Mispricing of Corporate Actions: A Statistical Arbitrage Approach

Master's Thesis in Econometrics and Management Science - Quantitative Finance

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Abstract

This paper examines the impact of seasoned equity issues and repurchases on short-term stock performance in the U.S. and Canada. Long-term performance has been abundantly discussed in the literature, although consensus is lacking. Performing an event-studies approach (Ibbotson's RATS methodology as well as a conventional asset pricing approach) reveals a static, statistically significant pattern in post-event returns for both issues and repurchases. These are supported by the Cumulative Abnormal Return estimates, which are significant across the board and of a level between 2 and 6 percent. The Calendar Time approach as suggested in Fama, 1998 also finds significantly positive abnormal returns. These results suggest a strong market inefficiency post corporate actions events. Applying this insight to a set of generalized trading rules for market-hedged short-term trades yields profitable results for almost all strategies. Issue strategies are more profitable than repurchase strategies and most strategies show low short-term risk metrics. None of the strategies pass the statistical arbitrage test devised in Hogan, Jarrow, Teo, and Warachka (2004).

1 Introduction

Equity issues and repurchases, together known as Corporate Actions (CACS), have become more and more common in the marketplace. The past quarter alone saw an increase in repurchases of 5.2% Year-over-Year, now representing an astounding $568.9 billion in deal values.[1] The professional investment community is divided on the issue. Short-term investors worry about dilution and distress signaling, whilst long-term investors are more excited about growth opportunities that stem from the increase in working capital. The work in Altı and Sulaeman (2012) shows that equity issues are typically timed rather well, as they occur often after times of high stock return in combination with institutional demand.

The effect of stock repurchases is no more agreed upon; several respected investors like Warren Buffett and Bill Ackman are pronounced proponents of the phenomenon, seeing the growth in earnings per share (EPS) from the repurchase as a fundamental driver behind stock price increase[2]. They hail the ultra low-interest environment as the perfect time to perform debt financed buybacks, increasing shareholder value by driving up prices. Empirical literature has, in part, shown this to be effective: significant, positive, abnormal returns are attained after repurchase announcements Ikenberry, Lakonishok, and Vermaelen (1995).

However, those results are viewed with distrust by several financial advisors and theorists, pointing to the weakened credit position of repurchasing companies and theorizing it is a tool of wealth extraction as opposed to wealth creation.[3] Furthermore, it limits companies' growth potential by soaking up cash which would be used for investment, reducing overall competitiveness.[4]

Recently, the work in Fama and French (2016) examined the asset pricing anomalies surrounding stock issues and buybacks, and found no significant abnormal returns over their five-factor model. However, this was achieved with a combined 'Net Stock Issues' factor, which is quite different from the research they compare their works to. 'Net Stock Issues' is essentially the difference in outstanding shares, which is then used for a sorting procedure. Other research, such as Evgeniou, Junque de Fortuny, Nassuphis, and Vermaelen (2016) and Loughran and Ritter (1995), shows that both equity issue effective dates and repurchase announcements achieve statistically significant abnormal

[1]http://www.factset.com/websitefiles/PDFs/buyback/buyback_3.17.16

[2]http://www.zerohedge.com/news/2014-08-13/bill-ackman-why-using-debt-buyback-stock-great-and-much-more-full-q2-investor-letter

[3]https://hbr.org/2014/09/profits-without-prosperity

[4]https://hbr.org/2009/07/restoring-american-competitiveness?cm_sp=Article-_-Links-_-Top%20of%20Page%20Recirculation

returns when compared to asset pricing models. Realistic economic viability has, however, not been extensively researched, especially in the short term.

It should be noted that the issues anomaly in most other papers has been modeled by using announcement date as the event date. Although this is a rational point due to the speed at which (public) information is incorporated in the market, the lack of testing on the effective is remarkable. Since an equity issue introduces large volume into the market at a (typically) discounted price, the traded price will not recover until the issue has taken place. This introduces a truncated set of prices where positive returns are not possible and standard assumptions on equity prices do not hold. It thus sets up the research to find negative anomalies. Due to this, the effective issue date will instead be considered in this research.

The dissonance in the discussion in both academic (empiricists versus theorists) and professional (activist and short term investors versus long-term investors) fields is a cause of uncertainty in the market. CACS announcements are consequently met with differing returns. This opens the door for a trading strategy that capitalizes on short-term mispricing such as statistical arbitrage. Applying the concepts of this field to the discussion mentioned above, the following research question arises: Is it possible to construct a profitable, (relatively) short term pair trading strategy that achieves statistical arbitrage around corporate action effective dates and announcements? To determine this the problem is deconstructed into two separate questions, those being:

- When compared to the five-factor model suggested in Fama and French (2015) as an event approach instead of combined into the net stock issues factor, do effective equity issues and announced repurchases capture anomalous return?

- Does the anomalous return for equity repurchases as noted in Evgeniou et al. (2016) and equity issues as noted in Loughran and Ritter (1995) constitute a profitable statistical arbitrage opportunity?

The tools to answer these questions are split into three sections: Anomaly, Trading Rules and Arbitrage.

The Anomaly section describes the event studies approach for determining effects on securities. This is done initially by applying the RATS method as described in Ibbotson (1975) and again by applying the Calendar Time method supported by both Fama (1998) and Mitchell and Stafford (2000).

The Trading Rules section refers to the general pair trading strategy, which attempts to mitigate market risk in order to capitalize on fundamental mispricing. In line with the business activities of Deep Blue Capital and in order to use testable framework for economic gain, the possibility of constructing a statistical arbitrage strategy which can capture short-term returns after CACS announcements will be the main focus. For building statistical arbitrage trading rules, three influences are considered: the work in Pole (2011), the suggestions by Deep Blue Capital and the structure requirements imposed by the asset pricing models. This leads to a pair strategy based on event time abnormal returns.

The Arbitrage section investigates whether a given trading strategy indeed constitutes a statistical arbitrage opportunity. Testing for statistical arbitrage is done in the way of Hogan et al. (2004). Evidence of the existence of statistical arbitrage in a trading strategy surrounding CACS has also been given in Thomakos, Papanastasopoulos, Wang, Hardouvelis, et al. (2007), however the NSI factor is used instead of announcement or effective events. Hence it is still of interest to use event dates for testing statistical arbitrage.

Taking earlier work, most recently in Evgeniou et al. (2016), as a base, this research moves forward by taking into account criticisms as raised in Fama (1998) and Fama and French (2016). Furthermore, the short time span considered in this research offers a different perspective from the long-term studies mentioned. Adding the outlined real-world trading framework provides a very robust testing environment for any abnormal performance found in the asset pricing tests. Given the ongoing debate in the field around CACS events a comprehensive research into the statistical arbitrage opportunities could provide strong evidence for market inefficiency. Since the framework is only dependent on the trading rules applied it does not suffer from many of the statistical issues plaguing the current asset pricing literature. Hence the results from this research are much less vulnerable to model criticism and can provide a much more concrete answer to the CACS question.

Of course, caveats still exist. For instance, perfect beta hedging is practically impossible, but is applied in the trading rules for both ease in calculation as well as the ability to directly relate the trading results to the asset pricing tests. Furthermore, since statistical arbitrage strategies can vary heavily in cash flow sign and magnitude, the trading evidence may be too noisy to pass the arbitrage test.

The initial database is retrieved from the SDC and contains about 180,000 issues and repurchases combined. The repurchases data has a notable spike during the dot-com era, where the issues data is mostly stable over the set, though a small positive trend can be seen. These effects remain after cleaning the data. The majority of issues and repurchases is removed, mostly because the initial data set included private repurchases, private placements and rights issues, whilst this research is only concerned with open market effects. In total, approximately 15,00 issues and 25,000 repurchases are considered.

The asset pricing models applied show short-term results in line with theory: issues give a significant negative spike to stock price on the event date, whilst repurchases show a significant positive spike. However, a positive spike of similar or greater magnitude is found for both issues and repurchases a few days later. This is not consistent with the efficient market hypothesis touted throughout the works of Fama and French on this topic, but can (mostly) be explained through short-term theoretical views encountered in the literature section. An alternative approach, dubbed the Calendar Time approach, suggested to combat statistical issues with the traditional event studies approach, provides a similar outperformance for both issues and repurchases on the short term. This finding is striking, as it shows the observed anomaly persists through criticisms levied in Fama (1998) and disagrees with findings in Fama and French (2016).

Forming simplistic trading rules from these findings, profitable trading results are obtained for both issues and repurchases, though the degree of profitability varies. Finally, applying the statistical arbitrage framework, the hypothesis of statistical arbitrage is rejected. In the case of issues, this is due to the 'change in variance' variable being non-negative, whilst in the case of the repurchases the variance itself is of too large a magnitude.

The paper is laid out as follows. First the current state of the literature of the various considered fields will be further clarified in the 'Literature' section. Next, the 'Methodology' section will describe the techniques used to answer the research questions. Afterwards, a brief consideration on the required data and its' sources is presented in the 'Data' section. The results are displayed and discussed in the 'Results' section. Lastly, a conclusion is delivered in the 'Conclusion' section. Past the conclusion the Bibliography and Appendix can be found.

2 Literature

First, the theoretical arguments for corporate actions are discussed. Corporate Actions present a core issue of modern corporate finance theory. Since the initial corporate interest tax deductions were set into law in the United States, the optimal leverage for a company has become nonzero, as documented in the seminal paper Modigliani and Miller (1958). The framework proposed therein breaks down tax into three relevant categories: personal, equity and corporate. This suggestion has been expanded upon by a plethora of papers, with the general conclusion that companies should have a (seemingly) high degree of debt financing. An overview of these papers can be found in Graham (2011).

Stock issues are met with negative returns, as the increase in outstanding shares (better known as 'dilution') will reduce EPS and other per-share based metrics. This is, however, inefficient according to corporate finance literature. As laid out in Asquith and Mullins Jr (1986), an efficient market should "see through" current EPS dilution in anticipation of greater future cash flows, as competent management ought only to use the increase in cash for growth opportunities. This seems to go unrecognized by the market as both the quoted paper and other works (such as Spiess and Affleck-Graves (1995)) shows short and long term underperformance for issuing stocks.

Conversely, stock repurchases are typically praised by retail and institutional investors alike since the EPS gain is seen as a driving factor behind equity returns. This reasoning has some caveats, however. The general criticism of repurchases stems from the use of capital: instead of investing in growth opportunities (investments with NPV>0), cash is returned to shareholders, which diminishes future earnings perspectives. In fact, it is recorded in Graham, Harvey, and Rajgopal (2005) that 41% of CFOs will favor meeting EPS targets (by use of repurchases) over investing in positive NPV projects. On top of that, as noted in Farrell, Unlu, and Yu (2014), stock repurchases are discouraged as earnings management mechanisms in the context of debt financing constraints. Considering the low cost of debt pervasive in the post banking crisis economy this barrier has been substantially decreased, as recorded by Blundell-Wignall and Roulet (2013). The current interest rate environment is also generally seen as a good time to issue debt in return for lowering equity.

The negative side of repurchases is highlighted in Kahle (2002), which finds that if many stock options are held by employees it tends to trigger a non value-adding repurchase, aimed at increasing the wealth of the management as well as funding more option purchases. This can lead to agency issues where management is primarily interested in using capital structure to their own benefit. Lin, Stephens, and Wu (2014) shows that takeover risk, as suggested by Cremers, Nair, and John (2009), increases after a repurchase announcements and it is proposed that this is the cause of the pricing anomaly, since an increase in risk should come at a premium. Note that the “risk” of a takeover is dubious as it would results in (large) premiums for the stakeholders. However, it is shown that if intertemporal hedging demands are present, firms with takeover risk ought to have negative returns. This observation is also suspect to the earlier criticism by Fama (1998) as results are clustered in the section of small stocks, but then that is to be expected of takeovers. Although an interesting finding, this is unlikely to impact this research due to the short time-frame applied here.

Behavioral Corporate Finance has also considered the Corporate Actions environment. The overview given by Baker and Wurgler (2011) categorizes three main incentives for Corporate Actions: fundamental value, catering and market timing. The first line of reasoning suggests that the repurchase or issue of equity at a certain time is a profitable investment. The second states that CACS are a tool to placate or “cater” to short-term investors, maximizing short-term return. Lastly, the market timing goal is centered around increasing value for long-term investors by taking advantage of current mispricing. These incentives are balanced by the manager’s characteristics, but can change over time due to career concerns or the market for corporate control.

Several other applicable behavioral quirks are brought to light: in stark contrast to the work of Ben-Rephael, Oded, and Wohl (2013), who show that large S&P 500 firms typically repurchase their stock at peak prices, Brav, Graham, Harvey, and Michaely (2005) show that 86.6% of CFOs agree that they repurchase equity at “good value, relative to its’ true value”. Similarly striking is the finding in Graham et al. (2005) that CFOs believe investors care more about EPS than cash flows. Optimism in managers and an upper bound on leverage reveal a pecking order in financing decisions that puts outside equity in last place. This optimism is very strong: Ben-David, Graham, and Harvey (2010) shows that the 80% confidence intervals CFOs give for their stock’s one-year return only contains the true return one-third of the time.

Signaling theory is also briefly considered. The suggestion as first discussed in Spence (1973) is that “good” managerial types can separate themselves by taking actions that are less costly to them than to “bad” managerial types. Due to well-known psychological mechanisms such as loss aversion and reference-point thinking, it is costly for a “bad” type to take similar actions, as “bad” types are unwilling to incur the expected future cost of missing a reference point. This is not specifically discussed for CACS, but the same inferences can be applied here. For instance, a share issue is a sign of a “bad” type, as management typically wants to avoid issues as a means of financing investments. A share repurchase would, conversely, be very costly to “bad” types, as the required liquidity is likely not available.

Reviewing the theoretical literature, a consensus is not reached. Classical corporate finance finds that the CACS decisions ought to impact the market price only to correctly adjust for tax benefits, given that no unprofitable projects are invested in. However, both behavioural corporate finance and signaling theory find reasons for negative reaction to issues and positive reaction to repurchases.

The empirical side is just as interesting as the theoretical argument. In a follow-up of own research, Miller (1977) finds that a companies by and large do not adhere to an optimal capital structure. This is attributed to personal tax rates, where its' increase offsets the gains from the corporate debt structure. However, modeling the financing situation of the cross-section of companies on personal taxes is rife with statistical pitfalls, most notably endogeneity (addressed in MacKie-Mason (1990)) and measuring issues (e.g., marginal personal tax rates). Using clever statistical techniques and proxies, Campello (2001) documents that the changes in corporate debt rates after the Tax Reform Act of 1986 are consistent with the aforementioned theory of personal tax rates.

Market reaction to Corporate Actions has also been extensively researched with econometric methods in the past half century. Since initial observations made in papers such as Ibbotson (1975) and Ikenberry et al. (1995), asset pricing modelers and efficient market theorists alike have attempted to understand the seemingly inconsistent reaction of markets to share issues and buybacks. Both fields are relevant to this research. The asset pricing theories surrounding CACS, although divided, give a clear picture of some of the pitfalls which ought to be avoided, as well as the current state of debate on the existence of a pricing anomaly. The efficient market discussion is equally important, since the existence of an anomaly would invalidate any efficient market hypothesis. Furthermore, the notion of an efficient market is incompatible with statistical arbitrage, as noted in Thomakos et al. (2007).

By definition, a repurchase increases shareholder value, as a repurchase for any price is simply an increase in demand, inevitably increasing that price. The findings in Ikenberry et al. (1995), Peyer and Vermaelen (2009) and Evgeniou et al. (2016) show that a repurchase announcement is followed by a long-term outperformance not captured by leading asset pricing models. This abnormal return shows a positive relation to a proxy for undervaluation before the buyback announcement, however the validity of this proxy is questionable. These observations are an important step to answering the anomaly question.

However, the methods used therein have faced significant criticism, most notably from Fama (1998) and Mitchell and Stafford (2000). Those papers take issue with the event-month approach used, arguing it ignores time related cross-correlation of corporate actions. Indeed, it is possible that in bull markets overvaluation is more widespread which could result in multiple equity issues. A solution is offered in the former of the two researches, in the form of a Calendar Time portfolio: by constructing a portfolio of repurchasing companies within a certain time-frame and weighing these by an estimate of their variance, cross-correlations are accounted for, and as such the return series from this portfolio can be correctly tested for significance.

The reverse may hold for repurchases. The quoted papers both strongly advocate an altered approach. The utilized assessment metric, the average Buy-and-Hold Abnormal Return (BHAR), is also called into question. It is shown that even with no additional outperformance after the announcement, which would be more consistent with an efficient market, the BHAR will continue to grow, giving a theoretically false suggestion of long-term results. A further point of contention is made of the results itself; the model suggested in Fama and French (1992) is, by own admission, inappropriate for small growth stocks. This is where the bulk of the anomaly evidence is concentrated. These criticisms provide some important pitfalls to avoid when researching any event-based financial hypothesis.

Another point of contention, as found in Ben-Rephael et al. (2013), is that smaller S&P firms tend to strategically time their repurchases to decrease equity, whereas larger S&P firms are more concerned with disgorging free cash flow. This leads to the result that large firms typically buy at pricing peaks: an abundance of free cash flow occurs only after (highly) profitable business operation, which is likely to increase stock price. This provides an interesting view the works of Peyer and Vermaelen (2009) and its' criticism, highlighting the need to properly address size characteristics. Jagannathan and Stephens (2003) shows that the operating performance of repurchasing firms decreases when compared to their peers following the repurchase.

Similarly, equity issues have seen extensive empirical research, spearheaded by the initial effort of Loughran and Ritter (1995) which finds a negative impact of issues on long-term stock price. Pontiff and Woodgate (2008) shows that issues are a better predictor for stock returns than size, value or momentum factors. A more recent study by Parreño, Ruiz, and Roux (2014) finds a negative excess return of 5% for equity issues, though it should be noted that this is compared to a relatively simple asset pricing model (the CAPM). A (slightly outdated) overview of the literature can be found in Ritter (2003), who documents the various views on Initial Public Offering (IPO) and Seasoned Equity Offering (SEO) effects. In short, it details that IPOs face short-run underpricing, long-term underperformance and extreme fluctuations in price and volume. SEOs are documented to have negative announcement effects, discounted offer prices from market price, long-run underperformance, and large fluctuations in volume. It is also documented that the initial effects are typically underreactions, as long-term abnormalities have the same sign as initial reactions. These papers set up the expected anomaly to be found for equity issues.

Thus, stock issues are typically perceived as a negative evolution in the company, triggering long-term negative returns with repurchases showing the opposite effect. In an effort to capture and combine the two effects, the Net Stock Issues (NSI) factor was applied to leading asset pricing models in Daniel and Titman (2006). This factor is equal to the net change in equity and thus is not equal to the phenomenon utilized in previous research, as in those cases mostly the announcement or effective was researched. The NSI factor is subsumed in the profitability and investment factors shown in the research of Fama and French (2016). This begs the question whether the abnormal returns caused by CACS effective dates and announcements are indeed explained by profitability and investment or whether NSI is too broad to capture the specific effects of announcements.

The Equity issue literature is not free of model criticism either. The reasoning of the cross-correlation criticism in Fama (1998) and Mitchell and Stafford (2000) holds for issues too and is laid out and improved upon in Schultz (2003). Citing the work of Pagano, Panetta, and Zingales (1998), the paper finds that since surveys show that companies attempt to time the market for equity issues (and aim to issue on peaks), the subsequent return is, in event-time, inevitably negative. Using realistic simulation, similar results to the empirical literature are found. This highlights the need to apply calendar-time solutions for equity issue models as well as repurchases.

Reviewing the empirical literature, it is clear that the behavioural finance and signaling theory suggestions hold sway over the markets. Issues trigger long-term negative returns, whilst repurchases trigger long-term positive returns. The research field is, however, littered with criticism of model specification, factor definition and choice of performance metric. This research tackles these three problematic areas in different fashions.

First, the model selection criticism is countered by applying both a traditional asset pricing approach as well as an event-driven model. Cross-correlation concerns are addressed by use of the Calendar Time approach as suggested in Fama (1998) and Ibbotson (1975). Factor definitions are not a problem as the research is centered around active issuing and repurchasing actions, rather than a passive net change in outstanding shares. A set of neutral metrics as suggested by many of the critics of earlier research, the Average Abnormal Return (AAR) and Cumulative Abnormal Return (CAR), are applied to avoid any misjudgement in performance.

In addition to the measures above, a real-world trading framework is applied to test economic merit of a possible anomly. This should give a much more robust result, as any event for which a simple strategy provides profit consistently is a rejection of the efficient market hypothesis. A fitting test for the consistency of these profits could provide a definitive answer to CACS anomalies. This test comes in the form of statistical arbitrage, the concept of which is essentially that to achieve statistical arbitrage, a set of trading rules should provide a stream of cash flows which, when time goes to infinity, reduces to zero volatility and positive mean. The test associated with this is derived from the work in Hogan et al. (2004). Although the asset pricing tests and the trading strategy results could already provide robust evidence of (the absence of) market efficiency, it is clear that if the simple strategies constructed from the results of the asset pricing tests constitute a statistical arbitrage opportunity, market efficiency is not established for CACS on the short term.

3 Methodology

To examine the two questions posed in the Introduction section, two different methods are applied. Firstly, to determine the existence and significance of a pricing anomaly surrounding CACS announcements, the models suggested by Ibbotson (1975), Fama (1998) and Peyer and Vermaelen (2009), that is the Returns Across Time and Securities (RATS) approach and the Calendar Time portfolio approach as well as a more conventional asset pricing approach are applied. These are outlined in the Anomaly section below.

For the conversion of anomalous behavior to trading rules, a simple trading framework is developed, inspired by both Pole (2011) and the methods used by Deep Blue Capital. This process is described in the Trading Rules section below.

Lastly, the testing framework developed in Hogan et al. (2004) to detect statistical arbitrage opportunities in a given set trading rules is applied. This method is outlined in the Arbitrage section below.

3.1 Anomaly

As a starting point, the conventional asset pricing approach can be used. In this case, the conventional form as shown in Equation 3.1 is applied.

As an event study methodology, it does differ from the usual asset pricing studies. Specifically, this method focuses on specific events and time frames that relate to the point of the event. It is less concerned with actual calendar sections of time (such as 'June' or '2012') and more concerned with time relative to the event (such as 't+1 months' or 't-2 days'). To define this, the term "event time" is applied, such that one month ahead in event time means one month ahead from the time (typically a date) of the event. This is applied as follows. First, transform all equity price series into excess return series. Next, reorganize these return series to event time. Note that the announcement date itself is typically included, however not the day before as it would require an investor to hold the stock before the announcement is made, which is not practically applicable. Returns are usually high in absolute value for these dates, which would then skew our results in favor of confirming an anomaly. The return from event day t+1 to event day t is applicable, though in this research it is also excluded to ensure practical applicability (more on this in the Data section).

It should be noted that the specific event date is not the same for issues and repurchases. For issues, the 'effective issue' date is used, which is defined as the day the issue becomes effective, i.e., the date that the new shares become legal. For repurchases, the announcement date is used. This is done for a few reasons. For one, the announcement date for issues was not always available. But more importantly, an issue is essentially a very large ask order placed into the market by the company. That means that the share price is very unlikely to exceed the issue price, as the players that tend to push the price can simply partake in the issue if the price is above issue price. Thus, the development of the stock price is far from standard and cannot rise beyond a certain point. Third, some issues take several days, while others are over the day they are announced. This would impose a serious timing issue on the data set, as the price effect mentioned would last longer for some stocks than others.

The announcement date can be used for repurchases, as this is not at all like a large bid order. Repurchases do not have to be reported up-front, and as such the company can decide and change they want to purchase their equity at, at any time. Issues do have to be reported up-front, as purchasers of the issue want to know how much they are buying for what price and the exchange has to be notified of the new shares. Repurchases are also typically defined in total size: a company will not make a tender offer for a certain price, but they will repurchase shares for a total amount. The exact number of shares repurchased is then reported at the conclusion of the program. These programs tend to take weeks to months, depending on the size of the repurchase. Hence the announcement date is the only applicable date for repurchases.

One last observation that needs to be made about the event-time is the selection of window length. Since the aim of this research is to construct a short-term trading strategy, the window should fit this description. In accordance with Deep Blue Capital, the window is set to 12 trading days, allowing for a flexible view on results whilst not featuring an overdue amount of observations.

Once this method has been implemented, checking for event anomalies is simply done by estimating β_i over a set of observations prior to the event date and constructing $\hat{R}_{i,t} = \hat{\beta}_i F_i$. Then determine $AR_{i,t} = R_{i,t} - \hat{R}_{i,t}$ and observe its behavior.

$$R_{i,t} = \boldsymbol{\beta_i F_t} + \varepsilon_{i,t} \tag{3.1}$$

where $R_{i,t}$ is the excess return on asset i at event time t and the factor $\boldsymbol{F}$ contains the risk factors returns of the selected asset pricing model, and $\varepsilon_{i,t}$ is the error term. The selection of asset pricing models is expanded upon later in the Methodology section.

A model more often applied in the event studies literature is the Returns Across Time and Securities ('RATS') as introduced in Ibbotson (1975). Using the same event-time series as used in the conventional model, cross-sectional regressions are performed using a separate asset pricing model for every observation in event time. The estimated coefficient for the constant (better known as α) is then analogous to the measure of abnormal return (under the used asset pricing model). To be precise, the following equation is estimated using OLS.

$$R_{i,t} = \boldsymbol{\beta_t F_i} + \varepsilon_{i,t} \tag{3.2}$$

where the interpretation of the variables is the same as for Equation 3.1. Standard t-tests are applied to the alpha coefficient estimate, more involved tests on the abnormal returns are expanded upon below.

The difference between these two approaches is not insignificant: the RATS approach attempts to model each 'coefficient' based on event-time results (effectively stating that event-based risk factor exposures supersede asset-specific risk factor exposures), whilst the conventional asset-pricing approach assumes all coefficients save α to remain constant over the event period. Hence, the difference in results between these models are informative about the stability of other coefficients over the event period.

These models can also be applied in a pseudo-moving window approach. Since not all days considered in the full sample have events, using a simple moving window approach would have a varying amount of CACS stocks at any given point. This produces a varying amount of model strength, which is undesirable. Instead, the moving window will move over events: a step forward in this moving window will simply mean including the next CACS event and discarding the oldest. This means that at every point it includes a set number (1000 is used for this research) of CACS events.

To determine the existence of an anomaly, the abnormal returns found by the asset pricing models are investigated. As discussed in the Literature section and as is usual in the event studies literature, several metrics are suggested for overall performance, such as Buy-and-Hold Abnormal Return (BHAR), Cumulative Abnormal Return (CAR) and Average Abnormal Return (AAR). Due to the legitimate criticism on the BHAR metric, the CAR is applied here, along with the appropriate t-test as suggested in Brown and Warner (1985). These are specified in Equation 3.3 and Equation 3.4. Note that $AR_{i,t}$ is defined as the Abnormal Return of asset i at point t (where t is in event time). Specifically it is defined as $AR_{i,t} = R_{i,t} - \hat{R}_{i,t}$ where $\hat{R}_{i,t}$ is the estimate from the asset pricing model. An added benefit of these metrics is the ability to use their averaged values over time for validating moving window results. To keep the comparison between the two asset pricing models clear and concise, traditional t-tests will be used for the full-sample results and the CAAR will be used for the moving window results.

$$CAR_i = \sum_{t=1}^{T} AR_{i,t}, \quad CAAR = \frac{1}{n} * \sum_{i=1}^{n} CAR_i \tag{3.3}$$

$$t_{CAR} = \sqrt{n}\frac{CAAR}{S_{CAAR}}, \quad S^2_{CAAR} = \frac{1}{n-1} * \sum_{i=1}^{n}(CAR_i - CAAR)^2 \tag{3.4}$$

To demonstrate the robustness of the anomaly it is beneficial to include several asset pricing models. Hence the CAPM framework will be applied and appended with several popular suggestions. The CAPM is defined as the factor model above, where $\boldsymbol{F}$ only contains the constant and the excess return on the market portfolio. Several popular factors are added, such as the size and value factors SMB and HML as suggested in Fama and French (1992) and the momentum factor MOM first discovered by Jegadeesh and Titman (1993). These models are all tested for the full-sample results. Applying all of these models to the moving window models would yield a staggering amount of results. Since in Fama and French (2016) the issue/repurchase anomaly was supposedly debunked using the 5-factor asset pricing model, this model will be used for moving-window results.

Besides this, a version for each of these models will be estimated with a industry return instead of general market return. These models are similarly applied in Fama and French, 2016.

As mentioned in the Literature section, the Calendar Time portfolio can be used to avoid cross-correlation issues in CACS event studies. The first suggestion for this method, as introduced in Ibbotson (1975), states that for every event observation one should randomly select at maximum one stock from all stocks that share a real date as their event date. In this context, if two companies issue shares or announce a repurchase on the same date, only one of those companies is selected. However, this does impact the estimators in that they are no longer minimum variance. Because of this, the suggestion in Fama (1998) features an amendment: form an equally-weighted portfolio for every calendar date of all companies that had an event within a certain amount of observations prior. For instance, a maximum of 30 days prior, which would constitute a maximum 30-day holding period. Then, instead of using each individual return in the asset pricing model, use the returns from this portfolio instead. This is effectively the same as taking the average of all abnormal returns for the companies considered in the selected time frame. The asset pricing model is then regressed on the return series of this portfolio.

The drawback from the initial approach of the Calendar Time portfolio is mitigated in this alternate version, but not removed, as this model will suffer from heteroskedasticitiy. Specifically, it is likely to have increased variance for periods with few stocks (but not zero) in the portfolio, due to lack of diversification. This drawback is not strict as idiosyncratic volatility can strongly vary. The cited paper notes this and suggests dividing the portfolio returns by an estimate of its standard deviation to achieve normalized returns which can be compared over time. Perhaps a more elegant solution would be to apply a Weighted Least Squares estimation method, which would also account for heteroskedasticity in the residuals. This last model is precisely the approach used in this research (through a Feasible Generalized Least Squares approach).

3.2 Trading Rules

Trading rules for statistical arbitrage can be deceptively simple. Indeed, following the work of Pole (2011) and the practical application by DBC, EWMA spread modeling can be applied. However, this method of trading rule construction is only very indirectly connected with the Anomaly detection models, as those aim to determine abnormal return on a (relative) time basis. Furthermore, this kind of spread modeling would require intra-day data to be reliable: if one were to only trade on the EWMA values for closing prices, few trades would be made.

Instead, since this research is focused on the statistical anomaly presented by the use of asset pricing models, the trading rules will also be based on relative time. That is, if the asset pricing models show outperformance for a certain period in event time, the trading rules will state to hold that stock and short the market (beta-adjusted) for that period, and vice versa for underperformance. Shorting the market replicates the behavior of the asset pricing models by consolidating the market risk factor. As the asset pricing results are constructed from Abnormal Returns, trading rules based on these results should attempt to hedge all risk factors included in the asset pricing models, however shorting the market (through futures) is the only practically feasible application.

This is not the most sophisticated method for constructing trading rules, but it does seem most applicable for testing the findings of the asset pricing models. Furthermore, the simplistic nature does negate data snooping criticism for the trading rules.

Although the concept is simple, the finer details are more complicated. To replicate a realistic strategy, slippage, trading cost and investment size must be considered. Slippage is what happens when an investor pushes the market by liquidating large positions fast[5]. This can cause major disruption to any trading strategy when left unaccounted for. As will become clear later, the size of the investment is highly relevant to overcoming slippage. In this paper, it is dealt with in the same manner as the

[5] http://www.automatedtrading.com/2014/04/30/measuring-slippage-make-top-priority/

'TradingBLOX' system: for every purchase, the price is increased by an x% towards that day's high price, and vice versa for sales[6]. It should be noted that the volume investment system advocated by DBC tends not to yield very small slippage, so the value for x is set to 5.

Second, trading costs are accounted for by increasing the price of purchase by 5 basis points, and decreasing the price of sale by the same amount. Lastly, the size of the investment is determined by the average daily volume. One can reliably sell 10% of the closing auction volume without pushing the price, according to DBC's practical experience. In turn, about 15% of daily volume occurs in the closing auction[7]. Hence, the investment for any stock will be 1.5% of a stock's daily volume, to a maximum of one million dollars absolute investment.

These decisions are important to note as they may be responsible for differences between the results of the asset pricing models and the results of the trading rules. Specifically, this system requires a convincing result to be profitable (slippage and trading cost will eat away at profits) and it will overweight high-volume stocks and underweight large high-volume stocks (due to the maximum investment size).

3.3 Arbitrage

To determine if the given market inefficiency constitutes a statistical arbitrage opportunity, the work of Hogan et al. (2004) can be applied. The framework presented in that research provides a quantifiable way of testing for statistical arbitrage irrespective of asset pricing model. Note that this does not constitute an undermining of this research: the aim of this research is to check if CACS (still) constitute market inefficiency in terms of the Five Factor model and confirm the result with a short-term trading strategy. Even if no significant evidence of an anomaly is found, the opportunity for statistical arbitrage may still be researched.

The cited paper outlines the following framework. Define the time series of discounted cumulative trading profits from the trading strategy defined earlier as $v(t_j)$. Let $\Delta v_j = v(t_j) - v(t_{j-1})$ denote the increments of the discounted cumulative trading profit measured at equidistant time points $t_j - t_{j-1} = \Delta$ with $t_j = j * \Delta$. It is shown in Hogan et al. (2004) that assuming constant mean return for the trading strategy is empirically valid and thus it is adopted here, without showing the model with unconstrained mean. Without loss of generality, Δ can be set equal to one, after which t_j is equal to j. Then the following structure is imposed on the discounted incremental

[6] http://www.automated-trading-system.com/slippage-backtesting-realistic/

[7] http://www.itg.com/marketing/ITG_BlotterBorkovec_GlobalIntradayVolume_20140527.pdf

trading profits.

$$\Delta\upsilon_j = \mu j^\theta + \sigma j^\lambda z_j \tag{3.5}$$

Where $j = 1, 2, ..., n$, z_i are i.i.d. N(0,1) random variables with $z_0 = 0$. Both $\upsilon(t_0)$ and $\Delta\upsilon_0$ are zero. Notice that changes in the mean are modeled by θ and changes in the variance are modeled by λ.

It is important to first consider the theoretical suggestion behind the statistical arbitrage testing framework, as it sheds light on the procedure described. Theoretically, arbitrage is only attained when there is an opportunity for a self-financing, riskless profit. Statistical arbitrage is then defined on four qualities:

1. $\upsilon(0) = 0$
2. $\lim_{t\to\infty} E^P[\upsilon(t)] > 0$
3. $\lim_{t\to\infty} P(\upsilon(t) < 0) = 0$
4. $\lim_{t\to\infty} \frac{Var^P[\upsilon(t)]}{t} = 0 \quad \text{if} \quad P(\upsilon(t) < 0) > 0 \qquad \forall\ t < \infty$

These four elements are composed of a self-financing quality, a positive expected value in the limit (profitable), a probability of loss converging to zero (riskless in the limit) and a time-averaging volatility converging to zero if the probability of a loss does not converge to zero in finite time. Hence the fourth condition applies only if there is always a positive probability of losing money. Otherwise, there exists some $T < \infty$ boundary, for which it holds that $\forall t \geq T,\ P(\upsilon(t) < 0) = 0$, which constitutes a regular arbitrage opportunity. Note that the self-financing quality is only indirectly applied in this research: due to non-constant investment (which gives an unbiased overview of performance) the self-financing quality is violated. However, as the model test is not contingent on this quality the framework does not change.

Next, the parameter estimates for such a strategy are needed. Following the cited paper once more, the discounted cumulative trading profits generated by the trading strategy are defined as follows.

$$\upsilon(t_n) = \sum_{j=1}^{n} \Delta\upsilon_j \sim \text{dN}\left(\mu \sum_{j=1}^{n} j^\theta,\ \sigma^2 \sum_{j=1}^{n} j^{2\lambda}\right) \tag{3.6}$$

Following this normality assumption and the increments denoted in Equation 3.5, one finds the following log-likelihood function.

$$\log L(\mu, \sigma^2, \lambda|\Delta\upsilon) = -\frac{1}{2}\sum_{j=1}^{n} \log(\sigma^2 j^{2\lambda}) - \frac{1}{2\sigma^2}\sum_{j=1}^{n} \frac{1}{j^{2\lambda}}(\Delta\upsilon_j - \mu)^2 \tag{3.7}$$

This leads to the following score equations.

$$\frac{\partial \log L(\mu,\sigma^2,\lambda|\Delta\upsilon)}{\partial\mu} \;:\; \hat{\mu} = \frac{\sum_{j=1}^{n} \Delta\upsilon_j j^{-2\hat{\lambda}}}{\sum_{j=1}^{n} j^{-2\hat{\lambda}}} \tag{3.8}$$

$$\frac{\partial \log L(\mu,\sigma^2,\lambda|\Delta\upsilon)}{\partial\sigma^2} \;:\; \hat{\sigma}^2 = \frac{1}{n}\sum_{j=1}^{n}\frac{1}{j^{2\hat{\lambda}}}(\Delta\upsilon_j - \hat{\mu})^2 \tag{3.9}$$

$$\frac{\partial \log L(\mu,\sigma^2,\lambda|\Delta\upsilon)}{\partial\lambda} \;:\; \hat{\sigma}^2\sum_{j=1}^{n}\log(j) = \sum_{j=1}^{n}\frac{\log(\mathrm{j})}{j^{2\hat{\lambda}}}(\Delta\upsilon_j - \hat{\mu})^2 \tag{3.10}$$

Putting this into the model specification discussed earlier and foregoing the entire theoretical derivation, a joint hypothesis test for the existence of statistical arbitrage consisting of the following conditions can be described as follows.

- H1: $\mu > 0$ and
- H2: $\lambda < 0$

Although H1 is obvious, H2 is not so. This inequality follows from the distribution of the profits and the definition of statistical arbitrage. If the latter requires that variance must decline to zero in the limit, we can see that $\lim_{n\to\infty}\sigma^2\sum_{j=1}^{n} j^{2\lambda}/n = 0$ requires that λ is negative. For a more expansive explanation of this hypothesis, the theoretical derivation mentioned above and the model as a whole, please refer to Hogan et al. (2004).

Thanks to the Bonferroni inequality, the sum of the p-values for the individual tests defines an upper bound for the Type I error of the joint hypothesis test. Standard errors are extracted from the Hessian matrix to produce t-statistics and p-values.

3.4 Validation

Since a test of statistical arbitrage is already supplied, whether or not statistical arbitrage is present given the constructed trading rules can be conclusively confirmed or rejected. However, this provides no information on the stability of this strategy. The nature of statistical arbitrage is that it works for many iterations, so the short-term results may vary. In order to address this, several alternative performance metrics are applied.

3.4.1 Performance

The statistical arbitrage framework described in the Methodology section provides a robust test for the performance of a well-hedged trading strategy. However, this does not explicitly test for performance in and of itself. Therefore it is important to assess the results of the trading strategy independently as well. AAR as well as CAR are appropriate metrics and supported by both Fama (1998) and Mitchell and Stafford (2000). However, since investment will not be stable (as explained before) and is not dependent on earlier results, cumulative trading profit is the analogous performance measure to CAR and is used for the same purpose. These variables can provide an initial assessment of trading strategy quality before applying the testing framework.

3.4.2 Risk Analysis

Maybe the most well-known measures for determining the risk of securities or portfolios are Value-at-Risk (VaR) and Expected Shortfall (ES). Simply put, VaR is the maximum percentage loss for a certain threshold and a certain time frame. Typically, the threshold value is 95% and the time frame varies. For this research a 1-day VaR return will be considered at 95% and 99% levels, relative to total investment on that day. Mathematically, the following formula applies.

$$\mathrm{VaR}_\alpha(L) = \inf\{l \in \mathbb{R} : P(L > l) \leq 1 - \alpha\} = \inf\{l \in \mathbb{R} : F_L(l) \geq \alpha\}. \tag{3.11}$$

Similarly, ES is the expected loss *given that* the loss exceeds the VaR threshold. In mathematical terms,

$$ES_\alpha = E[X|X \leq x_\alpha] \tag{3.12}$$

Where x_α is equal to the lower α quantile defined by the VaR. This is equivalent to

$$ES_\alpha = -\frac{1}{\alpha}\Big(E[X\ 1_{\{X \leq x_\alpha\}}] + x_\alpha(\alpha - P[X \leq x_\alpha])\Big) \tag{3.13}$$

Where $1_A(x)$ is the indicator function.

There are many caveats to using and computing the VaR and ES in such a setting. Typically VaR is calculated using the empirical distribution of returns. An alternative approach is taking a parametric VaR, but this is subject to the bad model problem. More involved methods that attempt to capture multivariate risk elements (such as in a portfolio) include Factor VaR and Copula models.

Whilst all of these models are applicable, a model for the returns of our trading strategy has already been defined in the arbitrage section. That is, if the test is believed to be accurate, the VaR and ES should be calculated based on the same distribution. However, this approach has a serious caveat. Since the trading strategy involves making portfolios in calendar time (as it must be practically applicable), the portfolio composition can change dramatically, especially in periods of high CACS activity. This creates structural breaks in sigma (due to diversification), which is allowed for in the testing framework (as long as there is a declining trend after the break) but would require a serious modeling effort when computing VaR/ES. Furthermore, this may be even more difficult in real-time trading. Therefore an empirical VaR/ES estimate is used.

This will have a downward bias on the VaR estimate (as large negative return will likely happen more often in undiversified portfolios, i.e., when there are very few stocks in the portfolio) and an upward bias on the ES estimate (as the undiversified portfolios will have more extreme results due to the lack of mitigation from other stocks). Yet it seems like the best option, given both the considerations above and the data in Figure 4.1. The biases are also on the 'safe' side, as a real-world investor would run less risk than estimated.

3.4.3 Data Snooping

Data snooping concerns abound when a research attempts to test many options in order to find statistical significance. After all, a 5% significance rate will still provide a type I error per 20 independent tests on average. Hence, data snooping is a plausible problem. It thus seems important to compare trading strategies at the construction stage, as feeding every strategy into the statistical arbitrage framework is likely to yield false positives.

The current way the strategies are defined are unlikely to yield many data snooping issues: the precautions taken in the asset pricing model section (the use of several asset pricing models, moving window, several performance measures, calendar time approach) should prevent the large number issue entirely. As the strategy only relies on the input of an event-time start and end date, the only 'optimization' is done by selecting those dates as a result of the anomaly results. Although it can be argued that there are many of these, it should be noted that both the moving window approach (through the CAAR metric) and the Calendar Time portfolio only measure abnormal return over the entire considered period. Thus, they can only yield one strategy: buy or sell for the complete duration of the event window.

The asset pricing models themselves could, in theory, suggest a large number of strategies. Should this happen, the easiest way to deal with erroneous strategies would be to simply observe their profit and loss. If the strategy is indeed faulty, then thirty years of trading on it should not reveal structural profit, let alone a statistical arbitrage opportunity. A more effective method still would be to perform an out-of-sample analysis for the trading rules, however this data was not available at the time of research.

Splitting the results from the trading strategies by company characteristics does pose a possibility for data snooping: as no inferences about company industry, location (other than all companies being in the U.S. or Canada) or size are made for the asset pricing test, comparing these ex-post and performing hypothesis tests is subject to data snooping. If performing any test of this nature, the desired p-value should be corrected for this.

3.4.4 Liquidity

As mentioned in Peyer and Vermaelen (2009) and Loughran and Ritter (1995) the repurchase and issue effects are concentrated in small cap stocks. Criticism has arisen from this, notably in Fama (1998), who states that it is a well-known observation in the FF 3-factor model that small growth stock have positive alpha. This seems like a circular reasoning, but the observation is nonetheless important for trading. Given that many repurchases and issues are likely to occur in small stocks, trading may be risky due to liquidity issues. Should this occur it would be useful to include daily trading volume to assess if the closing price used in testing is a realistic estimate for the selling price. Alternatively, recorded bid/ask quotes can be used.

4 Data

To apply the methods described in the section above, a large amount of data is required. This research considers only issues and repurchases from North America (being the U.S. and Canada).

In order to test for the anomaly, Equation 3.2 will need to be filled. For this, the pricing series for all issuing or repurchasing equities on a daily basis is required. The specific procedure for acquiring the returns is to acquire a list of CUSIP codes for issuing or repurchasing firms through SDC Platinum and retrieving their pricing series by means of the S&P Capital IQ database.

The Fama-French factors for North America can be retrieved from Kenneth French's website.

For determining the trading rules, volume, high prices and low prices are necessary for the same dates as before. The Arbitrage testing framework does not require additional data.

Before data cleaning, the data set includes 77,815 issuing companies and 32,093 repurchasing companies.

4.1 Data Cleaning and Parameters

The aim of this paper was to research the effect of CACS on short-term equity returns. This is to be achieved using an (adapted) asset pricing model. This already imposes certain data requirements:

- In order for the prices to be accurate but also to reflect innovations due to new information (such as an issue or repurchase), the considered assets must be traded publicly, on the exchange. "Over the counter" (OTC) equity cannot reasonably be included for several reasons. First, a repurchase is unlikely for OTC traded assets and will not follow the same mechanics as an open market repurchase. Second, equity issues for OTC assets are most likely of small size (not only are OTC assets typically smaller size than exchange-traded, but if a company wants to issue a large percentage of their market capital they are more likely to do so on the open market to increase liquidity), skewing results towards this characteristic. Thirdly, OTC market prices tend to remain very similar for lengthy amounts of time due to long-term holders and poor liquidity. This makes prices a poor proxy for value.

- Funds of all kinds (open-end, closed-end, Trusts and REIT) are removed from the data set. Although funds pay dividends and are publicly traded in some cases, the connotation of 'repurchases' and 'issues' is severely different than that of regular companies. Although this effect is not uninteresting, it is not the focus of this research and is thus omitted.

- Convertible equity, debt and all other non-common equity issues are removed. These can be (primarily) classified as debt issuance and are unlikely to have the same effect as (standard) equity issues. Similarly, issuing non-standard equity (such as non-voting shares, beneficial shares, units) is often done in a non-standard situation, where additional information is (much) more relevant to the share price than the issue itself. These issues are an interesting field for further investigation, however it is not the focus of this research.

- Initial Public Offerings (IPOs) are removed. Although IPOs could be subjected to the same short-term analysis this research offers, it is not the focus of this research. For further reading on this topic, see the work in Aggarwal and Rivoli, 1990, which finds that equity is typically subjected to positive overreaction, or 'fads', after its IPO.

- Firms with incredibly high share prices (20,000$ and up) are removed as these are likely OTC or other placeholder values for what are essentially private companies exchanging small amounts of shares between founders or suppliers of initial financing. Firms with very low share price (1$ and below) are similarly removed due to estimation issues.

- Duplicate observations are removed. These only occur in the issues data set, and it is in fact not impossible for a company to have two issues on one day. However, these are usually distinct only in the type of shares issued (voting/non-voting/preferential) and as such ought to be considered as a single issue.

- Observations with missing data are removed.

These rules yield the appropriate data set of companies that announced a repurchase or had a share issue take effect between Jan 1st 1985 and Dec 31st 2015. The last part of this sample (Dec 14th through Dec 31st) is removed for lack of Fama-French data.

4.2 Data Description and Summary Analysis

The data is organized in two main sets: the issues and repurchases data and the market data. The former set contains the date of occurrence, six-digit CUSIP, Nation and

Macro Sector for all observations. For the issues it furthermore includes (if reported) deal type, proceeds from issue, total shares offered, type of security and issue description. For the repurchases it furthermore includes (if reported) percentage of shares acquired, equity value at announcement, value of transaction, price per share, share price 1 day, 1 week and 1 month prior to announcement, book value per share, equity value per share, offer price to EPS ratio and purpose description.

The purpose for repurchase may be an interesting variable to consider, however it is quite incomplete. Especially for earlier repurchases, reported purpose was not recorded in the database. Those purposes that are recorded are categorized in the following categories: Acquire competitor's technology, Concentrate on core business activity, Create synergies, Dispose of surplus cash, Expand presence, General strategy, Increase shareholder value, Offset dilution and Other. Interestingly, these seem to be homogenized across the M&A database, hence the odd purposes such as 'Create synergies' and 'Expand presence'. It should be noted that 'General strategy' and 'Increase shareholder value' are in the vast majority of purposes.

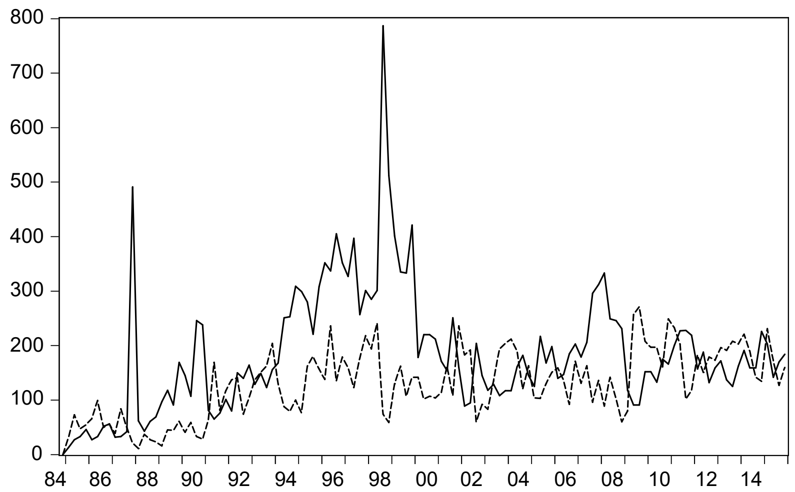

Fig. 4.1 Number of issues (dashed) and repurchases (solid), grouped by quarter

	Issues	Repurchases
No. Of Observations	15,709	23,429
Avg Amt of Shares Offered (m)	26.39	332
Avg Proceeds ($m)	139.5	-
Avg EPS	-	0.744

Table 4.1 Summary Statistics for Issues and Repurchases in the full sample

Figure 4.1 shows a graph of the number of CACS events over the considered sample. It can be seen that there is no clear trend on the data, which is useful for statistical inference. The internet bubble shows an increase in both repurchases and issues (though more so in repurchases) and the run-up to the financial crisis shows a negative impact on repurchases and a positive impact on issues, which recovers to normal levels late 2009.

Table 4.1 shows some summary statistics for the issues and repurchases data. Note that not all statistics can be compared due to the data available for the two groups. It may seem like a strange disparity between the two groups when comparing to the initial numbers: for issues, over 60,000 observations are removed, whereas for repurchases only about 10,000 observations are trimmed. Upon closer inspection, this is not strange: OTC companies, Convertible Equity and Debt, and IPOs are all removed types unique to issues. The incredibly high share price-rule is also exclusive to issues.

Interesting to note is the difference in shares offered: although this is somewhat contentious since the share price is not included, the average should be representative enough. It shows that issues are, on average, smaller than $1/10^{\text{th}}$ the size of repurchases. This is not strange when considering the average proceeds: 140m$ on average for issues is not a huge amount, especially considering that large companies have been using repurchases more as an alternative to dividend in recent years (increasing the average repurchase size). Yet, repurchases have many more observations. This is possibly an effect already described in the Literature section: the market has a distaste for issues and an appetite for repurchases, which causes larger companies that aim to please their investors to avoid issues and repurchase more.

Thus, the dataset may suffer from size bias. In Fama (1998) it is already suggested that the issue/repurchase anomaly is possibly the same as the anomaly they noted for small growth stocks. However, since the Fama-French 3 and 5 factor models are applied, this anomaly should be accounted for. Furthermore, the short-term perspective of this research is not so susceptible to this size bias: it is unlikely that systematic abnormal returns manifest within 12 trading days. That said, an abnormal return that is consistently different from zero may be cause to investigate this imbalance in size further.

Since the motivation for the Calendar Time approach is to tackle correlation in real time, it makes sense to include a summary analysis of how often issues and repurchases go effective or are announced on the same date. To this end, Figure 4.2 is included. In it, it is clear to see that the majority of issues and buybacks occur on unique dates or with at most two other companies. However, larger values are observed for both series, with maxima at 23 (for issues) and a stunning 79 (for repurchases).

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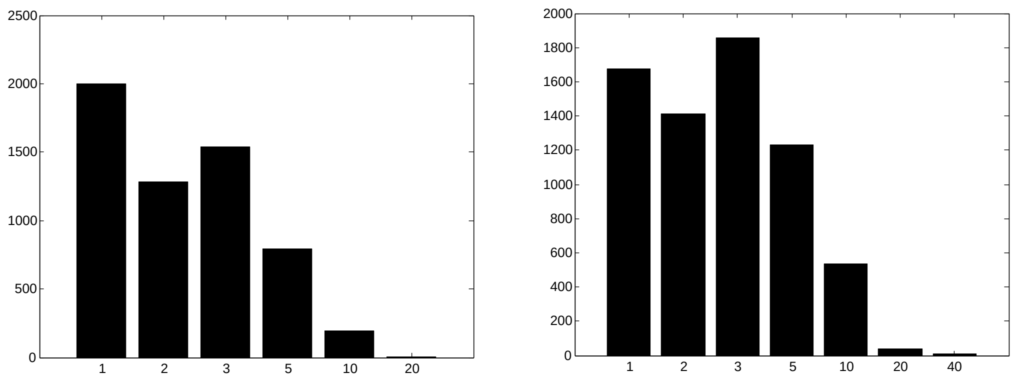


(a) Issues **(b)** Repurchases

Fig. 4.2 Histogram depicting occurrences of same-day issues or repurchases. The x-label shows the amount of companies on the same day (1 being a unique date).

5 Results

In this section the results for the employed models and tests will be presented.

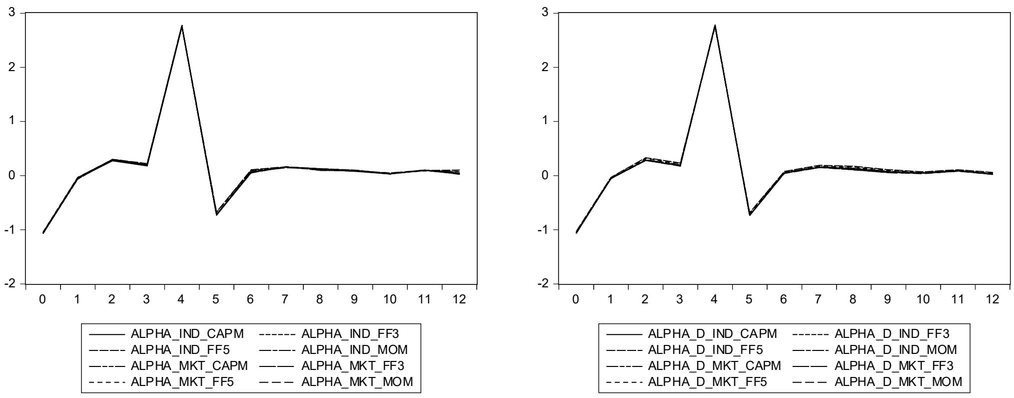
5.1 Anomaly

Applying the different Asset Pricing techniques described in the Methodology section yields several sets of results. The conventional asset pricing approach and the RATS approach are compared side-by-side, while the full sample and moving window results are split. Lastly, the calendar time approach results is presented.

5.1.1 Full Sample

Issues

Figure 5.6 shows the alpha coefficient estimates. It can be clearly seen that the conventional and RATS approach differ very little in results, as do the different Asset pricing models. Furthermore, most alpha results are centered around 0, indicating no systematic anomaly. However, a distinctive pattern also emerges, showing positive results from the second through fourth close, where the last observation shows a spike of nearly three percent abnormal positive return. The event date (observation 0) shows an expected negative return.



(a) Conventional **(b)** RATS

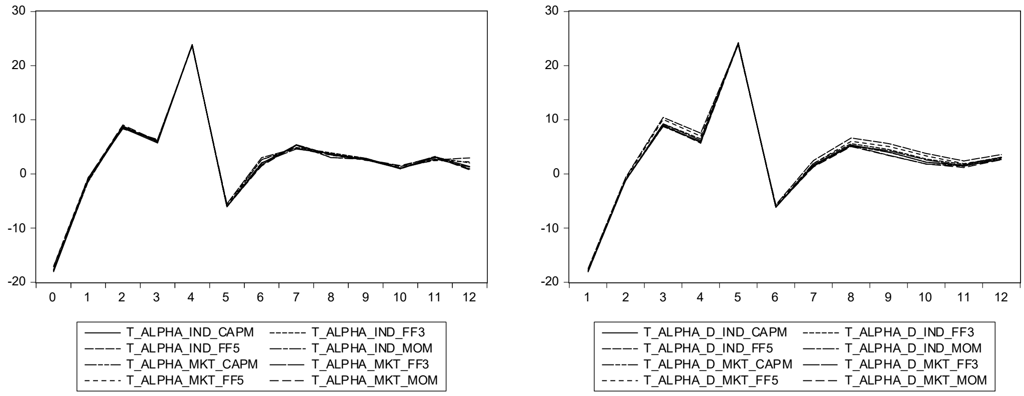
Fig. 5.1 Alpha coefficient estimates for all different asset pricing models and all periods after effective issue date. The x-axis denotes time after the effective date, the y-axis denotes the estimate of alpha in percentages. See Equations 3.2 and 3.1 for the specifications.

The small difference in different asset pricing models is not unexpected for the RATS methodology: the RATS methodology assumes that the risk factor exposure in event time is more influential than the asset-specific risk exposure. Although the exposure to market risk may very well function this way (as is suggested in Ibbotson (1975)), the interaction for other risk factors has not seen extensive research. It is possible that the event time assumption is invalid for factors other than market risk, in which case the factor exposure ought to be zero, since there is no relation between the event and the risk factor exposure. This would make the extensions in the Fama-French models and the Momentum model offer no extra information, and hence the results should be the same for all asset pricing models considered.

The t-statistic values are depicted in Figure 5.2. Here, the difference between the conventional method and the RATS methodology is also not obvious. Both the conventional and RATS approach shows almost all observations to be statistically different from zero. The same risk factor exposure reasoning can be applied here, which would suggest the RATS methodology t-scores should be close together for all asset pricing models. However, this is not the case: t-scores between asset pricing models are much more diverse than for the conventional model. This suggests that event-dependency in risk factor exposure is, in fact, correct. Due to the large number of observations (15.709 for issues, 23.429 for repurchases) the critical value for the t-statistic is the well-known 1.96.

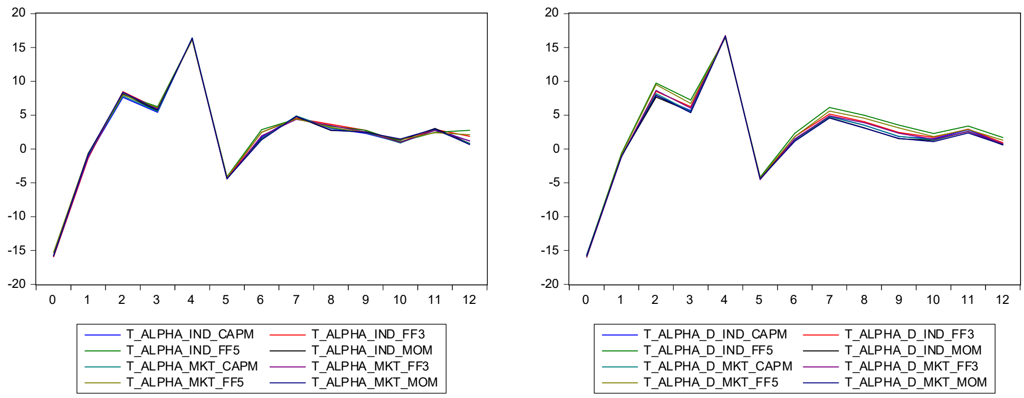
A point of interest is the excessively high t-scores obtained for the most interesting periods as discussed above. Absolute values of 20 are achieved. This is not entirely unexpected. As recently as the overview in Evgeniou et al., 2016, similar values are found for pre-event holding returns. However, there are some differences. The cited research focuses on issue announcements rather than effective dates, as well as taking a long-term approach. This long-term approach begins post-event returns six days after announcement date, and for this (and later) periods it finds no significant returns. These differences correspond to the results found here, as a constant, insignificant return is visible after the sixth return. The fact that announcement dates are used is not insignificant, however a short discussion has been given in the Introduction section on this topic.

Also included are the t-statistics for Newey-West adjusted standard errors. This due to the possibility of cross-correlation in events, as it was shown in the Data section that many events are not on a unique date. It can be clearly seen that this adjustment does not offer a different conclusion from the traditional standard errors, however the peak scores are more mitigated. This does suggest that cross-correlation is an issue within the model, but not to such an extent as to change the interpretation of the results.



(a) Conventional **(b)** RATS

Fig. 5.2 t-statistic values for the RATS model for all different asset pricing models and all periods after effective issue date. The x-axis denotes time period after the effective date, the y-axis denotes the t-score. See Equations 3.2 and 3.1 for the specifications.



(a) Conventional **(b)** RATS

Fig. 5.3 t-statistic values for the RATS model for all different asset pricing models and all periods after effective issue date. The x-axis denotes time period after the effective date, the y-axis denotes the t-score. See Equations 3.2 and 3.1 for the specifications.

These results are consistent with the short-term views expressed in the Literature section. The initial reaction is negative, due to the decrease in EPS and other per-share based metrics. This effect is continued for a second day with negative returns. A recuperation of stock price occurs in the fifth return after the effective date, which can be characterized as a market correction to earlier pessimism. It was already noted in many theoretical papers (such as Asquith and Mullins Jr (1986)) that a stock issue is not an inherently negative action: in fact, if the board of a company discovers a profitable investment but lacks the liquidity to pursue it, raising capital is the correct action.

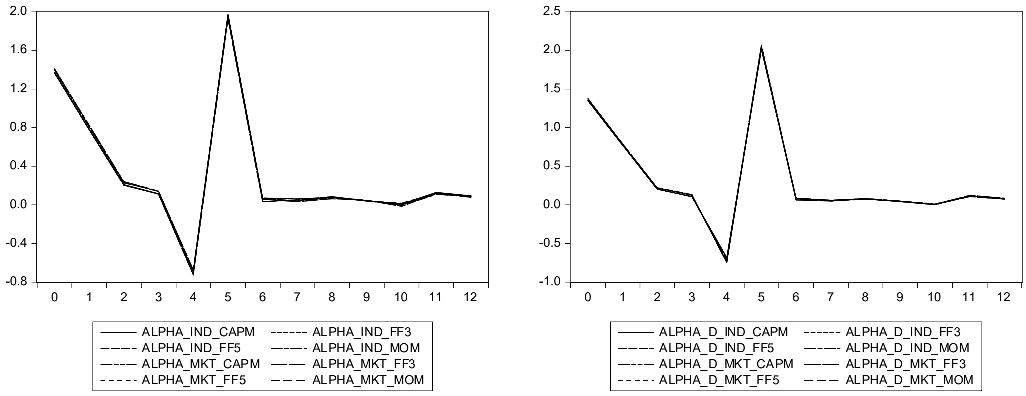
This market reaction is in line with the first and third categorizations given in the behavioral finance overview of Baker and Wurgler (2011): if an issue is the correct action given the fundamental value of the company and the market conditions, long-term investors are more likely to have a positive reaction (as they will reap the benefits of the issue) whilst short-term investors are less pleased (as they will not reap those benefits). It is then sensible that an immediate negative reaction is followed with a positive reaction from long-term traders who sense opportunity in the decreased stock price. However, even in Baker and Wurgler (2011), the theoretical perspective is not one-sided: in the second categorization of that second paper it is stated that CACS are (primarily) a tool to cater to short-term investors, which an issue clearly does not. Yet, in general, these results are in line with both classical as well as behavioral corporate finance literature.

Repurchases

Figure 5.4 shows a similar effect to the issues. The positive sentiment of the announcement day tapers off after three days' worth of returns. A negative spike precedes a large positive spike in the fifth closing auction. Later periods show no structural anomaly. Again there is little to no difference between the conventional and RATS approach nor between any of the asset pricing models.

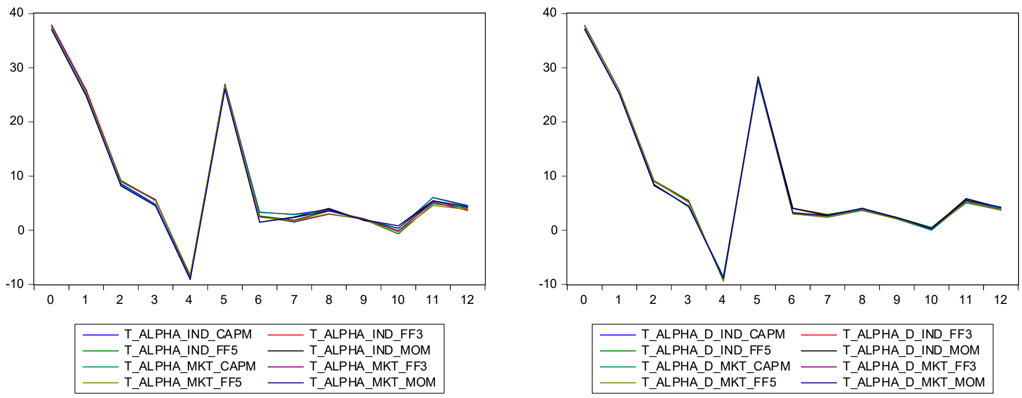
For the t-scores a different structure to the issues is found. Although the absolute t-scores are similar for both models, the disparity between asset pricing models here is closer for the RATS method, implying that event-dependent risk factor exposure is not at hand. Although this does agree with the alpha coefficient estimates, it is notable that this conclusion differs between issues and repurchases. Furthermore, for both approaches many returns are significant, with only the tenth return being insignificant. This suggests that a buy-and-hold strategy for the entire considered period may be profitable.

t-scores are of a large absolute magnitude, and again these results are not too distant from recent literature Evgeniou et al. (2016). The differences in t-score between



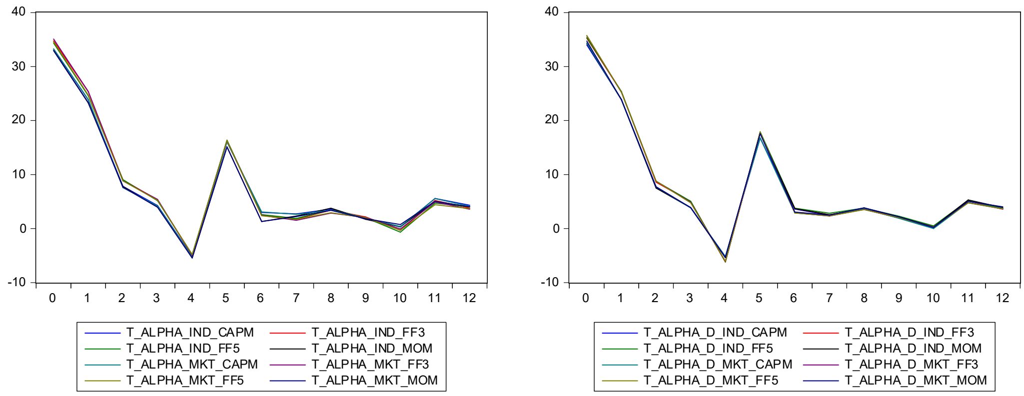
(a) Conventional **(b)** RATS

Fig. 5.4 Alpha coefficient estimates for all different asset pricing models and all periods after repurchase announcement date. The x-axis denotes time after the announcement date, the y-axis denotes the estimate of alpha in percentages. See Equations 3.2 and 3.1 for the specifications.



(a) Conventional **(b)** RATS

Fig. 5.5 t-statistic values for the conventional and RATS model for all different asset pricing models and all periods after repurchase announcement date. The x-axis denotes time period after the announcement date, the y-axis denotes the t-score. See Equations 3.2 and 3.1 for the specifications.



(a) Conventional

(b) RATS

Fig. 5.6 *t*-statistic values for the RATS model for all different asset pricing models and all periods after repurchase announcement date. The x-axis denotes time period after the effective date, the y-axis denotes the *t*-score. See Equations 3.2 and 3.1 for the specifications.

this paper and the cited paper are smaller as in both cases the announcement date for the repurchase is considered, whereas for issues different definitions of event date are applied (effective versus announcement). As the research is more similar, so are the results. The magnitude is not the same (Evgeniou et al. (2016) sees absolute values ranging up to 16 post-event) but this is not completely unexpected due to the longer term approach.

Similarly to the issues, applying the Newey-West standard errors does impact the *t*-scores of the post-event spikes, but not to such a degree that these become insignificant or would change their interpretation.

The results from repurchases are not as easily interpreted. The first two returns are consistent with behavioral corporate finance theory: repurchases can take advantage of a mismatch of share price and fundamental value, placating investors and sending share prices higher. Signaling theory would also suggest the same reaction: repurchases are very costly for “bad” types, as the liquidity required for repurchasing the shares is likely not available. However, the large spike in the fifth asset return is not consistent with these theories. General market efficiency dictates that positive news or signals should be incorporated in the share price instantly.

It is possible that the theory on repurchases is too pessimistic, where the market takes a more positive view. The work in Fama and French (2016) shows that the Net Stock Issues factor is absorbed into positive exposure to the CMA and RMW factors, signifying profitable, conservatively investing companies. Although the Net Stock Issues factor is not directly the factor under research here, the result may give a suggestion of the mechanism at work: if a repurchase is announced by a robust, conservatively investing company, liquidity may not have significant influence. Moreover, diminishing investment prospects can also be a sign of maturity in the corporation, owing to a more conservative investment strategy. In this case, repurchases can be viewed as an alternative to dividends (shielding the company's investors from dividend tax) which is a defensive investment strategy.

An alternative view is suggested in Peyer and Vermaelen (2009). Surveys show that 90% of CFOs agree or strongly agree that they repurchase stock at undervalued prices, which would suggest that the positive reaction is a market correction to this 'insider' knowledge. The paper shows results that this pattern emerges over the long term, which is dubbed the "underreaction" hypothesis. Although the theory is interesting, it is not supported by the work of Ben-Rephael et al. (2013) who shows that firms typically repurchase stock at peak prices. Furthermore, the reaction observed in these results is a short term positive spike return, indicating overreaction rather than underreaction. Still, it may be a validation of signaling theory: if repurchases are rational at market price, management should believe that price will rise due to some future event or information. This is essentially an application of the theory in Spence (1973).

Making a conclusive statement about the repurchase results is, then, not as straightforward: theory dictates that the large movies observed at the fourth and fifth close post-event should not systematically exist nor be positive, yet the results show they do. Several reasons why the market may give a positive correction are given above, however none specifically state a timing delay, such that a fully efficient market should price in all the information instantly anyway. The biggest conclusions to be drawn from these results is, then, that the popular theory on repurchases does not agree with the market reaction. Furthermore, the results for both issues and repurchases show no market efficiency surrounding CACS event dates.

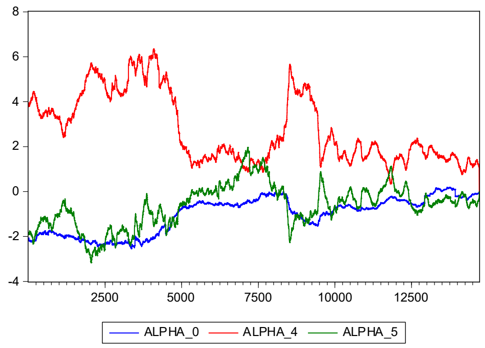
5.1.2 Moving Window

Issues

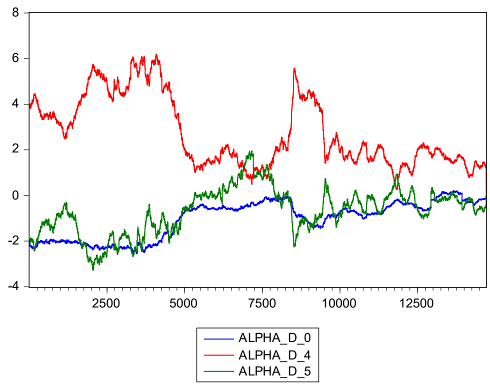
To improve readability, only the most remarkable results are included. Please see Figures A.1 and A.2 in the Appendix for the full results.

The moving window graph in Figure 5.7 shows a similar structure to the full sample results: the fifth return is (highly) positive across the moving window samples, while the sixth return is consistently negative. The event day return shows an expected negative impact. The estimates are all significant for the majority of the sample, but both the coefficient estimates and the t-scores are much closer to zero near the end of the sample. This may indicate an increase in market efficiency over the last few years. If this is the case, the trading strategies may perform (relatively) more poorly towards the end of the sample. This does not have to hold due to the varying investment size employed by the trading rules.

The omitted results do not show stable patterns in level or significance.

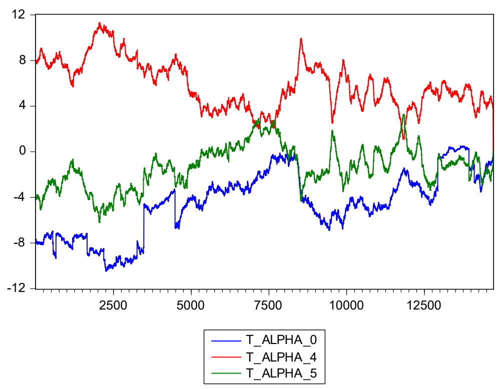


(a) Conventional

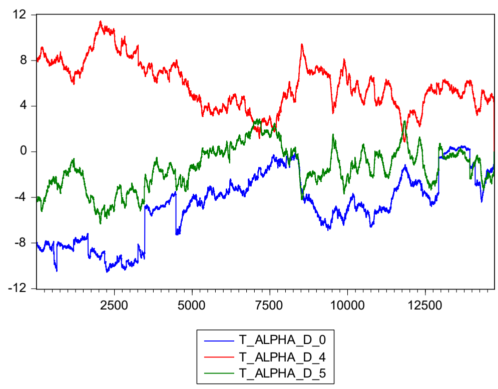


(b) RATS

Fig. 5.7 Alpha coefficient estimates for all periods following issue effective date over the 1000-stock moving window for the CAPM model specification. The x-axis denotes the index of the first included issue. See Equations 3.2 and 3.1 for the specifications.



(a) Conventional



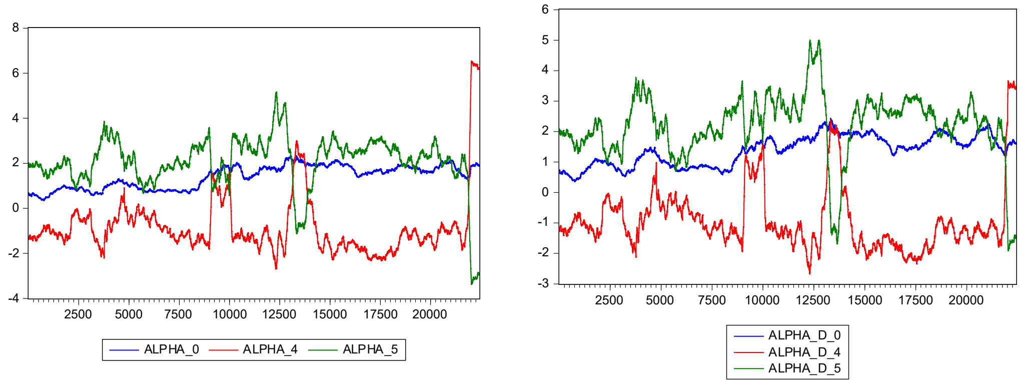
(b) RATS

Fig. 5.8 t-statistic values for the conventional and RATS model for all periods following issue effective date over the 1000-stock moving window for the CAPM model specification. The x-axis denotes the index of the first included issue. See Equations 3.2 and 3.1 for the specifications.

Repurchases

Again only the most interesting results are shown. Please see Figures A.3 and A.4 in the Appendix for the complete results.

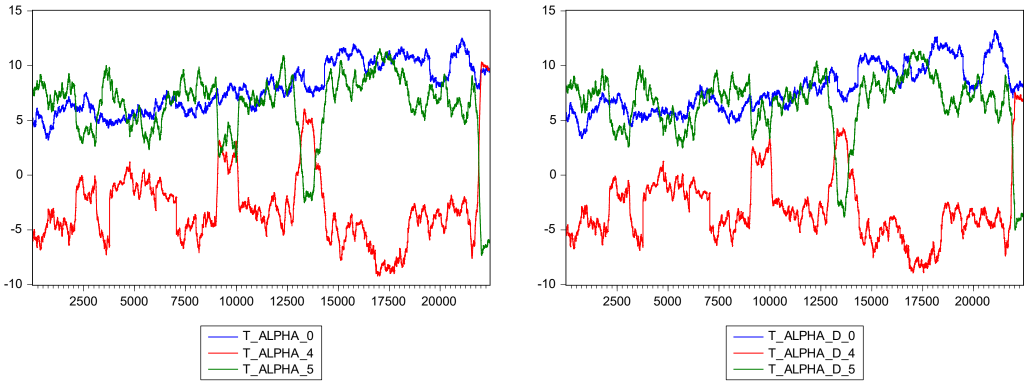
For the repurchases we again find similar results to the full sample. Figure 5.9 shows (large) positive results for the sixth return, negative returns for the fifth return



(a) Conventional

(b) RATS

Fig. 5.9 Alpha coefficient estimates for all periods following repurchase announcement date over the 1000-stock moving window for the CAPM model specification. The x-axis denotes the index of the first included repurchase. See Equations 3.2 and 3.1 for the specifications.



(a) Conventional

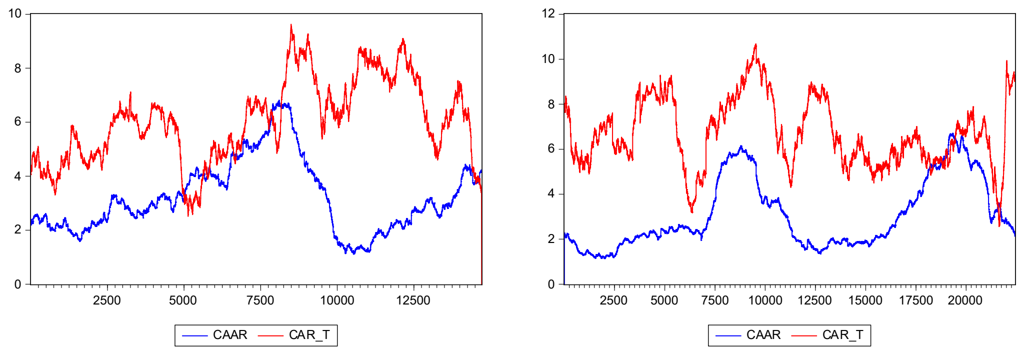
(b) RATS

Fig. 5.10 t-statistic values for the conventional and RATS model for all periods following repurchase announcement date over the 1000-stock moving window for the CAPM model specification. The x-axis denotes the index of the first included repurchase. See Equations 3.2 and 3.1 for the specifications.

and (small) positive returns for the first return. Similarly to the issues, the t-scores in Figure 5.10 show mostly significant results for these returns but strongly varying scores for all other periods. The estimates for these other periods are still centered at zero, such that the varying significance is not hugely important. Unlike the issues, neither the alpha coefficient estimates nor the t-scores are nearer to zero at the end of the moving window estimates. In fact, for the last few samples the estimate of the fifth and sixth return spike, perhaps indicating a recent change in perspective on repurchases. The t-scores do not reflect the same behavior, although these spiked estimates are significantly different from zero.

Again, the omitted results do not show stable patterns in level or significance.

5.1.3 Cumulative Abnormal Return



(a) Issues **(b)** Repurchases

Fig. 5.11 CAAR coefficient estimates and t statistics. See Equations 3.3 and 3.4 for the specifications.

Figure 5.11 shows the Cumulative Average Abnormal Return for the moving window estimates, as well as the t-statistics. As stated in the Methodology section, this is essentially the average (over stocks) of the sum (over time) of abnormal returns. It gives a good indication of the overall effect of a CACS event, in contrast to the overall asset pricing model which shows the impact per day after the event. The CAAR metrics range from two to six percent, with clear trends in the data. This suggests that the anomaly is not stable over time, both for issues and repurchases.

For issues, the abnormal return is increasing up until the 8500$^{\text{th}}$ observation window, which corresponds to the 2004-2005 period. It is not exactly clear what caused this, but it is still interesting to compare this to the results of the trading strategy. The CAAR for repurchases is equally unclear: it is stable around 2% until the 7500$^{\text{th}}$ observation window, around 1996-1997, where it jumps to almost 6%. It declines again around the 10000$^{\text{th}}$ window, corresponding to 1998-1999, down to 2%. This pattern is repeated starting around the 17500$^{\text{th}}$ observation window, late 2007-early 2008, and declines again around the 20000$^{\text{th}}$ observation window, 2010-2011. Again the reasoning is not exactly clear: the first jump may be connected to the internet bubble, but it declines before the bubble bursts. Similarly, the gain just before the banking crisis is quite odd. In any case, it is clear that these results are also not stable over time, but in the case of issues and repurchases, it is highly positive across the sample.

The graph also shows significant results for all CAR estimates. Although the t-score is quite volatile for both issues and repurchases, it appears to trend over a constant mean. This does give credence to the overall existence of an anomaly surrounding CACS events. Moreover, as shown in Brown and Warner (1985), this test has low power. This reinforces the likelihood of achieving profitable results in the trading strategy, as well as confirm the results from our asset pricing models.

5.1.4 Calendar Time

The Calendar Time approach may also show a better overview of the abnormal effect, as well as give a possible suggestion for the trading strategy. The full-sample results can be viewed in Tables 5.1 for issues and 5.2 for repurchases. As the Calendar Time portfolio is a portfolio of stocks, its performance can be measured by a conventional asset pricing model approach, as is done here. For estimation, a Feasible Generalized Least Squares method is applied, with an estimate for volatility for each period and selection of stocks.

Issues

Variable\APM	**CAPM**	**FF3**	**FF5**	**MOM**
$\boldsymbol{\alpha}$	0.1565	0.1622	0.1718	0.1497
$\boldsymbol{t}$**-score**	7.909	8.369	8.863	7.558
$\boldsymbol{\beta}$	0.7225	0.7945	0.7513	0.7182
$\boldsymbol{\mu}$	0.2035	0.2035	0.2035	0.2035
Residual $\boldsymbol{\sigma}$	2.632	2.591	2.586	2.629
Unweighted Adj $\boldsymbol{R^2}$	0.1149	0.1421	0.1458	0.1166
Weighted Adj $\boldsymbol{R^2}$	0.1368	0.1732	0.178	0.1392

Table 5.1 Full-sample results for the Calendar Time portfolio for effective issues. See the Methodology section for the specification of the portfolio.

Table 5.1 shows a significant, positive alpha coefficient for the two-week holding period portfolio of approximately 15 basis points. This reinforces the existence of a CACS anomaly. Furthermore, the Adjusted R^2 statistics show an increase when using the FGLS procedure with a 100-observation window for estimating standard deviation. The choice of asset pricing model seems to have more influence than in the cross-sectional approaches, however the differences are within five basis points of one another, which is not a noticeable difference on the asset pricing graphs shown before.

Interestingly, the Fama-French five-factor asset pricing model attributes more weight to the alpha coefficient than any other asset pricing model. This is somewhat curious as it is claimed in Fama and French (2016) that this model should do away with the net stock issues factor (and thus the CACS anomaly). Considering these results, the suggested difference between the NSI factor and CACS event dates in this paper and Evgeniou et al. (2016) appears confirmed.

The contrast to the Moving Window results is not entirely unexpected: the CAR results take first the cumulative over all periods, such that the large spikes seen in the full-sample asset pricing models dominate the final result, whereas in the Calendar Time portfolio, this is merely one observation in the selection of stocks it holds.

Repurchases

Variable\APM	CAPM	FF3	FF5	MOM
α	0.3634	0.3633	0.3624	0.3636
t-score	26.75	26.74	26.63	26.73
β	0.0141	0.0157	0.0222	0.0141
μ	0.4098	0.4098	0.4098	0.4098
Residual σ	1.513	1.513	1.513	1.513
Unweighted Adj R^2	-0.0008	-0.0006	-0.0003	-0.0008
Weighted Adj R^2	0	0	0.0002	-0.0001

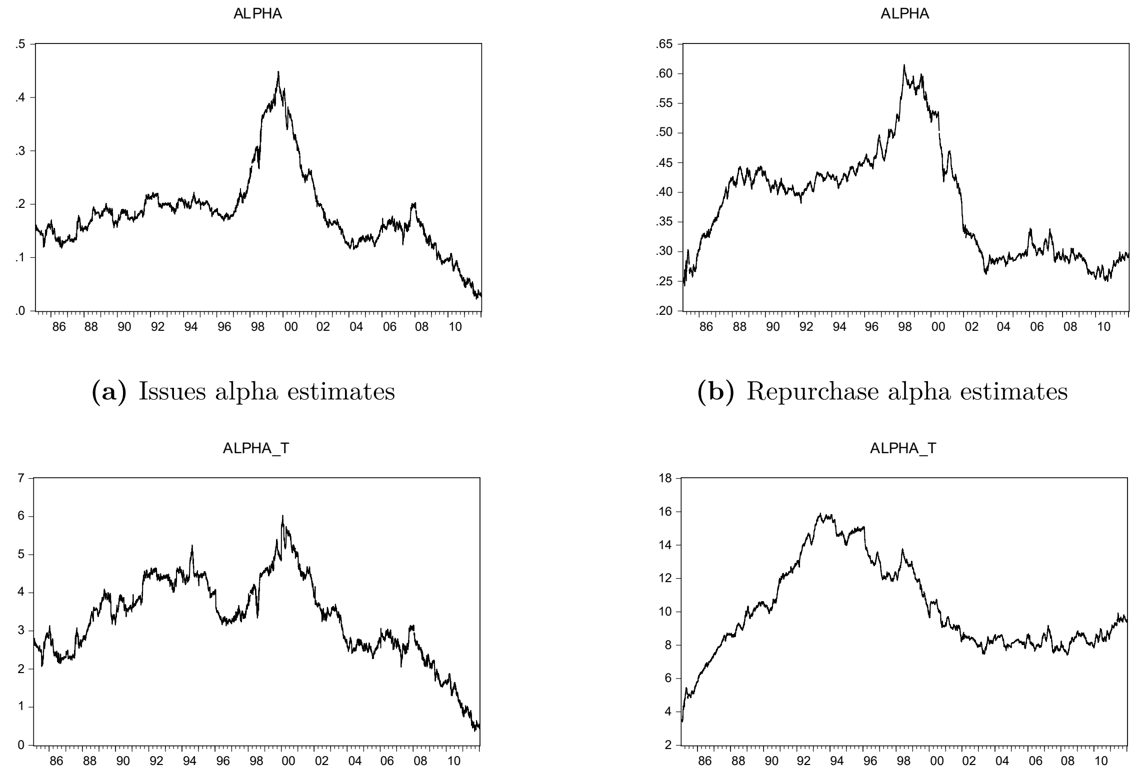
Table 5.2 Full-sample results for the Calendar Time portfolio for repurchase announcements. See the Methodology section for the specification of the portfolio.

For repurchases we find the results in Table 5.2 and see a similar pattern: significant, positive abnormal returns are recorded for all asset pricing models, confirming the CACS anomaly. The outperformance for repurchases is about 36 basis points over 12 trading days. In contrast to the issues, we find much higher t-scores but much lower adjusted R^2 scores. However, they too increase across the board by using the WLS approach.

The observed increase in alpha for the Fama-French five-factor model is not present here, however the difference between the asset pricing models is also smaller than for issues.

Moving Window

Of course, the Calendar Time portfolio can also be modeled in a moving window approach, to check the stability of coefficient estimates. These results are reported in Figure 5.12.



(a) Issues alpha estimates

(b) Repurchase alpha estimates

(c) Issues alpha t-scores

(d) Repurchases alpha t-scores

Fig. 5.12 Calendar Time portfolio moving window results. See Equations 3.1 and 3.2 for the specifications.

Figure 5.12 shows several interesting patterns. Neither alpha estimate series remains at a constant level. The issues estimates are relatively similar, except for the large spike between 1998 and 2004. This is quite a sizable gap. Since the repurchase estimates are much more volatile, a lack of robustness is evident. The t-scores show that the standard error is quite low in the period 1988 through 1996 which may imply a stable abnormal return at that time, however as the graph shows the increase in estimate is much larger than the increase in t-score, implying standard error has increased with the estimate. Another relevant observation is the decline towards zero of the alpha estimate at the very end of the moving window, signaling that the market may be becoming aware of the anomaly and pricing it in.

Constant estimates are not achieved in the repurchase estimates either. The estimates feature a clear spike from 1996 through 2002 and settle on a new, more stable level afterwards. This does show a currently consistent level of about 25 basis points abnormal return.

It should be noted that although these estimates are generated through an FGLS procedure which accounts for changes in standard deviation, this metric has not been calculated through the amount of stocks in the portfolio (i.e., risk mitigation through diversification is only implicitly included). As such, the instability could be caused by an unbalanced amount of events over time. This turns out not to be the case. Figure A.5 in the Appendix shows the amount of stocks in the portfolio for every date and it is on a relatively constant level.

The Calendar Time approach was suggested both by Ibbotson, 1975 and Fama, 1998 as a way to reduce misspecification of cross-correlation effects that can occur if events are clustered in time. In the case of Fama, 1998 this was specifically used as a defense for market efficiency (and thus a criticism of the found anomalies). Ironically, this method seems to yield more significant results than the individual asset pricing tests on the short term, thereby confirming the anomaly rather than dispel it. It is worthwhile to notice that the generalized nature of the Calendar Time approach combined with the strong results implies that the asset pricing models for individual days may give a limited representation of the possible returns: the BHAR used in previous research may not be appropriate for determining anomaly specifics but it may be more appropriate for determining possible statistical arbitrage trading strategies.

Given these results it should be possible to make a profitable trading strategy by simply holding event stocks from a day after the event. This should be most profitable for repurchases, although issues should also yield results.

5.2 Trading Rules

Given the results from the Asset Pricing Models we can define three strategies that ought to show the best results:

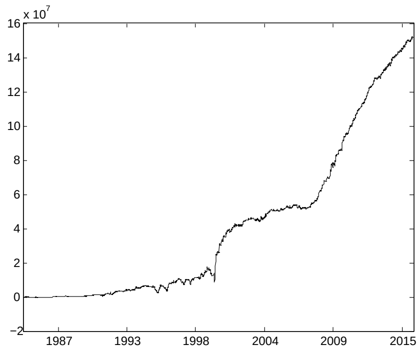
- Taking a long position in issuing companies at the second close after effective date and closing the position at the fourth close
- Taking a long position in repurchasing companies at the first close after announcement date and closing the position at the third close
- Taking a long position in repurchasing companies at the fourth close after announcement date and closing the position at the fifth close

In line with the Calendar Time results, the two-week buy-and-hold portfolio will also be tested for both issues and repurchases.

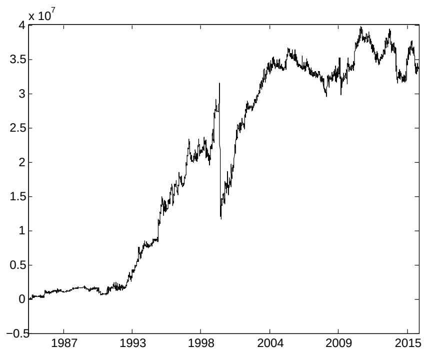
These are of course very simplistic strategies. In real-life applications, much more sophisticated data manipulation is included, such as intraday drift, spread modeling and price pushing mechanisms. However, the data required to backtest such strategies are unavailable to the research. Furthermore, applying more and more detailed strategies just to find profitability would not be sound arbitrage testing. The details of the strategy parameters can be found in the Methodology section.

As such the simple strategies noted above should provide a good indicator of statistical arbitrage possibilities. The cumulative cash flow graphs are included to give an overview of the profitability of the strategies. The strategies will be denoted as (abbreviations in brackets) 'Issues 2-4' (ISS 2-4), 'Issues full' (ISS full), 'Repurchases 1-3' (BB 1-3), 'Repurchases 4-5' (BB 4-5) and 'Repurchases full' (BB full) as per their holding period.

The graphs included in Figure 5.13 and 5.14 show the non-discounted, dollar-denominated, cumulative trading profits. That is, the final data point in the graph is the total profit or loss after the full sample period. The specifics for calculating the profits are outlined in the Methodology section, however it is worth to note that investment is dependent on the current CACS events. That is, the total amount of investment is not constant and is assumed to have no ceiling.



(a) Issues 2-4

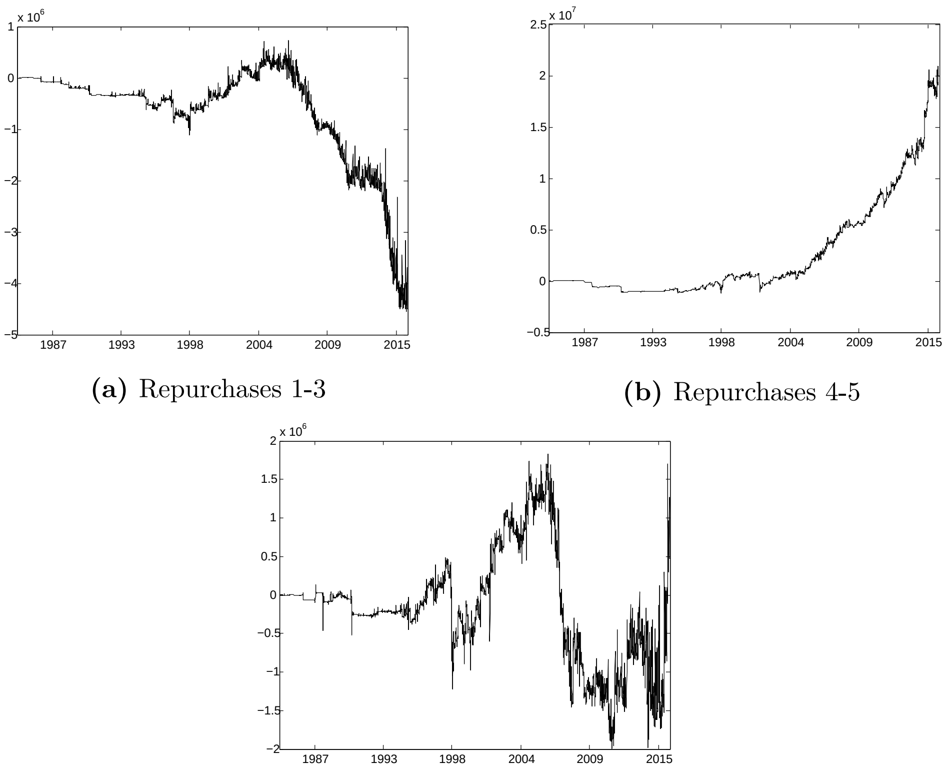


(b) Issues full

Fig. 5.13 Cumulative, non-discounted trading profit (loss) for issue strategies. See the Methodology section for the specifications.

The issues strategies show interesting results. Following the '2-4' strategy yields a total positive return of around 150m$, however this is concentrated in the latter half of the observation sample. As was shown in the Data section, the amount of issues is relatively stable over the whole sample, such that the anomaly seems to be more profitable over the latter half of the sample. This provides interesting contrast to the anomaly section, where the end of the sample showed a lower estimate for abnormal returns.

The complete buy-and-hold strategy shows overall positive results as well, however it is less stable. Upon closer inspection a change in trend is observed past 2004, and the total return in the 2004-2015 period is approximately zero. This is almost exactly opposed to the '1-4' strategy results. This indicates that the market may indeed have become more efficient: although returns are mostly similar for the period up to 1999, the 2-4 strategy is much more successful afterwards. It is possible that in this period (where financial technology has become more prevalent), prices adjust faster and the timing found in the anomaly section is more exact.



(a) Repurchases 1-3

(b) Repurchases 4-5

(c) Repurchases full

Fig. 5.14 Cumulative, non-discounted trading profit (loss) for repurchase strategies. See the Methodology section for the specifications.

The repurchase strategies are less stable. Profitable results are attained for the '4-5' and full strategies, although the full strategy seems to have a negative mean. The '1-3' strategy is flat for most of the sample, however around 2006 it starts to trend downward until the end of the sample. This may be an artefact of the same increase in timing efficiency seen in the issues trading results: the '1-3' strategy is defined on the enthusiasm of the repurchase which may nowadays be priced in on the event date itself.

The profitable '4-5' strategy shows a similar pattern to the '2-4' strategy from the issues section: the returns are mostly flat over the first half and increasing over the second half. Again, repurchases are mostly evenly distributed over the sample and investment is also not dependent on earlier return. However, the anomaly results for repurchases did not suggest an increase in efficiency towards the end of the sample, in fact, there were large increases at the very end. This may explain the trading results, but the increase is only observed for the very last observations, while the strategy is profitable for the entire second half of the sample.

5.2.1 Risk Analysis

Besides performance statistics, the (empirical) Value at Risk and Expected Shortfall statistics are calculated for every strategy based on total investment. These can be viewed in Table 5.3 Note that since the investment amount varies over time the VaR is calculated as a percentage of total investment.

	ISS 2-4	ISS full	BB 1-3	BB 4-5	BB full
95% 1-day VaR	1.425	1.889	2.070	2.054	3.215
95% 1-day ES	2.306	3.139	3.717	3.756	5.303
99% 1-day VaR	2.814	3.912	5.069	4.923	5.494
99% 1-day ES	3.904	5.38	5.292	5.804	8.955
Max Drawdown (Trading Profits)	8.60	19.8	5.28	0.087	3.82

Table 5.3 Empirical 1-day Value-at-Risk and Expected Shortfall percentages for all strategies. Drawdown in millions of dollars. See Equations 3.11 and 3.12

It is worth noting that almost all extreme returns are achieved in the first quarter of the observation sample (note this is not pictured in the presented graphs). However, as noted in the introduction, the market for repurchases and issues has grown in absolute size over the years. This is likely to increase total investment. Though Figures 5.13 and 5.14 show increasing jumps as well, the timing results in the returns imply that investment grows faster than trading profit.

Unsurprisingly, the VaR and ES estimates are relatively low, owing to the market risk hedging inherent in the strategy as well as the short time scale (one day). Large jumps are still possible, as is evident from the cash flow graph, but the general lack of volatility in cash flows is evident for most strategies. The most egregious exception here is the full repurchases strategy, which shows the highest estimates for all brackets except maximum drawdown. As discussed in the trading rules section, this strategy seems unfit for arbitrage, explaining the larger values for VaR and ES. The lack of drawdown owes to the more stable prices in repurchasing firms: all drawdown for repurchasing strategies are lower than for the issuing strategies. This may suggest that these strategies are less stable and will prove less suitable for arbitrage.

5.3 Arbitrage

Determining the arbitrage surrounding CACS events is done by means of the framework set out in the Methodology section. Hence, the Log-Likelihood equation specified in Equation 3.7 is maximized. An optimum can also be achieved by solving the system of equations given by Equation 3.8, 3.9 and 3.10. To put these results into perspective, some summary statistics for the series under investigation, $\Delta\upsilon$, are provided in Table 5.4. This vector is the difference vector of the cumulative, dollar-denominated trading profits discounted for riskfree rate (daily compounding).

	ISS 2-4	ISS full	BB 1-3	BB 4-5	BB full
Mean	13097	3264.6	-384.41	1654.8	38.56
Std dev	0.17	0.21	0.064	0.072	0.076
Max	2.7	2.2	1.1	1.1	1.1
Min	-1.1	-2.2	-1.1	-1.0	-1.0

Table 5.4 Summary statistics for the $\Delta\upsilon$ series per strategy. Standard deviation, maxima and minima in millions of dollars. See Equation 3.5 for the specification of the increments.

The summary statistics give an interesting overview of the profitability of each strategy, besides the already discussed graphs. The means are mostly positive, as only the clearly unprofitable 'BB 1-3' strategy has an estimated negative mean. The standard deviation is estimated at about \$200,000 for the issue strategies and \$70,000 for repurchase strategies. The maxima and minima are mostly mirrored for every strategy, except the 'ISS 2-4' strategy. This strategy shows highest profitability, yet all repurchase strategies have lower standard deviation. Due to this it is not clear which strategy will perform best in the arbitrage test.

Applying the full model, the values for θ appear to behave erratically. Indeed, checking for different values of θ yields no noticeable difference in function evaluation. The work in Hogan et al., 2004 notes a similar behavior and suggests fixing θ to a zero value, implying constant trading strategy returns. The results for this estimation are reported below in Table 5.5. These estimates are much more stable and produce no noticeable difference in Log-Likelihood evaluation score (although the effect on other estimates is nontrivial) and as such they will be considered the main test statistics. The unconstrained model estimates can be viewed in Table A.1 in the Appendix.

To frame these results more easily, remember that $\hat{\mu}$ was the mean estimate for trading profit per increment of time, $\hat{\sigma}$ is the estimate of initial standard deviation of trading profits per increment of time and $\hat{\lambda}$ is the estimate of the increase in σ. Thus we can easily see that the 'ISS 2-4' strategy is by far the most profitable per increment, followed by the 'ISS full'. However, $\hat{\sigma}$ is also much larger for these strategies than for

	ISS 2-4	ISS full	BB 1-4	BB 5-6	BB all
$\hat{\mu}$	5646.4	2474.4	-0.3254	1.7565	-0.6989
$\hat{\sigma}$	9990.9	9712.3	9.7848	21.967	41.44
$\hat{\lambda}$	0.3469	0.3718	1.0236	0.9449	0.8862
LogL value	-97727	-99060	-85680	-87106	-88415

Table 5.5 Results for maximization of Log-Likelihood function with constraint. See Equations 3.5, 3.6, 3.7, 3.8, 3.9 and 3.10 for the specifications.

the repurchase strategies. There appears to be a trade-off between high $\hat{\mu}$, high $\hat{\sigma}$ and low $\hat{\lambda}$. The trade-off between $\hat{\mu}$ and $\hat{\sigma}$ is fairly directly interpretable: as the estimate for μ increases, the average error becomes larger in absolute value, leading to a larger σ. However the relation with lambda is not as clear, and will be expanded upon.

The trade-off in values between $\hat{\sigma}^2$ and $\hat{\lambda}$ for issue and repurchase strategies is quite interesting. According to the specification in Equation 3.6, a value for $\hat{\lambda}$ smaller than 0 should yield a relatively stable series for $\hat{\sigma}^2$. This shows that the trade-off between high values of $\hat{\sigma}^2$ and high values of $\hat{\lambda}$ evident between the issue and repurchase strategies is not as odd as it may seem initially. That said, the coefficient estimates reported in Table 5.5 still yield an unstable series for $\hat{\sigma}$.

In removing the effect of time-varying average trading profit, we are left with only two hypotheses to test:

- H1: $\mu > 0$ and
- H2: $\lambda < 0$

The Bonferroni inequality states that the sum of the p-values for these tests must be greater or equal to the p-value for the combined test. Hence, we can use the sum of the individual tests as upper bounds. Therefore, if the summed p-value exceeds 0.05, we reject the notion of statistical arbitrage for a given strategy. The individual tests are simple t-statistics. Since we are testing one-sided hypotheses the critical value becomes 1.645 (or -1.645). The standard errors are retrieved from the Hessian matrix. The results can be viewed in Table 5.6.

Statistical arbitrage is rejected for all strategies. Of course, this was already evident from the coefficient estimates: all values of $\hat{\lambda}$ exceed 0, and since we are using a symmetrical distribution the p value for H2 will exceed 0.5.

t-scores	ISS 2-4	ISS full	BB 1-3	BB 4-5	BB full
H1	0.0482	0.0511	-0.0564	0.024	-0.1477
H2	0.0608	0.5855	1.9726	0.4205	0.6025

p-values	ISS 2-4	ISS full	BB 1-3	BB 4-5	BB full
H1	0.4808	0.4796	0.5225	0.4904	0.5587
H2	0.5243	0.7209	0.9757	0.6629	0.7266

Table 5.6 t-statistics and associated p-values for the statistical arbitrage hypotheses

6 Conclusion

Drawing conclusions, it is clear from the Anomaly section that market efficiency surrounding CACS has not been achieved. The Fama-French 5-factor model provides no significant improvement over other asset pricing models. Both issues and repurchases show significant abnormal returns within the first week after effective or announcement date respectively.

As discussed in the Literature section, the empirical side is largely divided between short-term traders and long-term investors. For equity issues, short-term traders are worried about dilution of value, whilst long-term investors are more excited about growth opportunities. Similarly, for repurchases, short-term traders gain significantly on the premium paid whilst long-term investors can view the decrease in liquidity as potentially harmful or see the repurchase as a signal of diminishing investment prospects. The impact from short-term traders is evident in the results, with large negative returns on event date for issues and large positive returns on event date for repurchases.

More interesting are the large and significant returns which occur within a short period after the event date. For issues, this is reasonably in line with some market inefficiency and behavioral finance literature: if issues are conducted at an opportune time, the action is in fact a positive development in the company, increasing prospects for long-term investors. For repurchases, the delayed positive spike is less easily explained. If some market inefficiency is again assumed, signaling theory and empirical work do give possible explanations for long-term optimism.

Moving Window estimates for the asset pricing models show no decisive trend in the estimates or t-statistics for either issues or repurchases, although the tail end of the issues sample does record decreasing abnormal returns. This may be a sign of increasing market efficiency. Opposing this is the Cumulative Abnormal Return estimate, which is shown to be increasing in the tail end. The CAR estimates for repurchases show cyclical variation in repurchase efficiency, of which the market is currently experiencing a lull in post-announcement abnormal returns.

The Calendar Time portfolio shows significant outperformance for holding both issues and repurchases after effective/announcement date for all considered asset pricing models. Interestingly, this negates criticism levied in Fama, 1998 that attributes abnormal returns to correlations across time. Furthermore, it confirms earlier results that market efficiency is not reached following effective issues and announced repurchases, as well as showing that the positive return spike seen in both models leads to cumulative positive return.

The results from the trading rules show that when compensating for practical investment costs such as slippage and trading cost the observed anomalies are in general strong enough to yield profitability. Most strategies give (large) positive trading profits.

Despite the positive trading rules results, none of the proposed strategies pass the statistical arbitrage test. Although the positive mean hypothesis is not confirmed in many cases, the point where all strategies fail is testing for the evolution of variance coefficient, $\hat{\lambda}$, to be negative.

The aim of this research was to determine short-term abnormal returns following corporate actions event dates, and test those findings for statistical arbitrage. If such arbitrage is present, market inefficiency cannot be denied surrounding these events. The results have shown that although abnormal return is present when compared to all leading asset pricing models as well as the Calendar Time portfolio method, it does not constitute a realistic statistical arbitrage opportunity. Despite this, several profitable strategies can be achieved by following the results from the asset pricing models. The inevitable conclusion is that although market inefficiency is present surrounding corporate actions and it is strong enough to yield profitable strategies over a long time-scale, it is not appropriate for any investor seeking to engage in statistical arbitrage.

6.1 Further Research

The first point of further research concerns the trading strategies. Although the reasoning for this particular method of strategy construction has its merit, in many practical cases more complex rules are applied. Extending the framework of this research with a more complex set of strategies that are nonetheless practically implementable (such as those incorporating intra-day pricing data) may reveal a viable statistical arbitrage strategy that can validate the abnormal returns found by the various asset pricing models.

Additionally, M&A risk may be of interest. Due to the nature of statistical arbitrage and the need to maintain positions, the takeover risk as suggested in Cremers et al. (2009) and applied to repurchases in Lin et al. (2014) may be of significant impact to the risk side of the investing strategy, as a takeover typically forces the trading company out of the position. For this extension it is important to check whether M&A offers are of increased frequency directly after CACS announcements, because potential bidders may require more time than the holding period of the statistical arbitrageur to make a takeover or merger offer.

Cremers et al. (2009) also considers merger waves, wherein a multitude of firms make M&A offers in a certain time frame. These are historically recognized in five periods (see Rhodes-Kropf and Viswanathan (2004)). In such a situation, repurchasing firms are even more likely to increase in value due to an additional increase in takeover risk. Because of this it may be sensible to identify the times which are considered takeover waves and monitor the behavior of repurchasing firms.

The CACS field has shown noticeably small interest in assessing differences in company characteristics such as size and industry. The data shows that Financial sector repurchases the most by far, and combined with the Tech sector they account for almost 40% of all repurchases. For issues, the field is not as clearly divided, but it did see a large spike in Tech issues prior to 2000. These imbalances in industry may provide better insight to the CACS question. Furthermore, a small discussion on size bias in this data set has already been given in the Data section, but it may also prove to have a profound effect on the reaction to CACS events.

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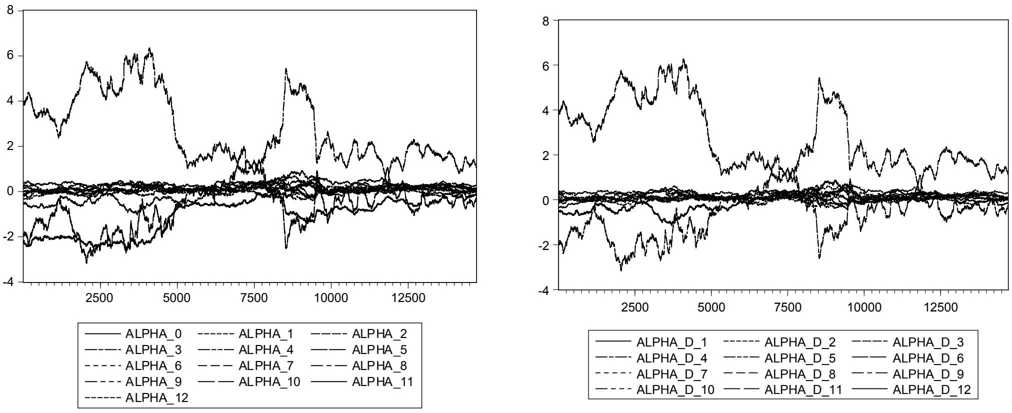
A Appendix

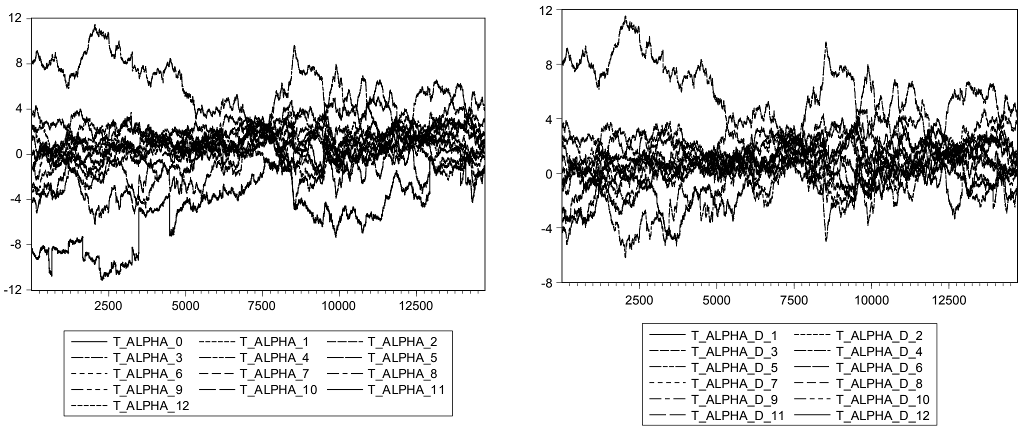
A.1 Full moving window estimation graphs



(a) Conventional

(b) RATS

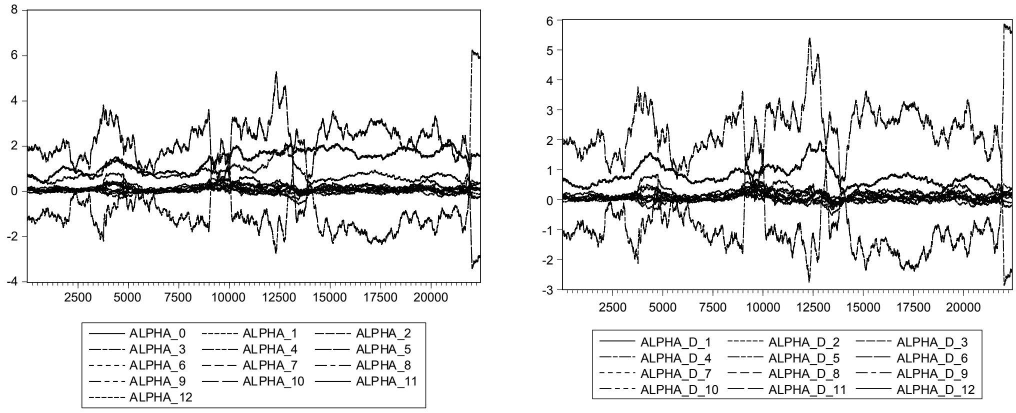
Fig. A.1 Alpha coefficient estimates for all periods following issue effective date over the 1000-stock moving window for the CAPM model specification. The x-axis denotes the index of the first included issue.



(a) Conventional

(b) RATS

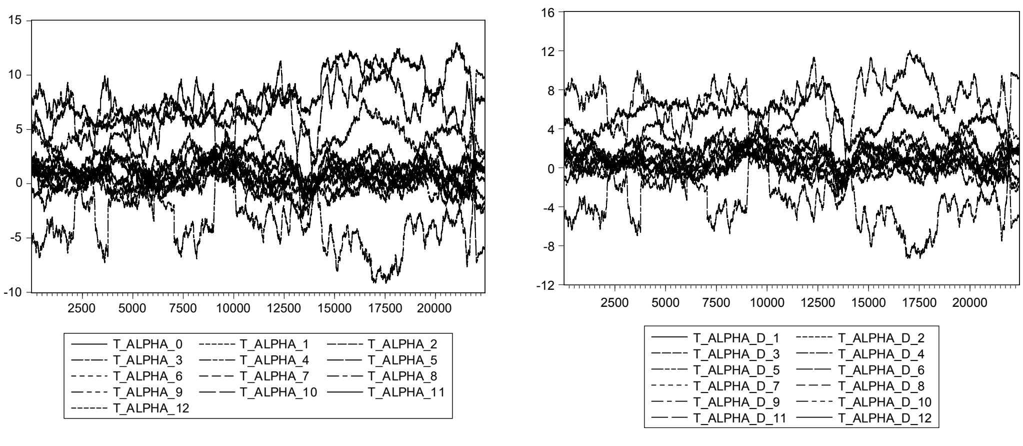
Fig. A.2 t-statistic values for the conventional and RATS model for all periods following issue effective date over the 1000-stock moving window for the CAPM model specification. The x-axis denotes the index of the first included issue.



(a) Conventional

(b) RATS

Fig. A.3 Alpha coefficient estimates for all periods following repurchase announcement date over the 1000-stock moving window for the CAPM model specification. The x-axis denotes the index of the first included repurchase.



(a) Conventional

(b) RATS

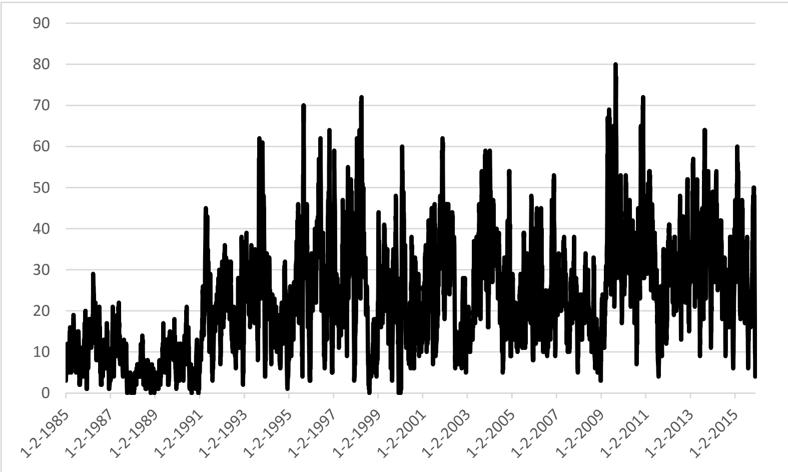
Fig. A.4 *t*-statistic values for the conventional and RATS model for all periods following repurchase announcement date over the 1000-stock moving window for the CAPM model specification. The x-axis denotes the index of the first included repurchase.

A.2 Coefficient estimates for the unconstrained statistical arbitrage model

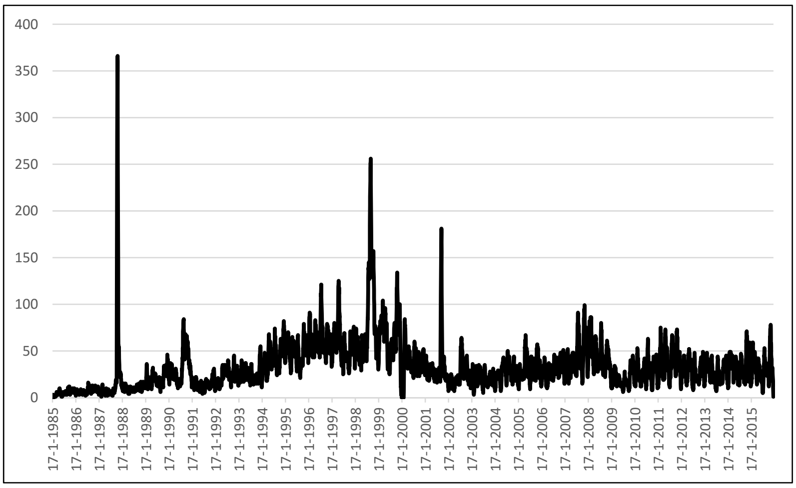
	ISS 2-4	ISS full	Repurchases 1-4	Repurchases 5-6	Repurchases all
$\hat{\mu}$	773.94	2962.0	-0.0336	0.1687	-0.9611
$\hat{\sigma}$	3662.6	9061.2	9.7856	21.967	41.42
$\hat{\theta}$	$-1.9 * 10^9$	$-1.9 * 10^8$	-44127	-587.19	0.4863
$\hat{\lambda}$	0.4726	0.3804	1.0235	0.9449	0.8863
LogL value	-97909	-99062	-85680	-87107	-88415

Table A.1 Results for maximization of Log-Likelihood function

A.3 Amount of stocks in Calendar Time Portfolio



(a) Issues portfolio



(b) Repurchases portfolio

Fig. A.5 Graph of amount of stocks in calendar time portfolio