An Empirical Analysis of the Efficient Market Hypothesis and the Quantifiable Impact of Financial Metrics on Abnormal Returns

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Motivation

- Personal interest in finance
- Technical analysis of stocks and its ability to beat the market
- Are financial results being priced in

Research Question

- Importance of the question
  - Assess whether funds are allocated efficiently
  - Technical analysts and analysis based on past behavior
  - Determine which trading strategies are lucrative
- Uniqueness
  - Panel data with 2015-2019 stock prices
  - Considering impact of financial metrics on returns

Data

- Weak form
  - Time series of S&P 500 daily close prices
  - From 01/01/2015 to 30/12/2019
  - 1,257 observations
- Semi-strong form
  - Panel data of top 10 S&P 500 firms daily close prices and standardized transaction volume
  - CBOE Volatility Indicator – VIX
  - 10-year treasury rate as of 24/02/2020
  - From 01/01/2015 to 30/12/2019

Data

- Financial Metrics
  - Panel data of EPS, ROE, current ratio, and debt to equity ratio observed quarterly for same firms as semi-strong form
  - Time series of CBOE Volatility Index, VIX to act as control
  - From 01/01/2015 to 31/12/2019
  - 20 observations for each firm

Literature Review

- Khan Masood Ahmad, 2006. *Testing Weak Form Efficiency for Indian Stock Markets*
  - Explores weak form in Indian stock market
  - Conducts non-parametric test and unit root tests to assess weak form efficiency
  - Provides detailed methodology and rigorous interpretation of results
  - Concludes Indian stock market does not resemble a random walk

Literature Review

- Malkiel, Burton G, 1989. *Is the Stock Market Efficient?*
  - Provides an excellent description of market functions and EMH
  - Debates empirical analysis conducted previously and laying the foundation of some arguments presented
  - Expounds historical findings exploring the weak form, providing arguments which reason with and against the evidence

Literature Review

- Wooldridge, Jeffrey M, 2016. *Introductory Econometrics: A Modern Approach*
  - ECO375 textbook
  - Easy to understand mathematical reasoning behind ADF test and conducting serial correlation tests
  - Focusses on autoregressive models of order one with added controls
  - Introduces testing random walk hypothesis

Methodology

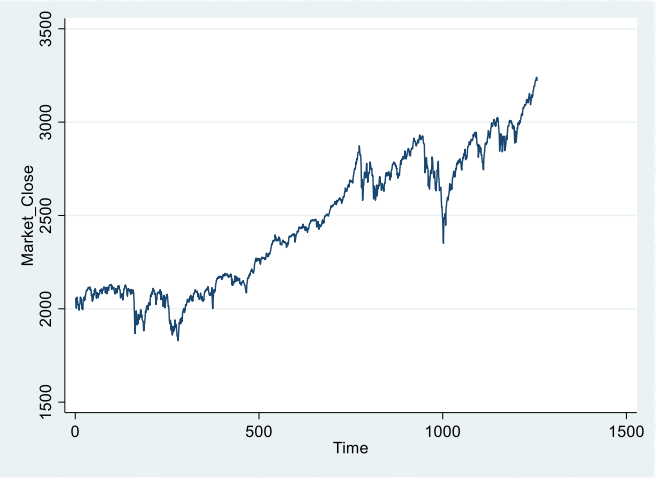
- Weak form
  - Non-parametric test (runs test)
  - Unit root tests (ADF and PP tests)
  - ADF test conducted using two models
- Semi-strong form
  - Regression of stock excess return on market's excess return
  - Truncated regression of standardized transaction volume on VIX
  - Regression of abnormal returns on fitted values from truncated regression

Methodology

- First model includes a drift term (intercept) to show the data evolves around a trend instead of a constant and can be shown $E(y_t) = t\beta_0 + y_0$

$$\Delta y_t = \beta_0 + \beta_1 y_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + u_t$$

$$\Delta y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 t + \sum_{i=1}^{p} \gamma_i \Delta y_{t-i} + u_t$$



- Second model includes a drift term and a time term to control for the rising trend observed in the graph
- Optimal lag p chosen by minimizing Akaike information criterion (AIC)
- For the market to be weak-form efficient, must fail to reject the null hypothesis that β_1=0 at the 5% significance level (unit root exists) and implies data is stochastic (is a function of time)

Methodology

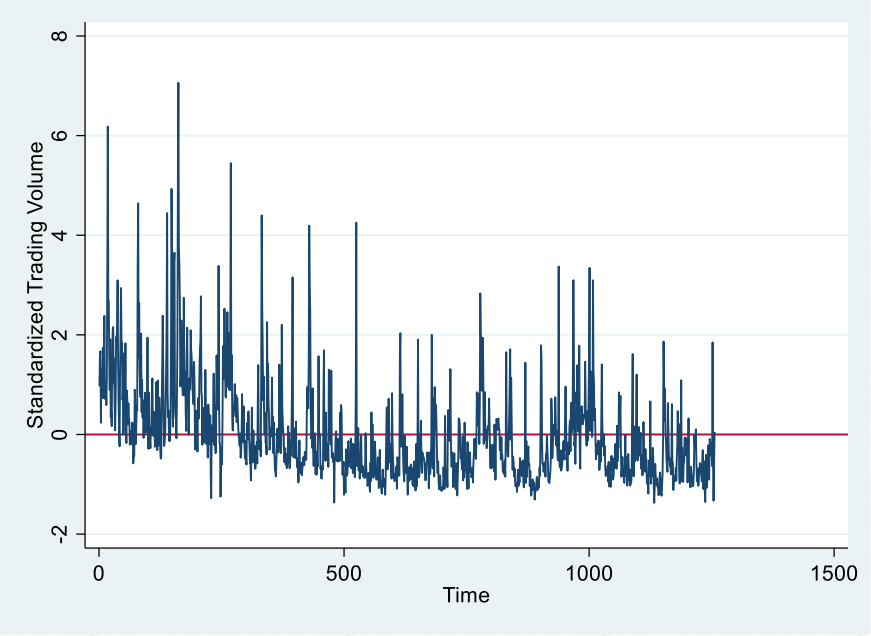
- Calculate stock's beta
  - A stock's beta is defined as $\beta_i = \frac{COV(R_i,R_M)}{VAR(R_M)}$
  - Easily obtained from regression of stock's excess return on market's excess return
  - Regression equation is $R_{it} = \alpha_{it} + \beta_i R_{mt} + u_{it}$ and coefficient β_i measures a stock's beta
- Calculate stock's abnormal return
  - Use CAPM to calculate stock's expected return
  - Abnormal return calculated from $r_{a_{it}} = r_{it} - [r_{f_t} + \beta_i \left(r_{m_t} - r_{f_t}\right)]$ where β_i is same estimate obtained from previous regression

Methodology

- Truncated regression
  - Want to estimate $r_{a_{it}} = \beta_0 + \beta_1 \widetilde{V_{it}} + u_t$ but there is a restriction on values that $\widetilde{V_{it}}$ can take and violates random sampling assumption of OLS
  - Use VIX as an IV since unrelated to stock returns (p-values all greater than 0.05) but related to transaction volume (p-values all less than 0.05)
  - Regress observed standardized transaction volume on 30-year bond yields so the regression equation is $\widetilde{V_{it}} = \beta_0 + \beta_1 VIX + u_t$
  - $\widetilde{V_{it}}$ is defined to be $\widetilde{V_{it}} \begin{cases} \widetilde{V_{it}}^* \, if \, \widetilde{V_{it}}^* > x_i \\ - \, otherwise \end{cases}$ where x_i is chosen to minimize the random noise in standardized transaction volume over time and $\widetilde{V_{it}}^*$ is the observed standardized trading volume

Methodology

- The figure shows AAPL's standardized trading volume over time
- x_i is chosen such that the random noise is eliminated whilst including spikes in standardized trading volume
- At a minimum, $x_i > 0$ since new information being released into the market is represented by trading volume being greater than the average trading volume



Methodology

- Assessing semi-strong form
  - Regress abnormal returns onto fitted values from truncated regression so the regression equation is $r_{a_{it}} = \beta_0 + \beta_1 \widehat{V_{it}} + u_t$
  - For a given stock to be semi-strong efficient, $\beta_1 < 0$ and statistically significant at the 5% significance level
- Impact of financial metrics on abnormal returns
  - Abnormal returns same as the ones calculated previously
  - Regression equation is $r_{a_{it}} = \pi_{0i} + \pi_{1i} EPS + \pi_{2i} ROE + \pi_{3i} Curr + \pi_{4i} DeEq + \pi_{5i} VIX + \tau$

Results – Runs Test

- Weak form
  - Market is weak form efficient in both models according to unit root tests
  - Runs test results implies market is weak form inefficient
  - Runs test conducted during a bull market so it is unlikely to see multiple runs

N	1257
N0	649
N1	608
R	14
E(R)	628.8313445
VAR	313.3315014
STD	17.70117232
z	-34.7339336
p	1.2116E-264

Results – ADF Test

Augmented Dickey-Fuller test for unit root — Number of obs = 1255

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Z(t) has t-distribution		
Z(t)	-0.191	-2.329	-1.646	-1.282

p-value for Z(t) = 0.4244

D.Market_Close_N	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Market_Close_N						
L1.	-.0003101	.0016256	-0.19	0.849	-.0034993	.0028791
LD.	-.0217703	.0282665	-0.77	0.441	-.0772253	.0336847
_cons	1.737561	4.025912	0.43	0.666	-6.160717	9.635839

Augmented Dickey-Fuller test for unit root — Number of obs = 1255

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-3.140	-3.960	-3.410	-3.120

MacKinnon approximate p-value for Z(t) = 0.0970

D.Market_C~N	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Market_Clo~N						
L1.	-.0162987	.0051903	-3.14	0.002	-.0264813	-.006116
LD.	-.0144702	.0282496	-0.51	0.609	-.069892	.0409517
_trend	.0165287	.0050978	3.24	0.001	.0065275	.0265298
_cons	30.5337	9.744913	3.13	0.002	11.41553	49.65188

Results – PP Test

Phillips-Perron test for unit root — Number of obs = 1256, Newey-West lags = 1

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-0.310	-20.700	-14.100	-11.300
Z(t)	-0.153	-3.430	-2.860	-2.570

MacKinnon approximate p-value for Z(t) = 0.9438

Close	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Close L1.	.9997174	.0016238	615.66	0.000	.9965317	1.002903
_cons	1.618697	4.022451	0.40	0.687	-6.27278	9.510173

Phillips-Perron test for unit root — Number of obs = 1256, Newey-West lags = 1

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(rho)	-21.026	-29.500	-21.800	-18.300
Z(t)	-3.264	-3.960	-3.410	-3.120

MacKinnon approximate p-value for Z(t) = 0.0724

Close	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Close L1.	.9830296	.0051642	190.36	0.000	.9728982	.993161
_trend	.0172653	.0050742	3.40	0.001	.0073104	.0272201
_cons	31.67626	9.699497	3.27	0.001	12.64721	50.7053

Results

- Semi-strong form
  - Only firms showing some degree of semi-strong efficiency are JPM and PG
  - Results can be justified by weakness of CAPM in predicting returns
  - Stock buybacks and bull market are another reason for observed results

Results

	(1) AbnormalRe~N
EPS_N	0.116* (2.30)
ROE_N	-0.00790 (-1.07)
CurrentRat~N	0.563 (1.45)
DebttoEqui~N	0.0578 (0.20)
VIX_N	0.00536 (0.58)
_cons	-0.303 (-0.56)
N	1256

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

AAPL

	(1) AbnormalRe~N
EPS_N	0.115 (1.82)
ROE_N	-0.0291 (-1.83)
CurrentRat~N	-0.640 (-0.38)
DebttoEqui~N	0.473 (1.52)
VIX_N	-0.0180 (-1.73)
_cons	1.447 (0.77)
N	1256

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

AMZN

Results

	(1) AbnormalRe~N
EPS_N	0.0109* (2.01)
ROE_N	0.00596 (0.85)
CurrentRat~N	0.178 (0.83)
DebttoEqui~N	0 (.)
VIX_N	-0.00147 (-0.34)
_cons	-0.154 (-1.50)
N	1256

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

BRK-B

	(1) AbnormalRe~N
EPS_N	0.00687 (0.05)
ROE_N	-0.000816 (-0.06)
CurrentRat~N	-0.0366 (-1.34)
DebttoEqui~N	-3.312 (-1.35)
VIX_N	-0.00593 (-0.55)
_cons	0.890* (2.10)
N	1256

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

FB

Results

	(1) AbnormalRe~N
EPS_N	0.00890 (0.90)
ROE_N	-0.0168 (-1.00)
CurrentRat~N	-0.0363 (-0.89)
DebttoEqui~N	-2.781 (-1.16)
VIX_N	-0.00969 (-1.17)
_cons	0.961** (2.70)
N	1256

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

GOOGL

	(1) AbnormalRe~N
EPS_N	0.00241 (0.10)
ROE_N	0.00729* (2.09)
CurrentRat~N	0.0627 (1.19)
DebttoEqui~N	-0.111 (-0.50)
VIX_N	0.000492 (0.08)
_cons	-0.795*** (-3.71)
N	1256

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

JNJ

Results

	(1) AbnormalRe~N
EPS_N	-0.0175 (-0.26)
ROE_N	-0.00369 (-0.88)
CurrentRat~N	0.0605 (0.60)
DebttoEqui~N	0.308* (2.31)
VIX_N	0.00118 (0.17)
_cons	0.297 (1.01)
N	1256

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

MSFT

	(1) AbnormalRe~N
EPS_N	0.146 (0.87)
ROE_N	-0.00537 (-0.62)
CurrentRat~N	-0.0342 (-1.22)
DebttoEqui~N	-0.0256 (-0.22)
VIX_N	0.0000992 (0.02)
_cons	0.364* (2.54)
N	1256

t statistics in parentheses
* p<0.05, ** p<0.01, *** p<0.001

V

Results

- AAPL, BRK-B, and JNJ displayed importance of at least one financial metric on abnormal returns
- Statistical insignificance in T-tests and F-tests of independent variables can be explained by stock buybacks and bull market leading to overvaluation of stocks
- No statistical significance observed for debt to equity ratio, except MSFT, due to firms' desire to maintain a stable and invariant amount of debt to prevent risk of financial distress

Conclusion

- Market is weak form efficient
- Safe to conclude market does not evidence of semi-strong efficiency
- Semi-strong efficiency can be explained by bull market and stock buybacks fuelling appreciation in stock prices leading to gains greater than those dictated by CAPM
- Could have improved calculation of abnormal returns by using a more complicated model relative to CAPM