To: Sury and Titman Investments, LLC

From: Jordan Ehlinger (je28596)

Subject: R&D Expenditure Quintile Exploration

Date: Tuesday, February 13th, 2024

This memo explores an improvement on the R&D expenditure strategy that I sent on January 23rd. The strategy breaks up the R&D portfolios into quintiles based on the weighted average of the R&D expenditure from the previous years. All companies with no R&D expenditure for the previous year are filtered into one portfolio. The new strategy still tests the hypothesis that companies with positive R&D expenditure generate higher returns than companies with no or negative reported R&D expenditure, but now we are adjusting for the hypothesis that firms that have more 'R&D capital' relative to their market caps should have high future returns. The portfolios were created using different weighting methods and filtering large market cap securities, while performance was measured by calculating CAPM alpha, Fama-French 3-factor alpha, and the Sharpe ratio.

The data was again sourced from the WRDS and Fama-French databases. The only change in the data imported was that the yearly R&D expenditure and market cap values were pulled instead of the quarterly values. This allowed us to run the back test all the way to 1980. The weighted average of the R&D expenditure was calculated from the R&D expenditures of the security over the previous 5 years with the more recent years being weighted more heavily. This weighted average is then divided by the year end market cap for the most recent year, which provides the R&D expenditure as a ratio of company size. Once the weighted average of R&D expenditure was calculated, this data frame was shifted forward one year, so it would match the returns for the next year. When building the portfolios at the start of each year, it is only possible to work with R&D expenditure for the previous year. After sorting the securities by this ratio of R&D expenditure, the securities with positive R&D expenditure were split into quintiles.

The portfolios were merged with the returns data and these returns were then weighted by both equal-weighted and value-weighted methods similar to the last back test we performed. The equal-weighted approach involved taking the mean of the securities in that portfolio for that month to find the total monthly return (for that portfolio for that month). The average of these monthly averages was then calculated to find the average return for that entire portfolio. In the value-weighted approach, each security was weighted by its market cap relative to the total market cap of all the securities in that portfolio. For this report, market cap was calculated using year-end common shares outstanding and the year-end close price from the CRSP/Compustat Merged cube within the WRDS database. The common shares outstanding values were simply multiplied by the equivalent close price to get the market cap for that year. Once the weighted returns were calculated using the market cap, they were added together for each month to get the total monthly return for that portfolio. Finally, the average of these total monthly returns was taken to provide an average return for that entire portfolio.

After creating the quintiles and non-R&D portfolio using both equal and value weighted returns, we create a new batch of portfolios where we first remove the 1000 firms with the highest market cap for each year. With these firms removed, we run the same process to create value-weighted portfolios broken into quintiles for securities with R&D expenditure and one portfolio for securities with no R&D expenditure.

The performance of each portfolio is tracked for three sample periods. The full sample period from July 1981 – December 2012; the pre-2000 period from July 1981 – December 1999; and the post-2000 period from January 2000 – December 2012. The average monthly returns for each portfolio for each sample period are calculated and displayed in the exhibits below. In addition, a long-short portfolio is calculated from the quintiles by subtracting the monthly returns for the Low Quintile portfolio from the monthly returns for the High Quintile portfolio. These returns are filtered to only include returns between July 1981 – December 2012. Using this long-short portfolio as the dependent variable, two alphas were calculated by running OLS regressions. The first regression used the Fama-French monthly market returns minus the risk-free rate as the independent variable to calculate the CAPM alpha. The second regression calculated the Fama-French 3-Factor alpha by using the monthly market returns minus the risk-free rate, the SMB (small minus big) monthly portfolio returns, and the HML (high minus low) monthly portfolio returns each as the independent variables. SMB evaluates company size based on market capitalization and HML evaluates the book-to-market (BTM) ratio of companies where companies with a high BTM ratio are viewed as value stocks and companies with a low BTM ratio are growth stocks. For BTM, book value is calculated by the company's assets minus its liabilities while market value is calculated by multiplying the number of shares outstanding by the share price. The statistical significance of each alpha is measured using its t-statistic and standard error. Lastly, the Sharpe ratio is calculated for the long-short portfolio by finding the average of the monthly returns and dividing it by the standard deviation of the monthly returns. To annualize the Sharpe ratio, it is multiplied by the square root of 12. These metrics are also available in the exhibits below.

After the three sets of portfolios were each evaluated for their performance using the process described above, the entire back test was re-run, but the full sample period was extended from December 2012 to December 2022. For each of the sets of portfolios, the average returns were calculated across the new sample period and a long-short portfolio was created including the new sample period as well. The performance of these long-short portfolios was tracked using the same process executed earlier. I've also attached a data frame that includes the monthly weighted returns for each portfolio for the entire sample period from July 1981 – December 2022.

Now I will walk through the results displayed in the exhibits below. For the equal-weighted portfolios, there is a clear pattern of growth of the average return as you move toward the quintiles with higher relative R&D expenditure. This certainly gives credence to our initial hypothesis that firms with more 'R&D capital' relative to their market caps should have high future returns. The performance of the long-short portfolio only provides further evidence. Against both benchmark portfolios, the long-short portfolio generates a statistically significant alpha around 1.3 and gives us an annual Sharpe ratio of 1.05 which is exceptional. Moving onto

the value-weighted portfolios, the performance becomes more realistic. We continue to see the trend of growth of the average return as you move toward the quintiles with higher relative R&D expenditure, which still benefits our hypothesis. However, the alphas are no longer significant. The Sharpe ratio sits at 0.31, which is right around the market Sharpe ratio of approximately 0.3. The over-performance of the equal-weighted portfolios can most likely be attributed to monthly rebalancing bias and excess returns being dominated by small stocks. Looking at the value-weighted portfolios that exclude the 1000 largest firms, performance improves again and finds a middle ground between the two previous groups of portfolios. The average returns still follow the trend of higher returns for securities with higher ratios of R&D expenditure. The alphas generated against the benchmarks both sit around 1.19 and are statistically significant as well. The Sharpe ratio echoes this strong performance with an annual value of 0.97.

When evaluating these portfolios under the entire extended sample period the performance does decrease. I ran the regressions on the extended sample period from July 1981 – December 2022 and calculated the new annual Sharpe ratios. For the equal-weighted long-short portfolio the alphas and the Sharpe ratio decreased. The value-weighted long-short portfolio experiences the smallest change in performance when incorporating the returns up to 2022. The alphas fluctuate slightly while remaining non-significant, but the Sharpe ratio does increase slightly. Lastly, for the value-weighted long-short portfolio without the 1000 largest firms, the alphas and Sharpe ratio minimally increase and remain statistically significant. Further experimentation is necessary, but based on these preliminary results it appears that there may be some validity to the hypothesis that firms that have more 'R&D capital' relative to their market caps have high future returns and this effect appears to continue in current market environment for the value-weighted long short portfolio that excludes the 1000 largest firms. But it is important to note that back testing on only recent market data is not recommended so it may be difficult to explore recent portfolio performance more. Furthermore, back testing performance is a good method for testing how a portfolio strategy would have performed historically, but it does not guarantee that the portfolio will perform similarly in the future. Therefore holding a value-weighted long-short R&D-weighted portfolio without the top 1000 largest firms appears to be a potentially profitable strategy, but performance should be continuously monitored for changing volatility and returns.

Exhibits

Exhibit 1: Portfolio Returns of the Equal Weighted Portfolio

L	2	3	4	H	Non-R&D
Full sample period (1981.07 – 2012.12)					
0.408	0.879	1.073	1.241	1.858	0.935
Pre-2000 Period (1981.07 – 1999.12)					
0.599	1.002	1.17	1.367	1.908	0.9
Post-2000 Period (2000.01 – 2012.12)					
0.136	0.703	0.935	1.063	1.786	0.983

Exhibit 2: Performance of the Long Short Equal Weighted Portfolio against different benchmarks

	CAPM (FF Mkt-RF)	**Fama-French 3-Factor (Mkt-RF; SMB; HML)**	**Sharpe Ratio (Annual)**
ALPHA	1.3503	1.3268	1.055
STD ERR	0.244	0.228	
T-STAT	5.545	5.809	
BETA	0.1748	0.0971; 0.6100; 0.0612	

Exhibit 3: Portfolio Returns of the Value Weighted Portfolio

L	2	3	4	H	Non-R&D
Full sample period (1981.07 – 2012.12)					
0.794	1.075	1.026	1.239	1.262	0.907
Pre-2000 Period (1981.07 – 1999.12)					
1.183	1.529	1.408	1.52	1.548	1.245
Post-2000 Period (2000.01 – 2012.12)					
0.242	0.428	0.483	0.838	0.854	0.427

Exhibit 4: Performance of the Long Short Value Weighted Portfolio against different benchmarks

	CAPM (FF Mkt-RF)	**Fama-French 3-Factor (Mkt-RF; SMB; HML)**	**Sharpe Ratio (Annual)**
ALPHA	0.2867	-0.0281	0.31
STD ERR	0.260	0.241	
T-STAT	1.101	-0.117	
BETA	0.3173	0.3758; 0.4649; 0.6840	

Exhibit 5: Portfolio Returns of the Value Weighted Portfolio without the Top 1000 Firms

L	2	3	4	H	Non-R&D
Full sample period (1981.07 – 2012.12)					
0.396	0.863	0.976	1.274	1.701	0.867
Pre-2000 Period (1981.07 – 1999.12)					
0.519	0.918	1.064	1.338	1.666	0.822
Post-2000 Period (2000.01 – 2012.12)					
0.22	0.785	0.85	1.182	1.751	0.932

Exhibit 6: Performance of the Long Short Value Weighted Portfolio without the Top 1000 Firms against different benchmarks

	CAPM (FF Mkt-RF)	**Fama-French 3-Factor (Mkt-RF; SMB; HML)**	**Sharpe Ratio (Annual)**
ALPHA	1.2076	1.1772	0.974
STD ERR	0.237	0.233	
T-STAT	5.085	5.042	
BETA	0.1719	0.1272; 0.3979; 0.0723	

Extended sample period (2013.01 – 2022.12)

Exhibit 7: Portfolio Returns of the Extended Period

L	2	3	4	H	Non-R&D
Equal Weighted					
0.475	0.801	1.106	1.01	1.123	0.812
Value Weighted					
0.653	1.29	1.28	1.357	1.405	0.889
Value Weighted w/o Top 1K					
0.497	0.919	1.185	1.153	1.897	0.804

Exhibit 8: Performance of the Long Short Equal Weighted Portfolio with Extended Period (1981.07 – 2022.12)

	CAPM (FF Mkt-RF)	Fama-French 3-Factor (Mkt-RF; SMB; HML)	Sharpe Ratio (Annual)
ALPHA	1.1352	1.1726	0.922
STD ERR	0.211	0.196	
T-STAT	5.382	5.991	
BETA	0.1801	0.0865; 0.6262; -0.0057	

Exhibit 9: Performance of the Long Short Value Weighted Portfolio with Extended Period (1981.07 – 2022.12)

	CAPM (FF Mkt-RF)	Fama-French 3-Factor (Mkt-RF; SMB; HML)	Sharpe Ratio (Annual)
ALPHA	0.3266	0.1485	0.37
STD ERR	0.218	0.200	
T-STAT	1.495	0.743	
BETA	0.3102	0.3154; 0.4929; 0.5759	

Exhibit 10: Performance of the Long Short Value Weighted Portfolio w/o Top 1K Firms with Extended Period (1981.07 – 2022.12)

	CAPM (FF Mkt-RF)	Fama-French 3-Factor (Mkt-RF; SMB; HML)	Sharpe Ratio (Annual)
ALPHA	1.2181	1.2449	0.983
STD ERR	0.209	0.205	
T-STAT	5.817	6.068	
BETA	0.1632	0.1056; 0.3738; -0.0160	