Drawdown	56%	84%	53%	81%	65%	36%	34%	29%	55%
D.D	3.05%	2.99%	2.59%	4.96%	2.92%	2.04%	2.05%	1.58%	2.73%
Sortino	0.17	0.09	0.15	0.26	0.11	0.19	0.16	0.35	0.19

Table 4: Data summary for long-short portfolios. Shows the summary statistics for long-short anomalies for the period 07/1963-12/2016. D.D. is downside deviation with zero as the target. M2 is the annual volatility matched (to the equity premium) return. μ is the average across anomalies. MKT is the equity premium, SMB is size, BTM is value, WML is momentum, OP is profitability, INV is investment, ACC is accruals and NI is net issuance.

Rho/P-val	MKT	SMB	BTM	WML	OP	INV	ACC	NI
MKT		0.00	0.12	0.00	0.00	0.00	0.00	0.00
SMB	0.17		0.00	0.04	0.00	0.00	0.00	0.00
BTM	-0.06	0.33		0.00	0.00	0.00	0.06	0.98
WML	-0.18	-0.08	-0.17		0.00	0.17	0.33	0.00
OP	-0.39	-0.54	-0.18	0.16		0.94	0.11	0.00
INV	-0.24	0.15	0.51	0.05	0.00		0.00	0.00
ACC	-0.17	-0.20	0.07	0.04	0.06	0.21		0.00
NI	-0.39	-0.34	0.00	0.21	0.38	0.30	0.20	
μ	-0.18	-0.07	0.07	0.01	-0.07	0.14	0.03	0.05

Table 5: Correlations long-short. Shows the correlations between long-short portfolios**.** Numbers below the diagonal are Pearson correlation coefficients. Numbers above the diagonal are p-values.

Correlation Long only/Short only									
RhoL/RhoS	MKT	SMB	BTM	WML	OP	INV	ACC	NI	μ (S)
MKT		0.98	0.93	0.79	0.88	0.94	0.92	0.92	**0.91**
SMB	0.78	0.66	0.93	0.74	0.80	0.90	0.86	0.88	0.87
BTM	0.83	0.78	0.67	0.72	0.82	0.92	0.90	0.84	0.86
WML	0.85	0.76	0.69	**0.55**	0.79	0.79	0.78	0.79	0.77
OP	0.93	0.69	0.75	0.78	0.76	0.86	0.86	0.84	0.83
INV	0.90	0.82	0.86	0.80	0.83	0.84	0.94	0.92	0.90
ACC	0.90	0.74	0.74	0.81	0.84	0.82	0.85	0.88	0.88
NI	0.95	0.70	0.83	0.77	0.91	0.87	0.81	**0.88**	0.87
μ (L)	**0.88**	0.75	0.78	0.78	0.82	0.84	0.81	0.84	0.94

Table 6: Correlations long only and short only. Numbers above the diagonal are the cross correlations between short only anomalies. Numbers below the diagonal are correlations between long only anomalies. Numbers in the diagonal are correlations between the short and long leg of the same anomaly. μ (L) is the average correlation for long anomalies. μ (S) is the average correlation between short anomalies. The intersection of μ (L) and μ (S) is the average long correlation divided by the average short correlation.

LS	SMB	BTM	WML	OP	INV	ACC	NI	μ
$\dot{\alpha}$	0.19%	0.42%	1.42%	0.53%	0.48%	0.39%	0.67%	0.59%
β	0.18	-0.06	-0.28	-0.40	-0.18	-0.12	-0.23	-0.16
t ($\dot{\alpha}$)	1.02	**2.52**	**5.41**	**3.15**	**3.72**	**3.15**	**6.79**	3.68
t (β)	3.52	-1.09	-3.24	-8.36	-4.99	-3.92	-9.40	-3.93
R2	2.9%	0.4%	3.2%	15.3%	5.7%	2.9%	15.0%	6.5%

Long	LSMB	LBTM	LWML	LOP	LINV	LACC	LNI	μ
$\dot{\alpha}$	0.16%	0.31%	0.48%	0.11%	0.19%	0.04%	0.23%	0.22%
β	1.11	1.00	1.17	0.96	1.09	1.14	0.91	1.05
t ($\dot{\alpha}$)	1.01	**2.70**	**3.78**	1.58	**2.05**	0.38	**4.46**	2.28
t (β)	25.7	26.0	32.0	47.6	41.8	42.3	63.1	39.79
R2	60%	70%	72%	86%	81%	80%	91%	77%

Short	SSMB	SBTM	SWML	SOP	SINV	SACC	SNI	μ
$\dot{\alpha}$	-0.03%	-0.11%	-0.94%	-0.42%	-0.29%	-0.35%	-0.44%	-0.37%
β	0.93	1.06	1.45	1.35	1.27	1.26	1.14	1.21
t ($\dot{\alpha}$)	-0.85	-1.47	**-4.98**	**-3.24**	**-3.60**	**-3.74**	**-5.35**	-3.32
t (β)	88.8	49.7	23.0	39.1	59.8	51.8	51.5	51.98
R2	95%	86%	63%	78%	89%	84%	86%	83%

Table 7: Anomaly alphas. Shows the slope and the monthly intercept from time series regressions of value weighted anomaly portfolios on the equity premium. T-statistics are calculated using heteroskedasticity and autocorrelation consistent standard errors.

VW	SMB	BTM	WML	OP	INV	ACC	NI	µ
Cost Short	-0.38%	-0.42%	-1.10%	-1.16%	-0.47%	-0.64%	-0.61%	-0.68%
Cost Long	-3.56%	-0.67%	-0.53%	-0.39%	-0.68%	-0.67%	-0.48%	-1.00%
Short ά	0.38%	1.32%	**11.24%**	**5.04%**	**3.48%**	**4.26%**	**5.28%**	4.43%
Long ά	1.88%	**3.71%**	**5.81%**	1.32%	**2.28%**	0.45%	**2.74%**	2.60%

Table 8: Short selling costs. Shows the annual borrowing costs associated with long and short value weighted anomaly positions. Borrowing cost calculations are made on sorts that exclude firms without borrowing cost data. Short/Long ά is the average annualized alpha where bolded coefficients are the statistically significant gross alphas.

Panel A - EW without NYSE break points								
	SMB	BTM	WML	OP	INV	ACC	NI	µ
Long ά	12.48%	10.17%	8.52%	3.94%	7.12%	4.92%	7.35%	**7.79%**
t (ά)	*4.44*	*4.93*	*4.23*	*3.08*	*2.55*	*2.06*	*5.92*	*3.89*
Short ά	0.27%	-6.30%	-6.00%	-1.27%	-7.94%	-3.77%	-7.26%	**-4.61%**
t (ά)	*0.56*	*-3.24*	*-1.71*	*-0.40*	*-4.38*	*-1.93*	*-3.67*	*-2.11*
Short EW Cost	-0.41%	-4.07%	-17.32%	-17.66%	-4.88%	-9.15%	-14.36%	**-9.69%**
Intercept	-4.19%	-4.78%	-4.27%	-4.24%	-4.47%	-4.52%	-5.22%	-4.53%
p-val	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	
Long	-18.07%	-2.58%	0.35%	2.31%	-8.67%	-5.17%	4.29%	-3.93%
p-val	*0.00*	0.00	*0.57*	*0.00*	*0.00*	*0.00*	*0.00*	
Short	3.78%	0.71%	-13.05%	-13.43%	-0.40%	-4.64%	-9.14%	-5.17%
p-val	*0.00*	*0.28*	*0.00*	*0.00*	*0.53*	*0.00*	*0.00*	

Panel B -VW Size Restricted								
	SMB	BTM	WML	OP	INV	ACC	NI	µ
Long ά	2.06%	3.56%	5.85%	1.31%	1.75%	0.41%	5.07%	**2.86%**
t (ά)	*1.40*	*2.75*	*3.70*	*1.55*	*1.80*	*0.37*	*5.25*	*2.40*
Short ά	-0.31%	-1.09%	-9.53%	-4.04%	-3.57%	-3.76%	-4.89%	**-3.89%**
t (ά)	*-0.67*	*-1.18*	*-4.80*	*-4.78*	*-3.65*	*-3.27*	*-4.92*	*-3.32*
Short VW Cost	-0.70%	-0.39%	-0.60%	-0.68%	-0.44%	-0.50%	-0.51%	**-0.55%**
Intercept	-5.08%	-5.05%	-5.06%	-5.05%	-5.05%	-5.02%	-5.40%	-5.10%
p-val	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	
Long	4.32%	4.47%	4.57%	4.55%	3.60%	3.77%	4.95%	4.32%
p-val	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	
Short	4.73%	4.05%	3.58%	3.91%	4.23%	4.01%	4.58%	4.15%
p-val	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	

Table 9: Market capitalization and anomaly performance. Panel A shows average annual alpha and short selling costs for equally weighted portfolios without NYSE break points. Panel B shows annual alpha for value weighted portfolios that exclude stocks below the median market capitalization and costs for sorts that exclude firms without market equity (me) data. Long and Short are the coefficients from regressing costs on dummy variables that take the value 1 for stocks that enter long and short portfolios respectively.

4.2. Short selling costs

Table 8 contains the borrowing fee of stocks in long and short positions. The results broadly confirm the intuition obtained from the sorts in Table 3. For size and value there is higher short selling cost in the long position. In addition, unprofitable and low momentum portfolios are the most expensive to short sell as expected. The annual short selling cost is 110 and 116 BPS for momentum and profitability respectively. Investments, accruals and net issuance do not exhibit high short selling costs or notable differences between cost in the long and short position. On average, short selling costs are only 15.4% of average short alpha and 13.6% of the average significant short alpha. Overall, costs are low relative to short anomaly profitability.

4.3. Equally weighted portfolios without NYSE break points

Researchers often use equally weighted portfolios without NYSE break points to investigate the cross-section of securities without a special focus on large market capitalization enterprises. It is prudent to consider how this alternative construction method affects the estimates. Table 9 reports alphas and shorting costs.

Equally weighted portfolios have three times the average long position alpha of value-weighted sorts. Especially the long position of size becomes strongly significant. This is intuitive as the approach emphasizes small stocks which allows the size anomaly to shine. On the other hand, short alphas in equally weighted sorts are almost equivalent to their value weighted counterparts. In short, all the added profitability from overweighting small caps comes from long positions. However, short selling costs for short positions are fourteen times larger! Only investments and book to market have short alphas higher than their associated borrowing cost. The increase in short selling costs comes from the large cross-sectional difference between the short selling costs of small and large market capitalization firms.

4.4 Restricted value weighted portfolios

High borrowing costs are concentrated in small stocks (see Table 3 and Figure 1). This section investigates how cost and profitability are affected by excluding small stocks from the analysis. More specifically, anomalies are reconstructed without stocks below the market capitalization median. Results are shown in Panel B Table 9.

The average short and long position cost are respectively 4.32% and 4.15% smaller than the -5.10% cross-sectional average that includes all securities (Table 9 Panel B). The average short alpha is reduced by 54 BPS annually relative to the value weighted approach without size restrictions (Table 9). Again, the reduction in profitability from excluding small market capitalization stocks is minimal in the short position. Costs also fall by 13 BPS relative to the unrestricted value weighted sort and are only 20 BPS away from the GC rate. Restricting the investment universe by excluding small market capitalization firms has a small detrimental effect on profitability and a minor positive effect on borrowing costs. Value weights and NYSE break points are already emphasizing large enterprises extensively. Consequently, additional restrictions to remove small firms only have limited impact on the results.

The regression results also confirm that portfolios constructed using value weights with NYSE break points are very effective at reducing costs in the extreme portfolios relative to the cross-section.

5. Scenarios

What is the impact of short selling restrictions on the joint profitability of anomalies? To investigate this question, several scenarios based on different short selling and investment restrictions are considered. Differences in risk-adjusted performance determine constraint relevance. There are four base scenarios: (1) market (long market), (2) long-only (includes long-only anomalies), (3) synthetic short (allows short selling the market portfolio) and (4) long-short (allows short selling individual securities).

Sharpe ratio improvements across scenarios are compared using two portfolio construction methods: (1) in-sample maximum Sharpe ratio and (2) equally-weighted. The equally weighted approach (EW) can be considered out-of-sample as it does not incorporate any future data for execution. In fact, past research suggests that EW is superior to out-of-sample alternatives due to sensitivity of optimization procedures to estimation error (DeMiguel, Garlappi, & Uppal, 2009). The goal is to not to compare performance between construction methods but between scenarios with different assumptions and restrictions. The statistical significance of differences in Sharpe ratios is assessed with the Ledoit & Wolf (2008) bootstrap procedure which accounts for non-normality and serial correlation.

Trading anomalies in reverse order, such as long growth short value, is disallowed across scenarios; as there are no empirical or theoretical justification to motivate a reverse bet. All scenarios are dollar positive with weights that sum to 100%. Scenarios with short positions assume 100% collateral at the risk-free rate[5]. The analysis starts without considering short selling costs. Latter sections derive the cost bounds that would cause a switch between execution methods.

5.1. Market: traditional investing

The simplicity of the market scenario makes it the default choice for many investors. In this base setting, anomaly investments are not utilized, and investors simply hold a passive long position in the market.

5.2. Long-only: including anomalies

Above and beyond financial instrument availability, investors often face regulatory or self-imposed leverage and short selling restrictions that make long only anomaly investing a valid real-world approximation. The widespread availability of long-only smart beta ETFs and anomaly replicating mutual funds has made this approach commonplace. The equally weighted approach assigns an equal weight to all the available investments. In the Max Sharpe approach constraints take the following form:

$$\sum_{j}^{J} w_j = 1$$

[5] Placing a 102% collateral requirement does not materially influence the results.

$$0 \le w_j \le 1$$

where $j = [LMKT, LSMB, LBTM, LWML, LOP, LINV, LACC, LNI]$

5.3. Synthetic short

Ideally, investors want to buy positive alpha whilst short selling negative alpha securities. In practice investors can often only easily short sell the market. In other words, investors can only easily short securities in their value-weighted proportions. The paper proposes a synthetic-short approach to anomaly investing as a substitute to short selling individual securities. Investors can use a market short to remove beta and overexposure to the equity premium. In addition, a market short can also help exploit overpricing.

Intuitively, combining a long decile position in the highest alpha portfolio with a market short implies a net short position on all stocks in the remaining nine deciles. Shorting securities that do not have negative alphas is suboptimal. However, the biggest concern is shorting positive alpha securities which can often accompany the second highest alpha decile. To ameliorate the issue, the paper uses a synthetic long-short bet which includes a modest purchase of the second highest alpha portfolio. The goal is to reduce the strong negative weight in the intermediate portfolio relative to a pure long-market-short approach. This can reduce the risk of short selling positive alpha securities. Adopting this alternative approach causes an improvement of 7% in-sample and 5% out-of-sample relative to a pure market short approach. The proposed strategy is as follows:

$$R^{synthetic} = \frac{2R^l + R^i}{3} - R^m + R^f$$

Where $R^{synthetic}$ is the long-short synthetic position. R^l is the highest alpha decile portfolio. R^i is a value weighted intermediate portfolio containing stocks that are in the second decile with the highest alpha. R^m is the (short position) in the market and R^f is the risk-free rate capturing the interest on market short collateral. Effectively, imposing a 100% collateral requirement makes only the short position self-financed.

In the max Sharpe approach, constraints take the following form:

$$\sum_i^I w_i = 1$$

$$0 \le w_i$$

where $i = [LMKT, SMBS, BTMS, WMLS, OPS, INVS, ACCS, NIS]$

where f SMBS or example refers to the synthetic size bet.

5.4. Long-short

In the long-short scenario, investors can take short positions in anomalies, but they must post 100% collateral at the risk-free rate. This effectively deleverages the portfolio as investors are forced to hold a significant investment in the risk-free asset (like moving down the capital allocation line). Moreover, in this scenario, short position must equal long positions in anomalies; that is, anomalies cannot be unbundled. This can happen in practice if investors only have access to format-fixed long-short investments that attempt to harvest a premium. Removing the unbundling constraint does not significantly improve performance. Moreover, removing the collateral restriction also has a limited impact on Sharpe ratios. The constraint moves the investor down the capital allocation line as it forces an investment in the risk-free asset. In the in-sample Max-Sharpe setting constraints take the following form:

$$\sum_{i}^{I} w_i = 1$$

$$0 \leq w_i$$

where $i = [LMKT, SMB, BTM, WML, OP, INV, ACC, NI]$

6. Scenario Results

6.1. Sharpe ratios

Table 10 shows the returns, standard deviation, Sharpe ratios and p-values for portfolios across scenarios. Several notable results emerge. First, there is a large improvement in Sharpe ratios when we include long-only anomalies. The Sharpe ratio raises by 32% in the EW case and 60% in the Max Sharpe approach. Improvements are statistically significant at the 1% level. The result implies that anomalies can add to performance even in a long-only setting.

Second, enabling a market short also improves performance. EW Sharpe ratios raise by 40% relative to the long-only setting. The improvement is significant at the 2% level. Sharpe ratios in-sample increase by 80% and are significant at the 1% level. Overall, the results suggest that the synthetic short approach is superior to long-only investing.

Third, allowing for the short selling of individual securities whereby investors are forced to hold collateral at the risk-free rate leads to a significant improvement. The out-of-sample EW Sharpe ratio further increases by 64% and is statistically significant at the 2% level. The in-sample Sharpe increases by 24% and is significant at the 5% level. In frictionless markets, short-selling individual securities is very profitable. Overall, all the constraints have an economically large impact on performance.

6.2. Weights

Table 11 shows the weights assigned to anomalies across scenarios and portfolio construction methods. It is first important to note that the market portfolio is redundant in the presence of long-only anomalies. This suggests that anomalies and the market are substitutes when anomaly shorting is prohibited. Intuitively, you always want to invest in the outperforming long-only anomaly portfolio that already embeds a significant equity premium exposure (Table 7). In fact, removing overexposure to the equity premium is the intuition behind the construction of the synthetic short. The conclusion that passive investments and anomalies are substitutes does not hold in long-short space as long-short anomalies tend to have low or negative market betas (Table 7).

As expected, in the long-only scenario, significant weight is assigned to the anomalies with the highest long alpha. Book to market, momentum and net issuance are the only strategies receiving a positive long-only weight. This can explain why value and momentum are so popular among mutual funds and ETF providers while anomalies that require significant short positions, such as accruals, operating profitability and investment are yet to gain significant traction as standalone products in practice.

The investment anomaly receives the smallest weight across scenarios. This can be expected given its high cross-correlation with other investments (see correlation Table 5 and 6). The finding suggests that the investment anomaly is irrelevant from an investment perspective in the examined setting. On the other hand, net issuance receives a substantial weight across scenarios.

7. Cost bounds

The decentralized nature of the borrowing market makes the matching of the universe of anomaly stocks to a meaningfully lengthy historical record of borrow fees a futile quest. Proprietary databases are inherently brief. Moreover, the cost of borrowing can vary between broker-lender relationships (Kolasinski, Reed & Ringgenberg, 2013). Rebate rates are not competitive prices and are thus inherently relationship specific. What was available to one borrower may not be applicable to another. Finally, even the perfect short selling data would only capture the marginal cost of borrowing. The marginal cost can be markedly different from the cost faced by a large arbitrageur that can move the market. These problems are common to the literature; the structure of the lending market makes the derivation of a 'true' cost estimate problematic.

Fortunately, shorting costs are known in advance. In addition, the decision to short sell individual securities or the market need not be constant. The optimal execution method can depend on prevailing market conditions. Interested arbitrageurs can estimate their own concurrent shorting costs before deciding how to execute an anomaly trade. Along this line of reasoning, it is more interesting to estimate the cost bounds at which switching from one method of execution to another is optimal.

It is important to keep in mind that long-short investing can be successfully approximated with the use of a synthetic-short which circumvents the entire messy business of short selling individual securities. It is therefore prudent to use the synthetic short approach as a benchmark (rather than long-only). A conservative annual cost of 45 BPS for shorting the market is assumed based on the value-weighted shorting cost in the data. A useful way to think of the market short is as a value weighted short on all stocks. Alternatively, shorting though derivative contracts or ETFs is another easy way to obtain a short market exposure.

The alternative to the synthetic-short benchmark is the leverage constrained long-short method with 102% rebate bearing collateral. Adding the market collateral level of 102% additionally reduces the attractiveness of shorting in the presence of costs. Demanding additional collateral magnifies shorting costs as it induces rebate bearing collateral on a larger position.

Table 12 shows the results. First, it is evident that at low levels of borrowing costs, there is undeniably a lot of benefit to short selling. Improvements are statistically significant both in-sample and out-of-sample for GC and value-weighted (VW) short selling costs. The statistical significance of improvements disappears at the 5% level when shorting costs exceed 125BPS annually. The economic usefulness of shorting individual equities disappears at an annual shorting cost of approximately 300BPS. The cost bound is large relative to the average anomaly short selling cost of 68BPS. This implies that in normal times the cost of short selling is small relative to the profitability of short positions in individual anomaly securities. Alternatively, the bound in Table 12 can be interpreted as the total cost bound (sum of all anomaly trading costs).

To conclude, investors have high degree of confidence that they should execute an anomaly trade using a security-short approach when annual short selling costs are below 125 basis points annually. Executing a market short becomes economically more practical when annual shorting costs exceed 300 basis points annually. Estimates of average anomaly borrowing costs imply that they are small relative to the profitability contribution of security-short selling.

8. Final remarks

The short selling cost associated with anomaly strategies can be partly offset by revenue received though the lending of stocks in long positions. The analysis assumed that investors are unable to use this income as incorporating lending fees requires information on lending utilization rates. Moreover, for a fair comparison, any income from the lending market would also need to be incorporated in the passive benchmark. In other words, the relevant question is whether stocks in long anomaly positions can deliver higher lending income than stocks in a passive value weighted index. This auxiliary question is left for future research.

μ (R)	Max Sh	EW
Market	0.9%	
Long-Only	1.3%	1.1%
Synthetic Short	0.6%	0.6%
Long-Short	0.9%	0.9%

Sh	Max Sh	EW
Market	0.12	
Long-Only	0.18	0.15
Synthetic Short	0.33	0.21
Long-Short	0.41	0.35

σ	Max Sh	EW
Market	4.4%	
Long-Only	5.0%	4.7%
Synthetic Short	0.7%	1.0%
Long-Short	1.2%	1.5%

p	Max Sh	EW
Market		
Long-Only	0.00	0.00
Synthetic Short	0.00	0.02
Long-Short	0.04	0.02

Table 10: Scenarios. Shows monthly performance across scenarios and optimization methods. Long-only allows for investments in long anomaly position. The synthetic short constrained scenario goes long the highest two alpha portfolios (at different weights) whilst short selling the market with a 100% collateral at the risk-free rate. The long-short scenario allows short selling but requires 100% interest bearing collateral at the risk-free rate. P–values are based on the Ledoit and Wolf (2008) bootstrap procedure and are calculated relative to the previous scenario.

	Long-Only		Synthetic-Short Constrained		Long-Short Constrained	
	Max Sh	EW	Max Sh	EW	Max Sh	EW
MKT	0.0%	12.5%	6.8%	12.5%	21.4%	12.5%
SMB	0.0%	12.5%	1.5%	12.5%	12.5%	12.5%
BTM	18.3%	12.5%	20.9%	12.5%	6.6%	12.5%
WML	53.9%	12.5%	5.2%	12.5%	7.8%	12.5%
OP	0.0%	12.5%	1.0%	12.5%	12.2%	12.5%
INV	0.0%	12.5%	0.6%	12.5%	0.0%	12.5%
AC	0.0%	12.5%	3.3%	12.5%	10.6%	12.5%
NI	27.8%	12.5%	60.6%	12.5%	28.9%	12.5%
Sum	100%	100%	100%	100%	100%	100%

Table 11: Portfolio weights across scenarios. Shows portfolios weights across optimization techniques and scenarios.

Cost (BPS)	Max Sharpe		EW	
	Sharpe	p-val	Sharpe	p-val
Base Long-Short	0.41		0.35	
35 (GC)	0.39	*0.00*	0.32	*0.00*
45 (VW Cost)	0.38	*0.00*	0.32	*0.01*
65	0.37	*0.01*	0.31	*0.01*
85	0.36	*0.02*	0.30	*0.02*
105	0.35	*0.02*	0.29	*0.03*
125	0.34	***0.05***	0.28	***0.04***
150	0.33	*0.11*	0.27	*0.07*
200	0.30	*0.32*	0.24	*0.18*
300	0.26	*0.83*	0.19	*0.70*
Synthetic Short (-45BPS)	0.27		0.18	
Base Synthetic Short	0.33		0.21	

Table 12. Shorting cost variation and performance. Shows portfolio performance for changing short selling cost assumptions. Cost is the annual rebate rate. Portfolios are leverage constrained and short positions require 102% rebate bearing collateral. Anomaly unbundling in optimization is prohibited. The benchmark for the p-values is the market short method with an annual market short cost of 45 BPS. 45 VW is the value weighted cost of short selling in the sample. 35 GC is to the general collateral rate in the short selling sample. P–values are based on the Ledoit and Wolf (2008) bootstrap procedure.

9. Conclusion

An explanation of anomalies grounded on arbitrage asymmetry implies two hypotheses: (1) anomaly profitability should be concentrated in short positions and (2) exploiting this profitability should be too costly. The paper finds evidence against both claims. Long-only investing is profitable and can be further improved though a synthetic short. High short selling costs tend to be concentrated in small stocks and can be easily avoided though the use of value-weighted sorts with NYSE break points. The profitability of security-short positions that do not overweigh small market capitalization securities is large relative to their borrowing cost. Short selling costs are only large enough to annul short position profitability of small stocks. Nevertheless, small stocks are not necessary for obtaining large short anomaly alphas.

Arbitrageurs interested in anomaly investing can compare their concurrent borrowing costs to estimated cost bounds for switching between execution methods. If short selling individual securities takes more than 125 BPS annually, investors are no longer confident that a security-short will outperform a synthetic short. Synthetic-short investing becomes economically more profitable when short selling costs exceed 300BPS. The cost bounds are much larger than the estimated borrowing cost associated with value weighted anomalies.

The paper makes three contributions: (1) it shows that long only investing works and can be significantly enhanced using a synthetic short (2) it demonstrates how overreliance of small stocks in anomaly construction can overstate short selling costs to the extent that it alters analysis conclusions and (3) it derives cost bounds for switching between execution methods and compared them to recent borrowing fees. Overall, the results suggest that short selling frictions cannot explain anomaly persistence and are inconsistent with the predictions of arbitrage asymmetry.

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Appendix – Supplementary tables and figures

	LSMB	LBTM	LWML	LOP	LINV	LAC	LNI	μ
R	0.73%	0.82%	**1.08%**	0.60%	0.75%	0.62%	0.69%	0.76%
t-stat	*2.91*	*3.93*	*4.51*	*3.34*	*3.55*	*2.81*	*4.18*	3.60
σ	6.33%	5.30%	6.07%	4.55%	5.35%	5.61%	**4.20%**	5.35%
Sharpe	0.11	0.16	0.18	0.13	0.14	0.11	0.17	0.14
M2	6.33%	8.60%	10.03%	7.22%	7.75%	6.07%	9.09%	7.87%
Skew	-0.15	-0.02	-0.46	-0.46	-0.39	-0.45	-0.48	**-0.34**
t-stat	*-1.57*	*-0.23*	*-4.78*	*-4.75*	*-4.05*	*-4.62*	*-4.94*	-3.56
Ex. Kurt.	2.47	3.55	1.87	2.29	2.45	1.69	2.16	2.35
t-stat	12.76	18.35	9.65	11.86	12.69	8.73	11.18	12.17
Max	29%	30%	21%	17%	21%	18%	16%	22%
Min	-30%	-26%	-27%	-25%	-29%	-25%	-21%	-26%
Drawdown	80%	56%	54%	57%	59%	77%	51%	62%
D.D	4.20%	3.38%	3.99%	3.06%	3.54%	3.85%	2.77%	3.54%
Sortino	0.17	0.24	0.27	0.20	0.21	0.16	0.25	0.22

Table 13: Data summary for long only portfolios. Shows summary statistics for long only anomalies minus the risk-free rate for the period 07/1963-12/2016. D.D. is downside deviation with zero as the target. M2 is the annual volatility matched (to the equity premium) return. μ is the average across anomalies. LSMB is small, LBTM is high book to market, LWML is winners, LOP is profitable, LINV is low investment, LACC is low accruals and LNI is negative share issuance.

	SSMB	SBTM	SWML	SOP	SINV	SAC	SNI	μ
R	0.45%	0.43%	**-0.19%**	0.27%	0.36%	0.29%	0.14%	0.25%
t-stat	*2.68*	*2.18*	*-0.61*	*1.02*	*1.53*	*1.22*	*0.67*	1.24
σ	4.21%	5.04%	**8.07%**	6.80%	5.96%	6.08%	5.45%	5.95%
Sharpe	0.11	0.09	-0.02	0.04	0.06	0.05	0.03	0.05
M2	5.74%	4.66%	-1.27%	2.17%	3.27%	2.59%	1.42%	2.65%
Skew	-0.36	-0.25	0.61	-0.56	-0.48	-0.52	-0.35	-0.27
t-stat	*-3.77*	*-2.63*	*6.35*	*-5.77*	*-4.94*	*-5.33*	*-3.57*	-2.81
Ex. Kurt.	1.73	1.60	4.22	1.84	1.37	1.74	1.45	1.99
t-stat	2.68	2.18	-0.61	1.02	1.53	1.22	0.67	1.24
Max	18%	24%	45%	19%	19%	18%	20%	23%
Min	-20%	-23%	-26%	-33%	-28%	-31%	-25%	-27%
Drawdown	61%	69%	**99%**	**91%**	75%	75%	79%	78%
D.D	2.88%	3.46%	5.54%	4.93%	4.25%	4.36%	3.92%	4.19%
Sortino	0.15	0.13	-0.04	0.06	0.08	0.07	0.04	0.07

Table 14: Data summary for short only portfolios. Shows summary statistics for the short leg of anomalies minus the risk-free rate for the period 07/1963-12/2016. D.D. is downside deviation with zero as the target. M2 is the annual volatility matched (to the equity premium) return. μ is the average across anomalies. SSMB is big, SBTM is growth, SWML is losers, SOP is unprofitable, SINV is high investment, SACC is high accruals and SNI is high share issuance.