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Abstract

This paper revisits the Piotroski F-score strategy in the U.S. stock universe from an investor's perspective. Primarily, we aim to answer the question, whether the high abnormal returns of more than 20 percent p.a. previously proclaimed by academics (Piotroski, 2000) and practitioners (AAII, 2015) can be feasibly captured by individual or professional investors. As such, our focal point is a pragmatic approach an average investor could opt for as well. We use the software Stock Investor Pro from the American Association of Individual Investors to obtain screenshots of the U.S. stock universe from 2005-2015 on a weekly basis. Next, we devise a long-only and a long-short variant of the Piotroski strategy with monthly or weekly rebalancing frequencies. At first glance, our findings re-confirm the high returns of this fundamental value strategy. Specifically, the monthly (weekly) long-only strategy generates raw returns of 30.93 (65.41) percent p.a. These returns outperform relevant benchmark indices and can only partially be explained by common systematic risk factors. However, consideration of liquidity constraints and an estimate of trading costs in this low liquidity stock universe render both strategies virtually unprofitable. Nevertheless, there may be potential for further research aiming at implementing such a strategy on more liquid investment universes.

Keywords: Piotroski F-score, value investing, financial statement analysis, high-book-to-market, stock screening, fundamental analysis

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1. Introduction

During several decades of financial research, diverse capital market anomalies have been established that stood the test of time and independent scrutiny. In a recent study, Jacobs (2015) provides an excellent overview of 100 anomalies, categorized in 20 groups. One of these groups is built upon fundamental analysis, meaning abnormal returns are generated by composing portfolios based on information usually contained in financial statements or provided by financial analysts. The supporting literature is vast and can be clustered as follows (Piotroski, 2000; Mohanram, 2005; Jacobs, 2015):

Value vs. growth stocks: Rosenberg et al. (1985) provide early evidence about the outperformance of value stocks with high book-to-market (BM) value over growth stocks with low BM value. These findings are substantiated in several subsequent papers, most notably in Fama and French (1992) and Lakonishok et al. (1994). There are two explanations for this return phenomenon. First, Fama and French argue that high BM firms are in financial distress and thus earn higher excess returns due to the higher risk involved. Vassalou and Xing (2004) support this view by showing that the BM effect is driven by default risk, meaning that "value stocks earn higher returns than growth stocks, if their risk of default is high" (Vassalou and Xing, 2004, p. 866). Hence, logically, high BM firms often show other signs of financial distress, such as low return on equity, leverage, earnings uncertainty or dividend cuts (Fama and French, 1995; Chen and Zhang, 1998). Second, Lakonishok et al. (1994) and Haugen (1995) assume mispricing to be the key driver for the BM effect. According to their reasoning, low BM firms lack investor attention and their disappointing prior performance builds up overly pessimistic expectations. The latter are corrected with positive earnings surprises "that are systematically more positive for value stocks" (La Porta, 1997, p. 859).

Fundamental analysis: This stream of literature relies on financial statement information to predict future earnings or returns. Ou and Penman (1989) successfully use an aggregation of a large set of financial statement items to predict future changes in earnings. Holthausen and Larcker (1992) devise a similar strategy to directly predict the sign of future excess returns. The downside of these complex strategies is the excessive use of historical information with a potential risk for overfitting the data. Lev and Thiagarajan (1993) use a simplified system consisting of 12 financial signals relevant for financial analysts. They show that these signals are directly correlated with contemporaneous returns after controlling for macrovariables and other factors. Abarbanell and Bushee (1997) find evidence that Lev and Thiagarajan's factors have explanatory power for future earnings changes as well as future analysts revisions. Later, Abarbanell and Bushee (1998) develop a trading strategy based on these fundamental factors, which earns significant abnormal returns. Frankel and Lee (1998) devise a more holistic fundamental investment strategy, based on a valuation model in combination with analysts' earnings forecasts. They identify and purchase stocks whose prices seem to be lagging their intrinsic values, thereby generating statistical significant abnormal returns. Piotroski (2000) sets his focal point on the identification of winning stocks in a high BM environment. Specifically, he devises the F-score, a scoring system to identify companies exhibiting financial strength in an undervalued, neglected investment universe with potentially higher risk due to financial distress. A corresponding long-short strategy produces statistically significant annual returns of 23 percent between 1976 and 1996. Mohanram (2005) expands on Piotroski's results and develops the G-Score, a contrasting system for low book-to-market firms. Similarly, Mohr (2012) uses the F-score for predicting growth stock returns for the European market. Scatizzi (2010) and Gray and Carlisle (2013) test slight variations of the Piotroski screen with similar high results. Finally, Fama and French (2006) find that firms with higher profitability have higher expected returns and Novy-Marx (2013) shows that "[c]ontrolling for gross profitability explains most earnings related anomalies and a wide range of seemingly unrelated profitable trading strategies" (Novy-Marx, 2013, p. 1).

The success of these fundamental strategies has sparked the interest of individual and professional investors. As of today, many nonprofit and commercial providers allow for simple and easy screening of large investment universes according to different criteria found to be profitable in academics. In this respect, a popular screen is the Piotroski High F-score, as described in the last paragraph. It is readily available on several websites, for example, on www.aaii.com, www.meetinvest.com or www.valuestockscreener.com. In this paper, we focus on the interpretation of the Piotroski strategy of the American Association of Individual Investors (AAII), "an independent, non-profit corporation formed for the purpose of assisting individuals in becoming effective managers of their own assets through programs of education, information and research." (AAII, 2015). Ever since May 2002, AAII (2015) use their software Stock Investor Pro (SIP) to run a live version of the Piotroski screen on paper with regular updates every month, showing raw returns of 23.7 percent from January 2005 to April 2015 for the U.S. stock market. However, the impact of market frictions such as trading costs, liquidity constraints and microstructure effects in not considered. Also, the exposure to common systematic risk-factors has not been evaluated. Nevertheless, AAII is a reliable platform for investors, that has recently become important for the scientific community as well. For example, the AAII sentiment survey has found its way into several high impact journals, see, among others, Fisher and Statman (2000); Brown and Cliff (2004); Jacobs (2015).

This paper aims to answer the question if investors following the simple AAII Piotroski screen can actually achieve statistically significant, risk-adjusted returns. By pursuing this goal, we contribute to the literature in several respects: First, we provide an out-of-sample test of an adapted Piotroski strategy from 2005 until 2015 that is implementable for investors on the U.S. stock universe. Second, we validate the AAII Piotroski screen in terms of data quality, trading costs, liquidity constraints and further market frictions. Also, we run a fully-fledged performance evaluation and analyze the return distribution, the (tail) risk, diverse risk-return as well as drawdown metrics and exposure to systematic sources of risk. Third, we consider a variation of the Piotroski strategy and run it on weekly instead of monthly data for further improvements. The combination of a scientifically rigorous approach with the ease-of-implementation provided by AAII makes this paper highly relevant for researchers and practitioners alike. Please note that for our implementation, we closely follow Krauss et al. (2015), who test the feasibility of an earnings momentum strategy in the U.S. stock market with AAII's Stock Investor Pro.

We find that our interpretation of the monthly long-only Piotroski screen shows statistically significant raw returns of 30.93 percent p.a. prior to trading costs. The weekly counterpart even produces 65.41 percent per year. Both returns are economically as well as statistically significant and can only be partially explained by common sources of systematic risk. Both strategies excel relative to selected benchmarks across a wide-range of performance indicators. However, the incorporation of trading costs in combination with liquidity constraints and a one-day-waiting rule is detrimental to the returns. The monthly strategy may still be implementable on a very small-scale for an individual investor, but definitely not for an institution. The weekly strategy is inadequate in light of market frictions due to the higher rebalancing frequency and thus increased levels of transaction costs. Overall, the value of the investment strategy seems to be mainly theoretical and feasibility is not given.

The rest of this paper is organized as follows: Section 2 covers the data sample used in this study. Section 3 reviews the approach for constructing and evaluating the Piotroski strategy. Section 4 presents the results and discusses key findings in light of the existing literature. Finally, section 5 concludes and summarizes directions for further research.

2. Data and software

SIP contains data for approximately 10,000 companies listed in the U.S., thereof 2,658 NYSE, 363 AMEX, 2,613 NASDAQ Capital, Global and Global Select markets and 4,403 NASDAQ Bulletin Board stocks. Moreover, 503 ADRs and 257 REITS are included (Lan, 2011). For each stock, more than 2,200 data fields are available, originally supplied to AAII by Thomson Reuters.

The advantage of SIP versus raw databases such as CRSP and Thomson Reuters Datastream is mainly based on its simplicity, making it highly suitable for analyzing the feasibility of the Piotroski High F-score from an investor's perspective. An everyday investor usually has no access to expensive professional databases and generally lacks the programming capabilities to implement complex investment strategies. SIP provides simple solutions to both issues: First, for each stock, it consolidates relevant data from Thomson Reuters. Second, there are pre-implementations for more than sixty strategies - one of them the Piotroski High F-score. As such, investors are able to obtain lists of stocks to buy and sell within a few clicks.

Following this spirit, we obtain the full investment universe and all data relevant to the Piotroski strategy for any given month's end from January 2005 until April 2015 and for any given week's end from January 2005 until beginning of May 2015. We then apply the pre-defined F-score filtering criteria described in section 3.

When scrutinizing the data, we recognized that AAII runs their backtests on the unadjusted price supplied by Thomson Reuters. In order to fully adjust for capital actions, stock splits and dividends, we match the SIP stocks required during backtesting with Datastream and obtain the corresponding return indices. The latter are based on the adjusted price and include reinvested dividends. Our matching accuracy between SIP and Datastream is greater than 97 percent; all remaining stocks are excluded from the analysis.

3. Methodology

3.1 Selection criteria

In our baseline portfolio, we follow the AAII interpretation of the investment strategy of Piotroski (2000). In a first step, we filter the investment universe as described in section 2. Specifically, we exclude all ADRs and over-the-counter stocks. Then, we focus on the highest book-to-market quintile and submit it to further screening. As in Piotroski's paper, we create nine fundamental indicator variables to assess financial strength along three dimensions, i.e., profitability, capital structure and operating efficiency. The indicator variables are binary, and we assign one in case of favorable realizations and zero in case of unfavorable realizations. The F-score as aggregate measure is defined as the sum of the indicator variables. The highest possible financial strength corresponds to a score of nine points, the lowest to a score of zero points. In the following paragraphs, we discuss all indicator variables by category, thereby closely following Piotroski (2000) and AAII (2015).

Profitability: This category measures the ability of a firm to generate positive cash flows or profits. It is measured with four key performance indicators (KPIs). A value of one is assigned for each of the following conditions that is met:

- $F1\_ROA$ - Return on assets: Return on assets for the previous fiscal year is greater than zero. Positive profits are uncommon among distressed companies and a signal of strength. For example, Piotroski (2000) finds that 42 percent of high BM firms experience a loss in the last two fiscal years.

- $F2\_CFO$ - Cash flow from operations: Cash flow from operations for the previous fiscal year is greater than zero. Positive cash flows are key for internal financing and thus a signal of strength.

- $F3\_\Delta ROA$ - Delta return on assets: Return on assets for the previous fiscal year is greater than return on assets for the fiscal year two years ago. This variable gives an indication for a positive trend in return on assets.

- $F4\_ACL$ - Accruals: Cash flow from operations for the previous fiscal year is greater than income after taxes for the previous fiscal year. This variable shows if earnings are genuine (score of one) or driven by positive accrual adjustment (score of zero).

Capital structure: This category measures changes in leverage, liquidity and sources of funding. It provides an indication about the ability to meet debt service obligations. A value of one is assigned for each of the following conditions that is met:

- $F5\_\Delta LEV$ - Delta leverage: The long-term debt to assets ratio for the previous fiscal year is less than the long-term debt to assets ratio for the fiscal year two years ago. Increasing leverage for a financially distressed firm is regarded as a negative sign, because it is indicative for the inability to generate internal funding.

- $F6\_\Delta LIQ$ - Delta liquidity: The current ratio for the previous fiscal year is greater than the current ratio for the fiscal year two years ago. An increasing current ratio is a positive sign for a financially distressed firm, because the current assets increase relative to the current liabilities, leading to increasing flexibility.

- $F7\_\Delta ASO$ - Delta average shares outstanding: The average number of shares outstanding for the previous fiscal year is less or equal to the average number of shares outstanding for the fiscal year two years ago. An increasing average number of shares outstanding is a proxy for issuing common equity. Again, the latter is a negative sign for a financially distressed company.

Operating efficiency: This category measures changes in a companies' productivity levels and how well it makes use of its assets. A value of one is assigned for each of the following conditions that is met:

- $F8\_\Delta GM$ - Delta gross margin: The gross margin for the previous fiscal year is greater than the gross margin for the fiscal year two years ago. An increasing gross margin is always a positive sign, since it is either caused by rising prices or sinking costs.

- $F9\_\Delta TURN$ - Delta liquidity: The asset turnover for the previous fiscal year is greater than the asset turnover for the fiscal year two years ago. Increasing asset turnover signifies rising productivity levels.

These three categories with a total of nine KPIs are aggregated to the F-score FSC as follows:

$$FSC = F1\_ROA + F2\_CFO + F3\_\Delta ROA + F4\_ACL + F5\_\Delta LEV \\ + F6\_\Delta LIQ + F7\_\Delta ASO + F8\_\Delta GM + F9\_\Delta TURN \quad (1)$$

As stated previously, values range from zero to nine, with higher values being an indicator for higher financial strength. According to Piotroski and to AAII, companies with a score of eight or higher are included on the long side of the portfolio. Note: The F-score is relatively robust: Piotroski (2000) tests a continuous version of his metric with similar results. Scatizzi (2010) evaluates different variations of the Piotroski screen: Including companies with an F-score of seven still leads to abnormal returns, albeit at a lower level. Using trailing twelve-month (TTM) instead of fiscal year data only has a marginal impact. Gray and Carlisle (2013) develop an alternative F-score relying on ten criteria, which results in slight improvements. Considering the above, we opt for a straightforward implementation and follow AAII (2015).

3.2 Portfolio formation and backtesting

We closely follow the backtesting procedure suggested by AAII (2015). We use SIP to download the investment universe at the end of each month (week) from 2005-2015, as described in section 2. Next, for each month (week), we apply the screening criteria described in subsection 3.1 in order to obtain the companies with an F-score of 8 or above to be included on the long side of our portfolio. As previously mentioned, we eliminate the small number of stocks we cannot match with Datastream. Then, we calculate the monthly (weekly) total returns, using the return index values from Datastream instead of the unadjusted prices. We assume that we invest one dollar in each company and compute equal and value weighted average returns per month (week). Re-balancing of the portfolio occurs each month (week), meaning that a stock is sold and re-purchased in case it obtains an F-score of 8 or higher twice in a row. Divestment occurs when a company does not meet the screening criteria anymore in the next period.

3.3 Strategy variants

Long-short strategy: In addition to going long high F-score firms, Piotroski suggests to short low F-score firms with an aggregate measure of zero or one points. However, the feasibility of strategies addressing capital market anomalies is often more aggressively challenged on the short-side of the portfolio - see, for example, Korajczyk and Sadka (2004); Lesmond et al. (2004) making this case for momentum strategies. Hence, from an investors' perspective, we opt for a simple solution: We create a dollar-neutral portfolio by going short the same dollar amount in the S&P500 as we are invested in the high F-score firms. Clearly, this strategy is not necessarily market neutral, since the high F-score firms in the high BM universe may well exhibit an aggregate beta unequal to one. Also, the exposure to small companies and the high book-to-market universe is not hedged. On the other hand, this long-short strategy can easily be implemented at low cost and is deemed suitable from a practitioner's perspective.

Long-only strategy: Many investors are subject to short-selling restrictions. Individual investors may abstain from it due to the higher sophistication, and institutional investors underlie regulatory constraints. As such, we also implement a long-only variant of the strategy.

Trading frequency: As mentioned before, we have weekly and monthly data at our disposal. In the baseline approach, we rebalance the portfolio on a monthly basis, following AAII. Conversely, we test if rebalancing on a weekly basis leads to higher risk-adjusted returns. Clearly, we face elevated trading costs due to an increasing trading frequency. However, acting faster on the arrival of new information may also lead to higher alphas. For example, let us assume a stock has an F-score of nine but is just not yet part of the the highest book-to-market quintile. In case the market value declines sufficiently, this stock would be included in the portfolio either the following week or the following month. The former may allow for capturing higher alphas, since we act earlier on the available information.

Market frictions: Finally, we consider market frictions. First, following Jones (2002) and Do and Faff (2012), average commissions amount to 13 basis points (bps) in the period from 1989 to 2009 and 8 bps in the period from 2007 to 2009. We assume 10 bps, which is also in line with current offerings of discount brokers and thus available to retail investors, see Bogomolov (2013). Second, market impact for the Piotroski strategy has not been studied yet. We opt for a pragmatic approach and use the data feed of Interactive Brokers to obtain live prices at random time points for all stocks selected by the monthly strategy from 2013 to 2015, i.e., a total of 35 unique stocks. We calculate the bid-ask spread in percent of the ask price, eliminate a few outliers exceeding values of 10 percent and present summary statistics. The median bid-ask spread amounts to 0.42 percent, the mean to 1.55 percent. However, some of these companies may have lost liquidity over time from 2013 onwards. The most recent Piotroski portfolio as of July 2015 exhibits a median bid-ask spread of 0.20 percent and a mean bid-ask spread of 0.49 percent. Based on this data, we conservatively assume a market impact of 0.5 percent per round-trip. Further price-impact beyond the bid-ask spread is omitted at this stage. Hence, round-trip trading costs for the long-only strategy are at 0.7 percent, i.e., one-time bid-ask spread plus two-times commissions. Trading costs for shorting the S&P500 are negligible. Third, we incorporate liquidity constraints. The latter are fairly common in the small cap stock universe the Piotroski strategy addresses. Hence, we also run a variant of the strategy which excludes stocks with daily trading volume less than a certain liquidity threshold on the day of the signal. Fourth, we incorporate a one-day-waiting rule to consider potential microstructure effects, such as the bid-ask bounce (Gatev et al., 2006). It means, that we delay transactions by one day after the signal.

4. Results

We run a fully-fledged performance evaluation for all strategy variants. Specifically, we examine the return distribution, run a value at risk analysis, evaluate the risk-return characteristics and assess drawdown measures. Finally, we check the exposure to common systematic risk factors, thereby relying on different factor models. We have used the statistical software `R`, and most notably, the package `PerformanceAnalytics` by Peterson and Carl (2014). The majority of selected KPIs is discussed in detail in Bacon (2008). All depicted KPIs encompass the entire sample period from January 2005 to April 2015 in case of monthly rebalancing and from January 2005 to beginning of May 2015 in case of weekly rebalancing.

4.1 Monthly rebalancing

Return characteristics: In table 1, the return characteristics of the monthly long-only (L) and long-short (LS) strategies are depicted. As potential benchmarks, we select the S&P500 as well as four further indices related to this strategy: The S&P500 Mid Cap 400 (S&PMC), the S&P500 Mid Cap 400 Citigroup Value (S&PMCV), the S&P Small Cap 600 (S&PSC) and the S&P Small Cap 600 Citigroup Value (S&PSCV). We see that the long-only strategy exhibits a high and statistically significant equal-weighted (EW) mean return of 2.71 percent per month with a Newey-West (NW) t-statistic of 2.4830. The S&P500 short overlay leads to a reduction of returns to 2.01 percent, albeit at a lower standard deviation. We can summarize that the raw returns of both strategy variants are large in a statistical and economical sense. At first glance, we conclude that the Piotroski strategy is profitable prior to market frictions. The remainder of table 1 provides information about the return distribution. Both variants of the strategy exhibit positively skewed returns, indicating fatter right than left tails. In comparison, all benchmarks are negatively skewed - the standard for financial market returns. The kurtosis takes values of 2.54 (L) or 2.23 (LS), so the return distribution is slightly platykurtic with thinner tails and lower peaks than a normal distribution. However, some of the benchmarks exhibit similar kurtosis and all of them are platykurtic - contrary to financial market returns of higher frequencies.

	L	LS	S&P500	S&PMC	S&PMCV	S&PSC	S&PSCV
Value-weighted mean	0.0242	0.0184	0.0063	0.0097	0.0089	0.0093	0.0088
Equal-weighted mean	0.0271	0.0201	0.0072	0.0094	0.0091	0.0091	0.0087
Standard error (NW)	0.0109	0.0084	0.0044	0.0051	0.0051	0.0051	0.0052
t-Statistic (NW)	2.4830	2.3795	1.6243	1.8353	1.7792	1.7781	1.6773
Minimum	-0.2262	-0.2028	-0.1680	-0.2174	-0.2178	-0.2015	-0.1961
Quartile 1	-0.0265	-0.0330	-0.0145	-0.0163	-0.0134	-0.0210	-0.0188
Median	0.0211	0.0046	0.0132	0.0156	0.0157	0.0161	0.0128
Quartile 3	0.0781	0.0666	0.0320	0.0425	0.0422	0.0436	0.0430
Maximum	0.4494	0.3537	0.1093	0.1487	0.1573	0.1746	0.1840
Share with return > 0	0.6452	0.5323	0.6532	0.6290	0.6532	0.6210	0.6532
Standard deviation	0.0963	0.0825	0.0421	0.0505	0.0514	0.0546	0.0563
Skewness	0.4989	0.8150	-0.8274	-0.7838	-0.7698	-0.5174	-0.4635
Kurtosis	2.5440	2.2340	2.1078	2.7651	2.6692	1.6831	1.5560

Table 1: Return characteristics of Piotroski monthly strategies versus benchmarks.

Value at risk: In table 2, monthly value at risk (VaR) measures are reported. Primarily, we opt for the historical VaR, as suggested by Mina and Xiao (2001). Following Huisman et al. (1999) and Favre and Galeano (2002), we additionally provide with the Cornish-Fisher (CF) VaR, which leads to better results in case the higher moments differ from those of a normal distribution. We see that the long-only strategy has substantial tail risk involved with an historical VaR of -0.2033 at the one percent level. The short overlay in the LS strategy leads to a slight improvement to -0.1606. Both values well exceed those of their benchmarks in magnitude, varying between 0.1025 and 0.1377. This view is consistent across other historical VaR levels and also applies to the CF VaR. The latter produces slightly more favorable results for the LS strategy at the one percent level, potentially driven by the higher positive skewness and lower kurtosis values. Also, the LS strategy exhibits the smallest maximum drawdown of 39.35 percent, compared to 63.09 percent (for the long-only strategy) and values around 50 percent for the benchmarks. Hence, the short overlay effectively reduces drawdown risk.

	L	LS	S&P500	S&PMC	S&PMCV	S&PSC	S&PSCV
Historical VaR 1%	-0.2033	-0.1606	-0.1025	-0.1068	-0.1125	-0.1253	-0.1377
CF VaR 1%	-0.2089	-0.1442	-0.1257	-0.1574	-0.1595	-0.1539	-0.1567
Historical CVaR 1%	-0.2156	-0.1826	-0.1372	-0.1623	-0.1654	-0.1642	-0.1685
CF CVaR 1%	-0.3590	-0.1442	-0.1501	-0.1574	-0.1599	-0.1835	-0.1895
Historical VaR 5%	-0.1226	-0.0883	-0.0715	-0.0719	-0.0841	-0.0754	-0.0838
CF VaR 5%	-0.1116	-0.0913	-0.0693	-0.0811	-0.0829	-0.0862	-0.0889
Historical CVaR 5%	-0.1764	-0.1330	-0.0977	-0.1092	-0.1128	-0.1172	-0.1235
CF CVaR 5%	-0.1431	-0.1102	-0.1102	-0.1388	-0.1406	-0.1338	-0.1359
Minimum	-0.2262	-0.2028	-0.1680	-0.2174	-0.2178	-0.2015	-0.1961
Share with return ≤ 0	0.3548	0.4677	0.3468	0.3710	0.3468	0.3790	0.3468
Maximum drawdown	0.6309	0.3935	0.5095	0.4962	0.5219	0.5215	0.5417

Table 2: Monthly value at risk of Piotroski monthly strategies versus benchmarks.

Annualized risk-return characteristics: In table 3, our focal point are annualized risk-return ratios, indicating the return an investor obtains per unit of risk. All metrics are based on equal-weighted returns. The Sharpe ratio is defined as excess return over the risk-free rate divided by the standard deviation. We see that the Sharpe ratio of the L strategy of 0.8745 exceeds that of the LS strategy of 0.7213. From this perspective, the short overlay has an adverse effect - return decreases more than risk involved in terms of standard deviation. However, both strategies exceed their benchmarks. The second best Sharpe ratio of 0.5001 is achieved by the S&P500 Mid Cap 400 index, which is well inferior to the Piotroski strategies. Other risk-return measures confirm this finding. The Sortino ratio measures the strategies' returns relative to the downside deviation. Its advantage lies in the lower partial moment metric in the denominator, only measuring downside deviations as actual risk (compared to upward deviations, which are actually favorable to an investor). The outperformance of the Piotroski strategies relative to its benchmarks is even clearer in this case, caused by relatively low downside deviations. The Upside Potential ratio is an enhanced Sortino ratio. It is composed of average upside performance, scaled by downside deviation. In respect to this metric, the LS strategy slightly outperforms the L strategy, indicating a better relation of upside performance to downside risk. The Information ratio is recommended compared to the original Sharpe ratio. It is defined as the active premium, i.e., the outperformance of an investment relative to its benchmark, divided by the corresponding tracking error. In this respect, the L strategy is clearly superior compared to the LS strategy and all benchmarks. This result is expected, provided that the short overlay produces larger tracking errors of the general market index at reduced return levels. Finally, Omega is a probability-weighted gain-loss ratio, which considers all higher moments. The L and LS strategy achieve similar values and outperform their benchmarks by far.

Hence, from a risk-return perspective, the L strategy is clearly superior to the LS strategy and to all benchmarks.

	L	LS	S&P500	S&PMC	S&PMCV	S&PSC	S&PSCV
Return	0.3093	0.2227	0.0783	0.1023	0.0976	0.0950	0.0887
Excess return	0.2917	0.2062	0.0638	0.0874	0.0828	0.0802	0.0740
Active premium	0.2288	0.1421	-0.0022	0.0218	0.0171	0.0145	0.0082
Standard deviation	0.3336	0.2859	0.1458	0.1749	0.1781	0.1891	0.1950
Downside deviation	0.1772	0.1411	0.1013	0.1187	0.1224	0.1276	0.1324
Tracking error	0.2823	0.3062	0.0149	0.0524	0.0547	0.0746	0.0809
Sharpe ratio	0.8745	0.7213	0.4374	0.5001	0.4650	0.4244	0.3796
Sortino ratio	1.7452	1.5783	0.7730	0.8621	0.7976	0.7446	0.6702
Upside Potential ratio	3.4047	3.4512	2.3469	2.4650	2.3851	2.4338	2.3637
Information ratio	0.8103	0.4641	-0.1478	0.4161	0.3125	0.1941	0.1012
Omega	2.1724	1.9822	1.5706	1.6323	1.6012	1.5417	1.5010

Table 3: Annualized risk-return characteristics of Piotroski monthly strategies versus benchmarks.

Drawdown measures: Table 4 elaborates on drawdown metrics. Sterling and Calmar ratio are both calculated by dividing the annualized return by the absolute value of the maximum drawdown. In case of the Sterling ratio, the latter is augmented by an additional 10 percent, reflecting an excess risk buffer. Considering the Calmar ratio, we see that the annual return of the L strategy lies at roughly 49 percent of the magnitude of maximum drawdown. This value improves to approximately 57 percent in case of the LS strategy. Both variants clearly outperform their benchmarks with values below 21 percent. We calculate the Burke ratio as the annualized excess return divided by the Euclidean norm of the drawdowns. This KPI incorporates a total of d drawdowns, while putting more weight on the larger ones due to the aggregation method. Nevertheless, we see a similar picture as for Sterling and Calmar ratios, meaning that the Piotroski strategies achieve higher returns in relation to this drawdown risk metric. Pain index is the sum of the absolute value of all drawdowns divided by the number of observations in the series, providing a mean drawdown per observation. Similarly, the Ulcer index is a "root-mean square measure of retracement" (Martin and McCann, 1989, p. 80), measuring depth as well as duration of percentage drawdowns. For both KPIs, the Piotroski strategies exhibit similar results as their benchmarks. We divide the mean excess return by the Pain index or Ulcer index to obtain the Pain ratio or Martin ratio, respectively. Once again, these metrics indicate an outperformance of the L and LS strategies, caused by higher returns at similar levels of average drawdown risk.

	L	LS	S&P500	S&PMC	S&PMCV	S&PSC	S&PSCV
Sterling ratio	0.4232	0.4512	0.1285	0.1717	0.1570	0.1529	0.1383
Calmar ratio	0.4903	0.5658	0.1538	0.2063	0.1871	0.1822	0.1638
Burke ratio	0.3330	0.2922	0.1284	0.1479	0.1385	0.1310	0.1183
Pain index	0.1070	0.0887	0.0899	0.0717	0.0837	0.0809	0.0922
Ulcer index	0.1956	0.1414	0.1710	0.1445	0.1619	0.1550	0.1700
Pain ratio	2.7269	2.3236	0.7090	1.2194	0.9890	0.9912	0.8030
Martin ratio	1.4914	1.4581	0.3729	0.6053	0.5114	0.5177	0.4354

Table 4: Drawdown measures of Piotroski monthly strategies versus benchmarks.

Common risk factors: Finally, we are interested in the exposure of the Piotroski L strategy to common systematic sources of risk. In this respect, we perform three types of regressions. First, we consider the standard Fama-French three-factor model, following Fama and French (1996). This regression captures exposure to the market, small minus big capitalization stocks (SMB) and high minus low BM stocks (HML). Second, we augment the latter model by a momentum factor similar to Carhart (1997) and a short-term reversal factor, similar to Gatev et al. (2006). Third, we use the recent Fama-French five-factor model, following Fama and French (2015). Baseline is again the three-factor model, enhanced by two additional factors, i.e., portfolios of stocks with robust versus weak profitability (RMW) and portfolios of stocks with conservative minus aggressive (CMA) investment behavior. All data related to these factor models is downloaded from Kenneth R. French's website[1]. Findings are summarized in table 5. Standard errors are depicted in parentheses.

Across all three models, we see that only a small portion of the equal-weighted mean return of 0.0271 per month can be attributed to the different risk factors. Depending on the model, the alpha varies between 0.0194 and 0.0253 per month at the one percent significance level and is thus 18-77 bps lower than the EW raw returns. As expected, the long-only strategy strongly loads on the market factor. Exposure to the SMB factor is also economically and statistically significant for all models, considering that Piotroski primarily targets small companies. The latter is confirmed by a factor loading close to one. Pre-selecting the highest book-to-market quintile of firms leads to strong loadings close to 0.8 on the HML factor for the three factor and the five factor model. Surprisingly, in case of the enhanced Fama-French 3+2 factor model, HML is no longer statistically significant. Conversely, the strategy negatively loads on the momentum factor at the one percent significance level, indicating that medium-term losers are selected. The latter finding is intuitive in the high BM stock universe - the price of neglected stocks in financial distress is likely to be under pressure. Interestingly enough, the recent five factor model does not offer any additional insights, with statistically insignificant RMW and CMA factors.

Market frictions: So far, the Piotroski strategy seems to generate risk-adjusted excess returns of approximately 2 percent per month, which are statistically and economically significant. In this step, we consider excluding low-liquidity stocks from the monthly Piotroski L strategy. In particular, we eliminate stocks whose trading volume VOL in thousands USD is below a certain level on the day of the signal. Also, we introduce a one-day-waiting rule to account for potential microstructure effects. The outcomes can then be compared to our estimate of monthly trading costs of 0.7 percent. Table 6 depicts the results: With additional liquidity demand, monthly raw

[1]We thank Kenneth R. French for providing the factor models on his website.

	Fama-French 3-Factor	Fama-French 3+2-Factor	Fama-French 5-Factor
(Intercept)	0.0194**	0.0200**	0.0253**
	(0.0070)	(0.0068)	(0.0088)
Market	0.8428***	0.7369***	0.8072***
	(0.1849)	(0.1986)	(0.1902)
SMB	1.0018**	1.0714**	
	(0.3387)	(0.3308)	
HML	0.8242**	0.5800	
	(0.3105)	(0.3151)	
Momentum		−0.4577**	
		(0.1583)	
Reversal		−0.1377	
		(0.2380)	
SMB5			1.0047**
			(0.3375)
HML5			0.7742*
			(0.3636)
RMW5			−5.0111
			(4.4989)
CMA5			−0.0732
			(0.6153)
R^2	0.3775	0.4200	0.3859
Adj. R^2	0.3620	0.3955	0.3599
Num. obs.	124	124	124
RMSE	0.0771	0.0750	0.0772

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table 5: Exposure to systematic sources of risk of Piotroski monthly long-only strategy.

returns decline from 0.0271 percent (original L strategy) to 0.0108 percent (minimum volume of 1,000,000 USD). On the same note, the average number of positions per month decreases from approximately nine holdings to less than three holdings per month. The introduction of a one-day-waiting rule also has a detrimental effect, albeit at lower levels than the liquidity constraints. Without minimal trading volume, delaying the trades by one day leads to a decrease in raw returns of 38 bps. This level decreases with increasing liquidity demands, but the waiting rule has a negative effect at all liquidity levels except the most aggressive one. The latter can probably be attributed to chance alone, given that there are less than three stocks in the portfolio on average.

After the consideration of minimum liquidity levels and microstructure effects, the strategy still remains profitable with monthly raw returns at the one percent level. However, average trading costs of 0.7 percent render the approach largely unattractive. For example, a minimum liquidity requirement of 100,000 USD on the day of the signal leads to monthly raw returns of merely 15 bps - i.e., close to the average risk-free rate of 11 bps over the period of study. This result indicates that any larger scale investor stands no chance of capturing the returns reported in AAII (2015) and most probably, also in Piotroski (2000). Both studies do not introduce liquidity constraints, i.e., by demanding minimum levels of trading volume or by excluding low capitalization stocks. For small scale investors, there may be a slight chance of capturing some of the abnormal returns, especially given that the adverse effect of the one-day waiting rule is only slight. However, frankly speaking, the benefit of this investment strategy seems to be largely theoretical.

Minimum VOL	Monthly return (no waiting)	Monthly return (1 day waiting)	⌀ positions
-	0.0271	0.0233	9.4839
10	0.0212	0.0175	8.0645
20	0.0159	0.0126	7.2016
30	0.0146	0.0117	6.7581
40	0.0139	0.0112	6.3468
50	0.0143	0.0117	6.1129
60	0.0137	0.0115	5.8145
70	0.0126	0.0112	5.7016
80	0.0125	0.0099	5.5161
90	0.0110	0.0099	5.2661
100	0.0088	0.0085	5.1048
1000	0.0108	0.0134	2.8226

Table 6: Liquidity constraints of Piotroski monthly long-only strategy.

4.2 Weekly rebalancing

In the following, we test if weekly rebalancing leads to improvements of the Piotroski strategy. As discussed in subsection 3.3, acting faster upon new information may result in higher returns.

Return characteristics: In table 7, we see that the equal-weighted mean of the L strategy exceeds one percent per week, or more than four percent per month. The corresponding return of the LS strategy is only slightly lower. Both strategy returns are statistically significant with NW t-statistics of 5.3998 and 5.6473. Also, they exceed the estimated trading costs of 0.70 percent per round-trip trade. The return distributions are still positively skewed, yet leptokurtic - most likely caused by the higher trading frequency. Before transaction costs, the strategies easily outperform their benchmarks.

	L	LS	S&P500	S&PMC	S&PMCV	S&PSC	S&PSCV
Value-weighted mean	0.0078	0.0068	0.0010	0.0018	0.0015	0.0015	0.0014
Equal-weighted mean	0.0109	0.0091	0.0018	0.0023	0.0023	0.0022	0.0022
Standard error (NW)	0.0020	0.0016	0.0010	0.0012	0.0012	0.0013	0.0013
t-Statistic (NW)	5.3998	5.6473	1.8067	1.9614	1.8569	1.7917	1.6761
Minimum	-0.1984	-0.1151	-0.1814	-0.1691	-0.1675	-0.1483	-0.1527
Quartile 1	-0.0144	-0.0118	-0.0097	-0.0119	-0.0127	-0.0140	-0.0142
Median	0.0067	0.0048	0.0026	0.0039	0.0043	0.0037	0.0033
Quartile 3	0.0311	0.0249	0.0146	0.0175	0.0174	0.0194	0.0200
Maximum	0.2906	0.2811	0.1209	0.1661	0.1691	0.1533	0.1624
Share with return > 0	0.5955	0.5696	0.5696	0.5751	0.5622	0.5529	0.5566
Standard deviation	0.0483	0.0393	0.0250	0.0297	0.0300	0.0312	0.0325
Skewness	0.9896	1.5428	-0.5924	-0.3178	-0.2844	-0.1689	-0.1155
Kurtosis	6.2375	7.8897	7.4794	5.6475	5.5838	3.5544	3.6268

Table 7: Return characteristics of Piotroski weekly strategies versus benchmarks.

Value at risk: Table 7 yields the results of the VaR-analysis. Contrasted with the monthly frequency in table 2, the L strategy still has significantly higher VaR and CVaR levels than its benchmarks. Conversely to the monthly data, the LS strategy now exhibits much lower tail risk, arriving at levels comparable to the benchmarks or even better. For example, the historical VaR at the one percent level is -0.0829 for the LS strategy versus -0.0880 for the S&P500 Mid Cap 400. The latter is also reflected in vastly reduced maximum drawdown of the LS strategy at a mere 25.10 percent compared to 53.16 percent for the long-only strategy and values exceeding 54 percent for the benchmarks.

Annualized risk-return characteristics: In table 9, we see that the lower tail risk of the LS strategy discussed in the last paragraph also has an effect on the risk-return measures. The LS strategy has a similar Sharpe, but higher Sortino and Upside Potential ratios compared to the long-only variant. This effect is mainly driven by significantly reduced downside deviation of the LS vis-a-vis the L strategy. We summarize that all benchmarks are clearly outperformed prior to trading costs.

Drawdown measures: Table 10 further corroborates the superiority of the LS strategy compared to the long-only strategy and the benchmarks. The extent of the drawdowns is well reduced at yet

	L	LS	S&P500	S&PMC	S&PMCV	S&PSC	S&PSCV
Historical VaR 1%	-0.1102	-0.0829	-0.0675	-0.0880	-0.0928	-0.0925	-0.0947
CF VaR 1%	-0.1189	-0.0749	-0.1076	-0.1115	-0.1119	-0.0996	-0.1035
Historical CVaR 1%	-0.1460	-0.0964	-0.0945	-0.1157	-0.1167	-0.1107	-0.1130
CF CVaR 1%	-0.3535	-0.0749	-0.1076	-0.1115	-0.1119	-0.0996	-0.1035
Historical VaR 5%	-0.0533	-0.0416	-0.0390	-0.0441	-0.0423	-0.0495	-0.0509
CF VaR 5%	-0.0480	-0.0303	-0.0396	-0.0456	-0.0460	-0.0482	-0.0499
Historical CVaR 5%	-0.0888	-0.0656	-0.0591	-0.0720	-0.0732	-0.0745	-0.0781
CF CVaR 5%	-0.0480	-0.0316	-0.0830	-0.0836	-0.0831	-0.0785	-0.0800
Minimum	-0.1984	-0.1151	-0.1814	-0.1691	-0.1675	-0.1483	-0.1527
Share with return ≤ 0	0.4045	0.4304	0.4304	0.4249	0.4378	0.4471	0.4434
Maximum drawdown	0.5316	0.2510	0.5471	0.5476	0.5753	0.5739	0.5934

Table 8: Weekly value at risk of Piotroski weekly strategies versus benchmarks.

	L	LS	S&P500	S&PMC	S&PMCV	S&PSC	S&PSCV
Return	0.6541	0.5387	0.0797	0.1034	0.0981	0.0959	0.0893
Excess return	0.6299	0.5162	0.0639	0.0872	0.0820	0.0798	0.0733
Active premium	0.5695	0.4542	-0.0049	0.0188	0.0135	0.0113	0.0047
Standard deviation	0.3484	0.2832	0.1804	0.2138	0.2163	0.2248	0.2343
Downside deviation	0.1839	0.1364	0.1275	0.1497	0.1513	0.1554	0.1620
Tracking error	0.2797	0.3215	0.0142	0.0563	0.0606	0.0767	0.0857
Sharpe ratio	1.8080	1.8229	0.3541	0.4078	0.3790	0.3550	0.3128
Sortino ratio	3.5571	3.9491	0.6250	0.6905	0.6480	0.6167	0.5511
Upside Potential ratio	6.1990	6.8352	3.9053	4.0151	4.0042	4.1565	4.1109
Information ratio	2.0360	1.4129	-0.3447	0.3334	0.2224	0.1472	0.0547
Omega	1.9803	2.0211	1.2301	1.2532	1.2397	1.2210	1.2045

Table 9: Annualized risk-return characteristics oof Piotroski weekly strategies versus benchmarks.

high return-levels with a positive effect on the measures discussed in subsection 4.1. For example, a Calmar ratio of 2.1466 suggests that the annualized return lies at 2.1466 times the magnitude of maximum drawdown, indicating much faster recovery times compared to the L strategy, the benchmarks and of course, the monthly implementations.

Common risk factors: Table 11 shows similar results to the previous analysis. Again, standard errors are depicted in parentheses. The returns are largely robust to common sources of systematic risk. Weekly alphas lie between 0.89 and 1.23 percent and are statistically and economically significant. Factor loadings are comparable to the ones in table 5. A key difference is the statistical significance of the RMW factor at the one percent level and an enormous beta of -13.28. The latter indicates that the strategy negatively loads on portfolios composed of firms with robust in excess of

	L	LS	S&P500	S&PMC	S&PMCV	S&PSC	S&PSCV
Sterling ratio	1.0355	1.5350	0.1231	0.1596	0.1452	0.1423	0.1287
Calmar ratio	1.2303	2.1466	0.1456	0.1887	0.1705	0.1670	0.1504
Burke ratio	0.6978	0.8816	0.1041	0.1206	0.1113	0.1053	0.0933
Pain index	0.0597	0.0457	0.0880	0.0760	0.0857	0.0866	0.0932
Ulcer index	0.1054	0.0731	0.1622	0.1429	0.1565	0.1524	0.1610
Pain ratio	10.5422	11.2979	0.7254	1.1468	0.9569	0.9213	0.7867
Martin ratio	5.9758	7.0658	0.3938	0.6102	0.5238	0.5236	0.4553

Table 10: Drawdown measures of of Piotroski weekly strategies versus benchmarks.

weak profitability. Even though the F-score screens for financial strength in the high BM universe, we believe that profitability is still under average, which may explain this effect.

Market frictions: In table 12, we see similar effects as in the last subsection. Liquidity constraints reduce raw returns from 1.09 percent to 0.54 percent per week, while the average number of positions declines from 9.4 to 2.6. The waiting-rule leads to a reduction of 26 bps in case of no liquidity constraint. Again, this figure is declining with increasing liquidity demands. We see that already without additional liquidity requirements, weekly transaction costs of 0.70 percent consume the lion's share of the 1.09 percent weekly return. Constraining the minimum volume to 30,000 USD per day renders the strategy virtually unprofitable. The latter observation is exacerbated with increasing liquidity demands.

We conclude that the initial hypothesis regarding the weekly strategy can be confirmed. Acting faster upon the new arrival of information leads to much higher annualized returns. However, the higher rebalancing frequency is detrimental to the returns due to elevated transaction costs. Liquidity constraints that render the strategy feasible also render it unprofitable.

5. Conclusion

We have thoroughly investigated the Piotroski High F-score strategy in two feasible variants (long-only versus long-short) and at two trading frequencies (monthly versus weekly). Thereby, we have pursued a pragmatic approach that could easily be followed by an individual or institutional investor. In this respect, we have focused on the actual feasibility of the strategy, i.e., if risk-adjusted excess returns can actually be achieved in light of market frictions such as liquidity constraints and

	Fama-French 3-Factor	Fama-French 3+2-Factor	Fama-French 5-Factor
(Intercept)	0.0089***	0.0088***	0.0123***
	(0.0016)	(0.0016)	(0.0020)
Market	0.8769***	0.7763***	0.8562***
	(0.0741)	(0.0806)	(0.0761)
SMB	0.8023***	0.8464***	
	(0.1480)	(0.1474)	
HML	0.6808***	0.5084**	
	(0.1379)	(0.1553)	
Momentum		−0.1731*	
		(0.0835)	
Reversal		0.1749*	
		(0.0831)	
SMB5			0.7882***
			(0.1477)
HML5			0.5860***
			(0.1373)
RMW5			−13.2769**
			(4.4385)
CMA5			−0.0310
			(0.2695)
R^2	0.4128	0.4243	0.4215
Adj. R^2	0.4095	0.4189	0.4161
Num. obs.	539	539	539
RMSE	0.0372	0.0369	0.0370

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$

Table 11: Exposure to systematic sources of risk of Piotroski monthly long-only strategy.

transaction costs.

First, for the monthly strategy, we can confirm the findings of Piotroski (2000) and AAII (2015). The former claims high F-score returns of 31.3 percent p.a. for the long-only strategy from 1976 to 1996. Even though his implementation is different in terms of the holding period, we arrive at similar annualized returns of 30.93 percent prior to transaction costs. Compared to AAII, we exceed their returns of 23.7 percent by far, even though we investigate almost the same period and stocks. The differences are due to the fact that we have sanitized database errors and that we calculate returns based on a total return index as opposed to unadjusted prices, thus accounting for dividends, corporate actions and stock splits. Relative to both Piotroski implementations, we provide significant value added by running a fully-fledged performance evaluation, following current standards in the financial literature. We find the monthly long-only strategy to produce

Minimum VOL	Weekly return (no waiting)	Weekly return (1 day waiting)	∅ positions
0	0.0109	0.0083	9.3878
10	0.0093	0.0073	7.8609
20	0.0084	0.0078	7.0928
30	0.0073	0.0072	6.5733
40	0.0065	0.0056	6.1280
50	0.0058	0.0049	5.8293
60	0.0050	0.0042	5.5603
70	0.0051	0.0041	5.3859
80	0.0057	0.0046	5.1763
90	0.0055	0.0044	4.9907
100	0.0054	0.0047	4.8386
1000	0.0054	0.0048	2.6197

Table 12: Liquidity constraints of Piotroski weekly long-only strategy.

statistically and economically significant excess returns, that cannot be explained by common factors of systematic risk, proxied by the Fama-French factor models. To our knowledge, no other author has tested the Piotroski strategy to this extent on such a large stock universe. However, upon incorporation of liquidity constraints, trading costs and microstructure effects, which render the strategy feasible for individual investors, returns deteriorate significantly and do no longer beat adequate benchmarks.

Second, we have implemented a weekly variant of the strategy. Even though this change may seem subtle at first, it has a significant impact. The faster incorporation of new information leads to annualized equal-weighted raw returns of 65.41 percent for the long-only strategy - well superior to the monthly implementations and all other benchmarks. Surprisingly, for the weekly frequency, the LS strategy exhibits far less downside risk and outperforms the long-only strategy in terms of risk-adjusted returns across several measures. However, the consideration of liquidity constraints and trading costs has an effect that is far more detrimental than before. Demanding a mere daily trading volume of more than 30,000 USD on the day of purchase renders the strategy unprofitable after trading costs.

At this stage, we have to conclude that the Piotroski strategy is appealing at first sight and may potentially be implemented by an individual investor with a very limited capital base, i.e., just several thousand USD per position. However, such investors should handle the publicly proclaimed returns with care. Market frictions will most likely consume the majority of it, as shown in section

4. For institutional investors, the strategy is completely unfeasible, given the large amount of capital they usually need to deploy.

Further research should focus on an enhancement of the Piotroski strategy. Studies such as Jacobs (2015) indicate that it may also produce alpha on larger capitalization stocks which can be traded at much lower costs. Additional filters to the F-score could potentially allow for capturing higher risk-adjusted excess returns on a weekly basis that are actually robust to transaction costs and liquidity constraints.

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