UNIVERSIDADE CATÓLICA PORTUGUESA

Are IPOs underpriced or overpriced?

Testing for bubbles in IPOs.

Empirical Analysis

Trabalho Final na modalidade de Dissertação
apresentado à Universidade Católica Portuguesa
para obtenção do grau de mestre em Finanças

por

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sob orientação de
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Setembro 2015

Agradecimentos

Embora uma dissertação seja, pela sua finalidade académica, um trabalho individual, há contributos de natureza diversa que não podem e nem devem deixar de ser realçados. Por essa razão, desejo expressar os meus sinceros agradecimentos:

Ao Professor Doutor Carlos Santos, meu orientador, pela competência científica, pelas críticas, correcções e sugestões relevantes feitas durante a orientação e pelo sacrifício pessoal, mas acima de tudo por ter abdicado das suas férias para me auxiliar. Ficarei eternamente grato.

Aos meus amigos e colegas, em especial Nuno Almeida, André Cardoso, Mafalda Vilela, Sandra Coelho, Nuno Carvalho, Ana Matos, entre outros de que não menciono o nome mas que sabem quem são, por estarem ao meu lado durante esta fase, pela força e apoio que me deram em certos momentos difíceis.

Por último dirijo um agradecimento especial aos meus pais, pelo seu apoio incondicional, incentivo e paciência demonstrados e por me terem providenciado a melhor e possivelmente mais decisiva experiência da minha vida. A eles dedico este trabalho.

Resumo

Esta dissertação introduz um novo tipo de procedimento que permite detectar o comportamento explosivo no desempenho do preço das acções, no curto prazo, de empresas recém-cotadas na bolsa dos EUA, usando um novo tipo de dados, cotações intradiárias. Em contraste com a maioria da literatura, esta dissertação não se foca em determinar se as OPVs são subvalorizadas ou sobrevalorizadas, mas sim em detectar um possível comportamento exuberante no preço das acções das empresas imediatamente após a sua entrada em bolsa e determinar os momentos em que esse comportamento se evidencia e o possível colapso dessa exuberância. Este trabalho mostra que este novo mecanismo de detecção foi capaz de determinar que algumas OPVs evidenciaram um processo explosivo imediatamente após a Oferta Pública de Venda e foi capaz de assinalar a data do início desse comportamento e o seu colapso. Contudo, este teste detectou um comportamento explosivo em OPVs sobrevalorizadas, ou seja em empresas cujo preço das acções reagiu de forma oposta a um desempenho explosivo, logo é necessário fazer uma análise minuciosa a cada caso. Por fim, esta dissertação apresenta uma análise detalhada da empresa ReWalk Robotics Ltd, empresa essa que teve um comportamento exuberante inicial bastante assinalável, mas cujo preço, cerca de um ano após a sua OPV, era inferior ao seu preço de entrada no mercado.

Palavras-chave: Oferta Pública de Venda; recursive right tailed unit roots test; processos explosivos.

Abstract

This dissertation introduces a new type of procedure to detect ex-ante explosive behaviour in the post-issue short term stock performance of newly listed firms in the USA, using a new type of data, intraday quotes. Contrarily to most literature this dissertation does not focus on understanding if IPOs are underpriced or overpriced, but on detecting if the stock performance of the newly listed firm is having an explosive behaviour or not and in data stamping that explosiveness and a possible collapse. This work shows that this new detection mechanism has been able to find that some IPOs had an explosive process immediately after the IPO and it has been possible to determine the date of the beginning of the exuberant behaviour and the collapse. However, this test has detected explosive processes in overpriced IPOs, meaning that the stock price showed an opposite behaviour of explosiveness, therefore it is important to make a complete case-by-case analysis. Moreover, this dissertation presents a comprehensive analysis about ReWalk Robotics Ltd, a company in which has been detected initial exuberance, although it has underperformed almost a year after its IPO date.

Keywords: Initial Public Offerings; recursive right tailed unit roots test; explosive processes.

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1. Introduction

The stock behaviour after an IPO has been vastly studied and there is a growing consensus in the literature that the stock price after the IPO does not behave similarly to other comparative stocks or even to the market. The increasing number of companies going public, the successful IPOs such as those of Google and Apple and the belief that it is possible to gain profits in a short period of time, elicits investors to pay more than the fair price. Many authors such as Ritter (1991), Loughran, Ritter and Rydkqvist (1994), Ritter (1998), Jenkinson and Ljungvist (2001), Cheung and Liu (2006), and many more, either argue that IPO firms are underpriced in the short term, meaning that the stock price rises immediately after the IPO, or that the stock price of newly listed companies underperforms in the long term, with different time frames, or both. Cheung and Liu (2006) state that the IPO underpricing and long run underperformance in an established stylized fact. This price performance is similar to the performance of a bubble, a market determined asset price without any reasonable economic explanation.

The aim of this dissertation is to detect exuberance in the price performance after the IPO, in order to firstly determine if the IPO was underpriced or overpriced and secondly investigate if the underpricing was caused by an exuberant behaviour of the agents. There are some relevant differences between my dissertation and the available literature. On the one hand I will use a completely different methodology than most authors: while they estimate ex-post behaviour in the IPO market and try to find a motivation, either rational or behavioural, for that phenomenon, I will use a test procedure with predictive power, which can estimate the overshooting and the period of exuberance ex-ante. And on the other hand, I will use intraday observations in a 5 to 6 days'

time frame, with every 5 minutes quotes, as opposed to daily or monthly observations used by most authors, in order to more accurately detect the bubble component that can be attributed to the IPO event.

The test procedure I will use was created by Phillips, Wu and Yu (2011) and further developed by Phillips, Shi and Yu (2014) in order to detect bubbles and to time stamp the initial exuberance and collapse of the bubble, using a recursive right tailed unit roots test. Even though they design their detection mechanism for stock markets and with a longer time frame, I will investigate if it can be applied to the newly listed companies in a case-by-case basis.

With an initial sample of 11,220 from 9 companies listed in the NASDAQ stock exchange that issued stocks for the first time between August 1, 2014 and October 23, 2014, I found that this test procedure can detect exuberant behaviour in the stock price after IPO of some companies and indicate if they are underpriced or overpriced and it can time stamp the initial overshooting and its collapse. This test procedure has been more effective in some companies than in others, given that there was a case in which it detected an explosive behaviour but the stock price decreased from the first day.

In addition, I will make further analysis about a specific company, ReWalk Robotics Ltd, which showed statistical evidence of existence of explosive behaviour during the initial trading days. This analysis will be made based on specialized media and analyst reports from 3 different institutions, Barclays Capital Inc., Canaccord Genuity Inc., and Jefferies Group LLC throughout the year after the IPO, in order to understand if there were market fundamentals that justified the initial overshooting or not.

I found that ReWalk Robotics Ltd, who was considered the best performing IPO of 2014, had a very poor revenue performance and consistence losses, in spite of their innovative product that could revolutionize the wearable robotic exoskeletons market for personal use and rehabilitation purposes. However,

their below than expected performance throughout their first listed year, made the share price fall below the IPO price. The ReWalk Robotics Ltd price performance after the IPO has been short term underpriced and long term underperformed.

The dissertation is organized as follows: Section 2 summarises the relevant literature on after IPO price performance and on bubble detection mechanisms; Section 3 enunciates the hypothesis to be tested; Section 4 describes the data and the selection criteria; Section 5 presents the methodology used; Section 6 examines the empirical results; and Section 7 concludes.

2. Literature Review

2.1. An Overview of Initial Public Offerings

The number of companies going public has been increasing over the years and even with the recent economic crisis these numbers do not show any sign of slowing down. Investors are constantly looking for the next Google, or the next Apple, which may trigger a price performance that can be compared to a bubble. There is a substantial amount of both theoretical and empirical research on IPOs, and most of them find a common ground, that IPOs are underpriced in the short term and underperform on the long run.

Ritter (1991) documents that newly listed companies underperform a sample of matching firms from the first day of listing to three years after the IPO date, which indicates that IPO underpricing is a short run phenomenon. Loughran, Ritter and Rydkqvist (1994), Ritter (1998), and Jenkinson and Ljungvist (2001) show that the stocks issued in IPOs from various countries appear underpriced because they earn an average positive return immediately following the IPO. Cheung and Liu (2006) go further by stating that the IPO underpricing and long run underperformance is an established stylized fact.

Moreover, most of the theoretical literature starts by showing this bubble trend in multiple financial markets and revolves around trying to find different reasons for this behaviour. The explanations given are connected with information asymmetries between issuers, investors, and the investment bankers who manage the issue; adverse selection between investors; or allocations. There are authors that give different definition to the term Allocation: Aggrawal et al. (2002) define it as a proportion of issue that is allocated to a type of investor (institutional or retail), while Amihud et al. (2003) define it as the proportion of each subscriber's order that is filled in the IPO.

Amihud et al. (2003) examined theories of IPO underpricing, including Rock's (1986) theory of adverse selection and Welch's (1992) theory of information cascades, using data from the Tel Aviv Stock Exchange (TASE), in Israel. In the TASE during the study period, in case of oversubscribed IPOs, securities were allocated mechanically by equal proration to all subscribers, each receiving an equal fraction of his or her subscription. The study included 284 IPOs between November 1989 and November 1993, after which time the IPO method changed. The IPOs are composed by either units of stock only (15.5%), stock and warrants (62.3%), stock, warrants and bonds (mostly convertible) (18.3%) and stock and bonds (3.9%). Issues are sold either at a fixed predetermined price (13.7%) or at a price determined in a sealed-bid uniform-price auction (86.3%) with specific minimum and maximum prices.

The theory of underpricing is studied from measuring the initial IPO return six days after the issue day (securities issued in IPOs trade by a once-a-day auction, called Karam, which is used for small-cap securities). The initial return was then compared to the performance of the Karam market and they found an average positive return of 12% after six trading days. The analysis was also done for 15 and 150 days after the IPO day and it showed also a positive but declining return, which is consistent with the theory of underpricing in the short term and underperformance in the long run.

Using data on the rate of allocation to subscribers, Amihud et al. (2003) test Rock's (1986) theory of adverse selection by examining whether the allocation rate to subscribers is greater in overpriced IPOs and simulating the initial return that would be earned by uninformed investors by calculating the allocation-weighted initial return that would be earned by an investor who participated equally in either all or some random IPOs. They find evidence of adverse selection in IPOs and that uninformed investors earn a small negative initial return, even though there is a positive average return on IPOs, which means

that IPOs were slightly overpriced for uninformed investors, or that the demand of these investors for IPOs was on average too high, which is incoherent with Rock's (1986) statement that, in equilibrium, uninformed investors should earn the riskless rate.

In addition, Amihud et al. (2003) examine Welch's (1992) theory of information cascades or herding in IPOs, that states that if investors learn about the value of the issued company by observing the behaviour of other investors, issuers will underprice their stock to create a cascade of buyers. They found that investors either subscribe overwhelmingly to new issues, which results in very small allocations (by their definition), or largely abstain so that the issue is undersubscribed and subscribers receive full allocation, with very few cases in between, which is consistent with herding.

Cheung and Liu (2007) say that there are two reasons why the theoretical literature focuses on adverse selection, information asymmetries and allocations between institutional and retail investors. First, there is a wide perception that underwriters make a preferential allocation of IPO shares to institutional investors and, consequently, retail investors are not fairly treated, which is possible in some markets where the allocation is at the underwriters' discretion (USA). Second, institutional investors are different from retail investors in that they are more likely to be better informed and are capable of identifying IPOs with better long term performance potential, opting to keep IPOs with good prospects as long term investments and to sell IPOs with poor prospects to capture short term profits.

The empirical research performed by Cheung and Liu (2007) in the stock market of Hong Kong between May 1996 and December 2000, addresses the issue of whether IPO block traders have superior information on the newly listed companies that enables them to capture short term underpricing and keep shares in IPOs with good long-term prospects and if small investors can

use this as a signal for their investment decisions. They find that the IPO block trading level is related to its after listing performance and the buy and hold abnormal return of IPOs within the first year of listing is negatively associated with the block trading level. Moreover, they determine that the higher the IPO block trading levels on the first trading day, the lower the returns within the first year of listing, which indicates that institutional investors may have a higher level of information about the newly listed companies, therefore their activities may serve as a signal to small investors.

An alternative approach to the stock performance after the IPO can be the payout behaviour of IPO firms. When an investor buys shares of a company he expects to be remunerated through dividends, stock repurchases or by selling their stocks for a higher price, which can be called self-made dividends. Chen et al. (2013) analyse the buyback behaviour of initial public offering firms within three years of the IPO year and they propose three hypotheses to justify a stock repurchase: the free cash flow hypothesis, where companies due to the lack of investments opportunities will have lower capital expenditure and research and development expenses, hence cash distribution via repurchases might reduce firm's over-investment problem and may result in a positive market reaction in the long run; the signalling hypothesis, since firms may repurchase stocks to signal undervaluation; or the misleading hypothesis, given that IPO firms might manipulate earnings to support the firm's IPO and firms with a more aggressive accruals policy are likely to underperform more in the long run than other IPO firms. They found that in the US IPO firms send false signals to mislead investors and they tend to decline in operating performance in the long run, using the repurchase programmes to prop up the stock price.

2.2. A Review of Detection Procedures for Bubbles

The behaviour described above by many authors, the IPO underpricing followed by a long term underperformance, can be seen as a bubble, a high market determined asset price without any reasonable economic explanation. This behaviour can also be called a tulip mania in reference to the Dutch tulip mania, the first documented bubble that occurred in the 1630s, where the price of tulips rose to a maximum of $400 per ounce and then fell to less than 10% of that value (Garber, 1990).

One of the biggest concerns regarding bubbles is their power to spread across stock markets, economies, securities and business sectors. Several studies show that the financial crisis of 2008 started in the real estate bubble in the United States, where housing prices were increasing due to an increase in demand and limited supply. Speculation and the belief that the property value would continue to thrive and that profits could be made through short time buying and selling caused a rapid growth of demand, which was met by an increase of supply. Cheng et al. (2014) found that securitization agents increased their exposure to the real estate market. Eventually, demand started to stagnate and supply continued to increase, which resulted in a steep drop of the prices, the typical behaviour of a bubble.

During the Dot-com bubble, the IPO also showed abnormal underpricing. Ljungqvist and Wilhelm's (2003) paper about the pricing behaviour during the Dot-com bubble and states that the first day returns of IPOs in 1996 and 1999 averaged 17 and 73 percent, respectively, and a median of 10 and 40 percent, respectively. They also showed that Internet IPOs averaged 89 percent during 1999 and 2000, which he concludes were the early signs of the Dot-com bubble.

Gurkaynak (2008) made a survey of econometric tests of asset price bubbles in order to detect them with a satisfactory degree of certainty. He assumes that the price of the asset today has two components, a "market fundamental" part,

the discounted value of expected future dividends and a "bubble" part. In order to test for bubbles, the validity of the standard model is tested, observing either whether it fails at all, or whether it fails in a way that can be attributed to bubbles. The standard model, or the market fundamentals model, implies that the value of the bubble is zero at all times, which means that the equity prices are fully explained by the market fundamentals. Gurkaynak (2008) focused only on the detection of rational bubbles, which equity prices contain if investors are willing to pay more for the stock that they know is justified by the value of the discounted dividend stream because investors expect to sell the asset for an even higher price in the future, thus making the current high price an equilibrium price.

The survey focused on three tests: the Variance Bounds tests of Shiller (1981) and LeRoy and Porter (1981); West's tests of Bubbles (1987, 1988a); and the integration/ cointegration based tests (Diba and Grossman, 1988a, b) and Evans' (1991) criticism of this approach. Gurkaynak (2008) concludes that these bubble tests do not do a good job of differentiating between non-specified fundamentals and bubbles and that they are powerful against certain types of bubbles. The available econometric tests are not effective because they combine the null hypothesis of no bubbles with an overly simple model of fundamentals, the present value of future dividends. Therefore, the rejection of the standard model does not necessarily indicate the presence of bubbles but can be explained by an alternative set of equally plausible fundamentals. This hypothesis is consistent with the literature due to the fact that for every test of bubbles there is another paper that disputes the particular bubble interpretation.

Even though Gurkaynak (2008) disputes the effectiveness and reliability of econometric tests, Phillips et al. (2011) propose a new recursive right-tailed unit

roots tests that aims at detecting bubbles. The test procedure is based on the autoregressive process:

$$x_t = \mu + \delta x_{t-1} + \sum_{j=1}^{J} \emptyset_j \Delta x_{t-j} + \varepsilon_t$$

where x_t is the time series of interest, $E(\varepsilon_t) = 0$ and $E(\varepsilon_t^2) = \sigma^2$. The unit root null hypothesis is H_0: $\delta = 1$ and the right-tailed alternative hypothesis is $H_1 > 1$. Given a fraction r_0 of the total sample as an initial window size, the equation above is estimated recursively fixing the first observation as the starting point, and using the subsets of sample data increased by one observation stepwise. For a subsample starting from the first observation and at a fractional size of the full sample r, where $r_0 < r \leq 1$, the corresponding Augmented Dickey Fuller (ADF) test statistic can be denoted by ADF_r. Moreover, ADF_1 corresponds to the ADF test statistic of the full sample. The $SADF$ test statistic is the supremum value of ADF_r, for $r_0 < r \leq 1$:

$$SADF_{(r_0)} = \sup_{r \in [r_0, 1]} \{ADF_r\}$$

This test is capable of detecting periodically collapsing bubbles and is robust against multiple breaks due to a possible burst of the bubble. Evidence of explosive behaviour is obtained on certain time series if the SADF statistic is larger than the right-side critical values for a chosen nominal size.

The purpose of these tests is to identify the origination, termination and the extent of the explosive behaviour. The use of recursive tests allows the location of exploding subsamples of data and the detection of periods of exuberance. Although these testing procedures cannot determine the date where the exuberance emerges and collapses, it is possible to match the time series of the recursive test statistic ADF_r with $r \in [r_0, 1]$, against the right-tailed critical values of the asymptotic distribution of the Dickey-Fuller t-statistic, thus enabling the consistent estimation of origin and collapse dates.

In their paper, Phillips et al. (2011) apply their econometric approach to the NASDAQ index over the full sample period between 1973 and 2005, in order to detect the origin and collapse of the Dot-com bubble of the 1990s. They were motivated by a remark from the former chairman of the Federal Reserve Board, Alan Greenspan, made in December 5, 1996, to the herding behaviour of the stock market that served as a warning that the market might have been overvalued and in risk of a financial bubble, which he called "irrational exuberance".

Phillips et al. (2011) found that the empirical application of their method to the Nasdaq experience in the 1990s confirms the existence of "irrational exuberance" and is able to data stamp its origination and collapse, which they found to have been originated in mid-1995, peaked in February 2000 and collapsed between September 2000 and March 2001.

Bettendorf and Chen (2013) and Phillips et al. (2014) advocate that the SADF econometric test for explosive unit roots has a diminished discriminatory power when in presence of multiple bubbles, since it has the limitation of fixing the first observation of the sample as the starting point. Therefore in the presence of multiple bubbles in the sample, one bubble can dominate the other.

In order to overcome this limitation and deal with multiple breaks of exuberance and collapse, Phillips et al. (2014) introduced the Generalized Sup ADF (GSADF) method to test for the presence of multiple bubbles and a recursive backward regression technique to data stamp the origination and termination dates of the bubble. The new method still relies on recursive right tailed ADF tests but instead of fixing the starting point of the recursion on the first observation, it extends the sample coverage by changing both the starting point and the end point of the recursion over a reasonable range of flexible windows. The GSADF is consequently a right-tailed double recursive test for a unit root.

The empirical application of the methodology in the paper was conducted on S&P 500 stock market data over a long historical period from January 1871 to December 2010, constituting 1680 monthly observations. The new approach successfully identifies the most famous historical periods of exuberance and collapse, including the great crash, the post war boom in 1954, the Black Monday in October 1987, and the Dot-com bubble. On the other hand, the previous approach is much more conservative and locates far fewer episodes over the same historical period, only detecting the 1990s stock bubble.

Bettendorf and Chen (2013) apply the recursive right-tailed unit roots tests to the foreign exchange markets, trying to find evidence of explosive behaviour in the Sterling-dollar exchange rate. Their sample ranges from January 1972 to June 2012, which totalizes 486 monthly observations. According to their results, the log nominal exchange rate shows clear evidence of multiple periods of explosive behaviour, more specifically in 1976 and 1985, which corresponds to the 1976 Sterling crisis and the US dollar appreciation against several currencies, respectively. However, they found no evidence of explosiveness in the relative ratio of the exchange rate to the traded goods fundamental, thus the explosive behaviour in the nominal Sterling-dollar exchange rate may have been driven by the relative prices of traded goods between the US and Great Britain.

3. Hypothesis Development

The purpose of this dissertation is to investigate whether IPOs are underpriced or overpriced and if it is possible to detect exuberant stock behaviour in the first trading days. In order to do so I intend to apply a recent procedure, a recursive right-tailed unit root test developed by Phillips et al. (2014), to a new context, namely to IPO bubbles. In addition, I will use intraday observations, which is a novel approach, given that most papers use daily or monthly observations due to the limited access and high storage costs and with the purpose of covering a wider time frame. The proposed test procedure does not allow testing a set of IPO firms, but instead it can determine the presence of a bubble or multiple bubbles in each individual IPO firm, and it can estimate the time or data frame of overshooting and the collapse of the bubble, if it is present in the sample.

The test procedure used in this dissertation has predictive power, meaning that it can estimate the overshooting and the period of exuberance ex-ante, which can in fact be critical for both investors and regulators. In case investors can detect this exuberant behaviour they can adapt their hedging strategies, thus anticipating the collapse of the stock price and avoiding buying overvalued stocks. Moreover, investors might take precautionary measures in order to ensure a smoother collapse and contain the contagious effect that characterizes the bubble phenomena.

The implications of the presence of bubbles are the explosive characteristics in prices that they manifest. The definition of exuberance in terms of explosive autoregressive behaviour is motivated by the statistical property of the process of the form $X_t = \mu_x + \delta X_{t-1} + \varepsilon_{x,t}$ where $\delta > 1$ for some sub-periods of the data. Phillips et al. (2011) give the example illustrated in figure 1 as some

typical time series plots for stationarity ($\delta = 0.9$), random walk ($\delta = 1.0$), and explosive processes ($\delta = 1.02$) with intercept $\mu_x = 0$ and inputs $\varepsilon_{x,t} \sim i.i.d.N(0,1)$. The difference in the trajectories is fairly obvious and it is reasonable to expect that the explosive behaviour will not last for the entire time frame, thus bubbles are feared for their predictable collapse.

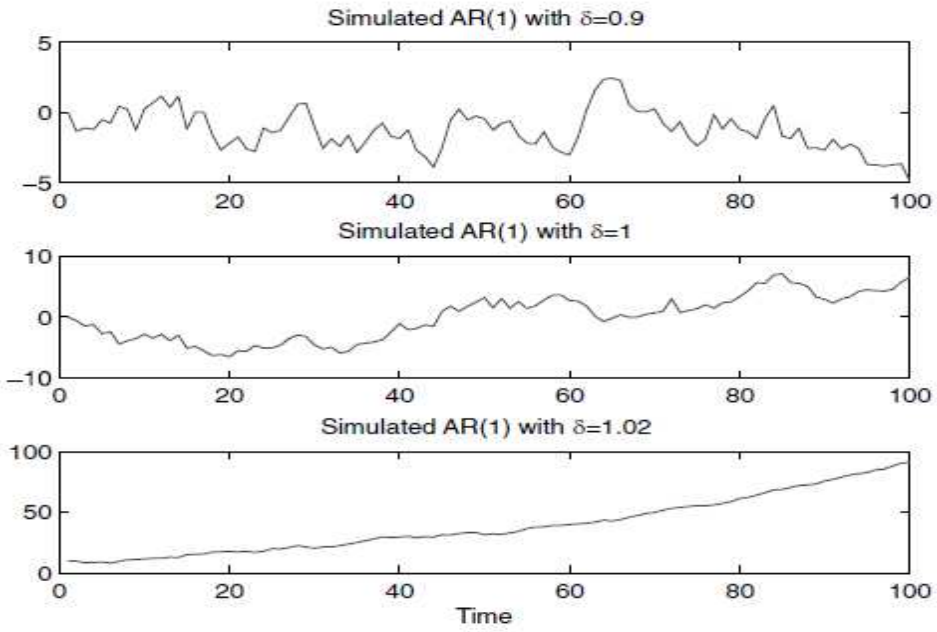

Figure 1 Typical stationary, random walk, and explosive autoregressive trajectories (Source: Phillips et al. (2011))

So far the literature has not used this test procedure on the IPO market, focusing more on index prices and detecting the most popular and widespread bubbles, such as the Dot-com bubble or the real estate bubble. Bettendorf and Chen (2013) applied the test to the foreign exchange market and Phillips et al. (2014) focused on detecting the most famous bubbles on NASDAQ. I believe that the recursive right-tailed unit roots test can be applied to the IPOs, that most literature on the subject advocates a consistent underpricing, characterized by a short-term steep rise of the stock price following the IPO date. Given that Amihud et al. (2003) studied the theory of underpricing from measuring the initial IPO return six days after the issue day, my sample will consist of intraday observations during the initial five to six days of each

company. Amihud et al. (2003) found an average positive return of 12% after six trading days, and a smaller average return after 15 and 150 days, which leads me to believe that in case there is exuberant behaviour in IPOs, it can be detected in the initial five to six days of public listing.

The literature is unanimous regarding the stock behaviour after the IPO, supporting the generally underpricing behaviour after the IPO day, meaning that the stock price increases shortly after the IPO, but they also mention that there is evidence of long term underperformance, which implies that companies whether fall below the IPO price or they never reach the price observed in the first days after the IPO. However I will only focus on the short term under or overpricing with this test procedure.

Furthermore, I will try to explain the bubble reaction of a specific company, ReWalk Robotics Ltd, in a wider time frame, not only to hypothesise about the fundamentals behind the initial overreaction, but also to study if the price decline or the bubble collapse was justified or not.

In sum, I intend to apply a new test procedure, the recursive right-tailed unit roots test, to a new subject, the IPO market, with a new type of data, intraday observations and perform a case study to determine if the bubble was a rational or irrational exuberance that could have been cause by herding behaviour or information asymmetry from investors.

4. Data and Selection Criteria

The selection criteria of the IPO firms was by convenience sampling, given that there were a number of constraints regarding time frame and available information. Table 1 enumerates the 9 companies chosen for this study.

Most literature uses daily or monthly observations because most financial databases do not store intraday quotes due to the high cost of storing that amount of data. Therefore, in order to conduct this study with intraday observations I would have to restrict myself to the IPO firms that went public in the previous 90 days from the day (October 23, 2014) the data was obtained. Moreover, I chose to conduct this study with newly listed firms from August 01, 2014 to October 23, 2014, with the purpose of having almost one year of trading to make a better analysis in my case study.

Having said that, the initial sample of 11,220 is drawn from the population of some firms listed at NASDAQ that could have been identified as conducting IPOs between August 1, 2014 and October 23, 2014.

The goal of this study was to conduct a recursive right tailed unit roots test on the first five to six trading days, with the purpose of detecting the bubble directly attributed to the IPO, thus each firm needed to have a sample size between 1,200 and 1,300 observations and the observations were spaced out by 5 minutes. From those 1,200 to 1,300 observations were excluded all the moments that did not have a corresponding quote, more specifically when the stock market was closed, which gives us a sample range between 200 and 300 observations for each firm, therefore the final sample as 2,187 observations, has shown in table 1.

Listed company	Sample	Included observations	First trading day
Loxo Oncology Inc.	1,249	237	01/08/2014
ReWalk Robotics Ltd	1,295	295	12/09/2014
Affimed N.V.	1,233	230	12/09/2014
Tokai Pharmaceuticals Inc.	1,209	208	17/09/2014
Alibaba Group Holding Ltd	1,249	249	19/09/2014
Vascular Biogenics Ltd	1,238	221	01/10/2014
Vivint Solar Inc.	1,249	249	01/10/2014
Cyberark Software Ltd	1,249	249	24/09/2014
Mobileye NV	1,249	249	01/08/2014
Total	11,220	2,187	

Table 1 Sample distribution per listed company and respective first trading day

5. Methodology

The fundamental purpose of this dissertation is to study the stock behaviour after the IPO, more specifically to assess if the IPO is under or overpriced. There is consensus in the literature that IPOs are underpriced in the short term, whether for rational or behavioural reasons, but are followed by long term underperformance, which is the typical pattern of a bubble. In a standard bubble there is an initial explosive behaviour, commonly known as overshooting, where investors overvalue and channel their resources for that asset, forming exuberance.

The bubble phenomena have been extensively studied by econometricians and there are several studies and tests available with different degrees of popularity and confidence. Gurkaynak (2008) made a survey of different econometric tests for detecting bubbles, focusing on the variance bounds tests of Shiller (1981) and LeRoy and Porter (1981); West's tests of bubbles (1987, 1988a); and the integration/ cointegration based tests (Diba and Grossman, 1988a, b) and Evans' (1991) criticism of this approach. Gurkaynak (2008) concludes that these econometric tests are not effective because they do not differentiate between non-specified fundamentals and bubbles, meaning that their testing of bubbles focuses in overly simplified model of fundamentals, therefore the rejection of the standard model does not necessarily indicate the presence of bubbles but it can rather be explained by an alternative set of equally plausible fundamentals.

In a recent paper, Phillips et al. (2011) propose a new recursive right tailed unit roots test for detecting bubbles, which they apply to the NASDAQ index, while Bettendorf and Chen (2013) employ it for bubble detection in the sterling

dollar exchange rate. In order to analyse financial bubbles it is necessary to start with the asset pricing equation:

$$P_t = \sum_{i=0}^{\infty} \left(\frac{1}{1+r_f}\right)^i E(D_{t+i} + U_{t+i}) + B_t$$

where the after-dividend price of the asset is determined by the risk free discounted cash flows from dividends and unobserved fundamentals plus the bubble component. The quantity $P_t^f = P_t - B_t$ is usually denominated as market fundamental and B_t fulfils the submartingale property $E_t(B_{t+1}) = (1 + r_f)B_t$.

As a result, the price is determined by two components from the equation, the first term being the market fundamentals and the second term, the bubble component. When $B_t = 0$, in the absence of bubbles, then the price is controlled by the first part of the equation, the market fundamentals, composed by the risk free discounted cash flows from expected dividends and from unobserved fundamentals. However, if we assume that the risk free rate grows faster than the dividend growth rate, then the market fundamentals component is stationary while the bubble component does not converge with it. As a result, if there is no explosive behaviour from the market fundamentals, then the explosive behaviour observed in the price can only be explained by a bubble.

Moreover, it is assumed that the future price of the asset is not part of the price today due to the transversality condition that argues that the lost utility from selling the asset is lower than the sale value and in case this was not true, then all agents would want to sell the asset and the price would fall to the fundamental level.

Phillips et al. (2011) test the existence of explosive behaviour by applying the augmented Dickey-Fuller test for a unit root against the alternative hypothesis of an explosive root for each time series. In contrast with the Dickey-Fuller unit roots test, Phillips et al. (2011) focus is on the alternative hypothesis to study the possible departures from fundamentals and the presence of market excesses or

mispricing, using therefore right sided unit root tests, which detect the presence of bubble from the following autoregressive process:

$$x_t = \mu + \delta x_{t-1} + \sum_{j=1}^{J} \emptyset_j \Delta x_{t-j} + \varepsilon_t \sim NID(0, \sigma_x^2)$$

Thus, the unit root null hypothesis is given by $H_0: \delta = 1$ and the alternative hypothesis is given by $H_1: \delta > 1$. To perform the test it is necessary to fix an initial window size as a fraction r_0. Then to estimate recursively we have to fix the first observation as the starting point, and use subsets of sample data, that increase by one observation at a time, thus obtaining the ADF sequence. The SADF statistic is then obtained from the equation:

$$SADF_{(r_0)} = \sup_{r \in [r_0, 1]} \{ADF_r\}$$

which means that the $SADF_{(r_0)}$ is the supremum value of ADF_r for $r_0 < r \leq 1$, where 1 is the total sample and r the fraction size of the full sample. In case there is a bubble, than the SADF statistic will be larger than the right sided critical values for certain limited period of time.

Like I mentioned above this test was proposed by Phillips et al. (2011), however in a subsequent paper Phillips et al. (2014) argue that this test is only accurate when there is only one period of overshooting. In case there are multiple episodes of exuberance and collapse, then the procedure may suffer from reduced power and can be inconsistent. Bettendorf and Chen (2013) also support this view and then argue that in the presence of two bubbles, one might not be detected because it is overpowered by the other. As a result, Phillips et al. (2014) propose another procedure that is derived from the previous one, the Generalized Sup ADF (GSADF). This procedure is able to detect multiple breaks of exuberance and collapse as well as providing a recursive backward regression technique to time stamp the origination and collapse dates of the bubble.

The new method also relies on recursive right-tailed ADF tests but instead of fixing the starting point of the recursion on the first observation, it applies a rolling version of the SADF test, where the first window moves over the sample, increasing the sample coverage by changing both the start and the end point of the recursion.

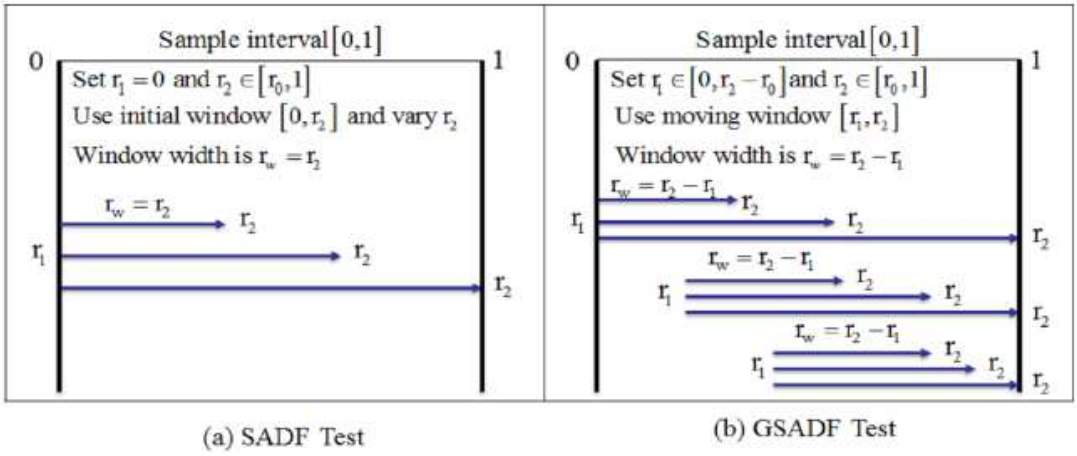

Figure 2 The sample sequences and window widths of the SADF test and the GSADF test. (Source: Phillips et al. (2014))

Figure 2 illustrates the different sample sequences between the methods SADF and GSADF. The GSADF test is then the rolling version of the SADF test, by nesting it in a loop, which increases the starting point to $r_1 \in [0, r_2 - r_0]$ each time it runs. The test is given by the formula:

$$GSADF_{(r_0)} = sup^{r_2 \in [r_0,1]}_{r_1 \in [0, r_2 - r_0]} \{ADF^{r_2}_{r_1}\}$$

As a result, both the SADF test and the rolling SADF test are replaceable by the GSADF test. Nonetheless, as pointed out by Bettendorf and Chen (2013), this procedure may fail to detect an early bubble if the starting window size is too large. The new bubble detection test covers more subsamples of data and has bigger window flexibility, being more efficient in detecting multiple exuberance behaviour when it occurs in the same data. Even though this procedure has never been used to detect bubbles in individual stock prices, Bettendorf and Chen (2013) used it for the detection of bubbles in the sterling dollar exchange rate and Phillips et al. (2014) in the NASDAQ index. I believe

that it can be applied to stock prices after the IPO, given that there is a consensus throughout the literature that they show evidence of explosive behaviour.

Furthermore, the detection of bubbles is only useful if it possible to data stamp the initial exuberance and the collapse of the bubble. So for the GSADF test Phillips et al. (2014) suggest a backward strategy for the SADF, given by the test statistic:

$$BSADF_{r_2}(r_0) = sup_{r_1(r_1 \in [0, r_2 - r_0])}\{ADF_{r_1}^{r_2}\}$$

The BSADF test executes a sup ADF test on a backward expanding sample sequence, by fixing the end sample at r_2, and recursively backward regressing up to the starting point, that can range between 0 and $r_2 - r_0$. The test is implemented repeatedly for each value $r_2$that belongs to the interval between $r_0$and 1. Through Monte Carlo simulations, Phillips et al. (2014) suggest that the initial window width should be chosen from $r_0 = 0.01 + \frac{1.8}{\sqrt{N}}$.

The next step is to determine the critical values, which are given by Phillips et al. (2014), and shown in figure 3, that are determined through numerical simulations with 2,000 replications and are obtained via Monte Carlo simulation.

	SADF			GSADF		
	90%	95%	99%	90%	95%	99%
Asymptotic critical values						
$r_0 = 0.190$	1.10	1.37	1.88	1.67	1.89	2.37
$r_0 = 0.137$	1.12	1.41	2.03	1.78	2.01	2.48
$r_0 = 0.100$	1.20	1.49	2.07	1.97	2.19	2.69
$r_0 = 0.074$	1.21	1.51	2.06	1.99	2.20	2.62
$r_0 = 0.055$	1.23	1.51	2.06	2.08	2.30	2.74
Finite sample critical values						
$T = 100, r_0 = 0.190$	0.98	1.30	1.99	1.65	2.00	2.57
$T = 200, r_0 = 0.137$	1.12	1.40	1.90	1.84	2.08	2.70
$T = 400, r_0 = 0.100$	1.19	1.49	2.05	1.92	2.20	2.80
$T = 800, r_0 = 0.074$	1.25	1.53	2.03	2.10	2.34	2.79
$T = 1600, r_0 = 0.055$	1.28	1.57	2.22	2.19	2.41	2.87

Figure 3 The asymptotic and finite sample critical values of the SADF and GSADF tests against an explosive alternative. (Source: Phillips et al. (2014))

In order to perform the tests, determine the critical values and the data stamping there is a Matlab and a Gauss code that allows the implementation of this procedure. In order to test for bubbles in IPO firms, I had to make the tests and determine the critical values for each firm, thus the critical values will not be the same for every company.

6. Empirical Results

In this section I will present the results for the 9 companies selected for this study. This will serve as an introduction for the following section that provides an almost one year analysis of the performance of ReWalk Robotics Inc., which is the company that presented clearer signs of the presence of a bubble in the first trading week. The analysis is done case-by-case, given that it would not make sense to create an artificial IPO index because a bubble in one IPO might be offset by other IPO bubbles. In order to detect a bubble in an IPO it is not enough to analyse the GSADF test statistic and compare it with a chosen critical value. It is also necessary to analyse the time series of each IPO and the corresponding sequence of ADF_t statistics, mostly to observe the relative variation in the stock price, but also to assess if the period of exuberance is sufficient to corroborate the presence of a bubble.

6.1. Loxo Oncology Inc.

According to the results shown in table 2, there is enough statistical evidence to reject the null hypothesis of non-explosiveness at 1% significance level, which would suggest the presence of a bubble in the stock price of Loxo Oncology Inc. according to the GSADF test. Therefore, it is necessary to study the time series of the stock price and the corresponding sequence of ADF_t statistics, which are illustrated in figure 4. Then, it is possible to observe that there is an exuberant behaviour during 5 periods, which corresponds to a 25 minute time frame. During that period the price increased from 12.95 to 13.21, therefore less than 1%. Considering that the

Loxo Oncology Inc.	t-statistic
GSADF	3.053171
CV 1%	2.976698
CV 5%	2.214975
CV 10%	1.977487

Table 2 Tests for explosive behaviour in Loxo Oncology Inc. stock price after IPO

IPO price was 13.07, it is not accurate to say that there is an explosive behaviour.

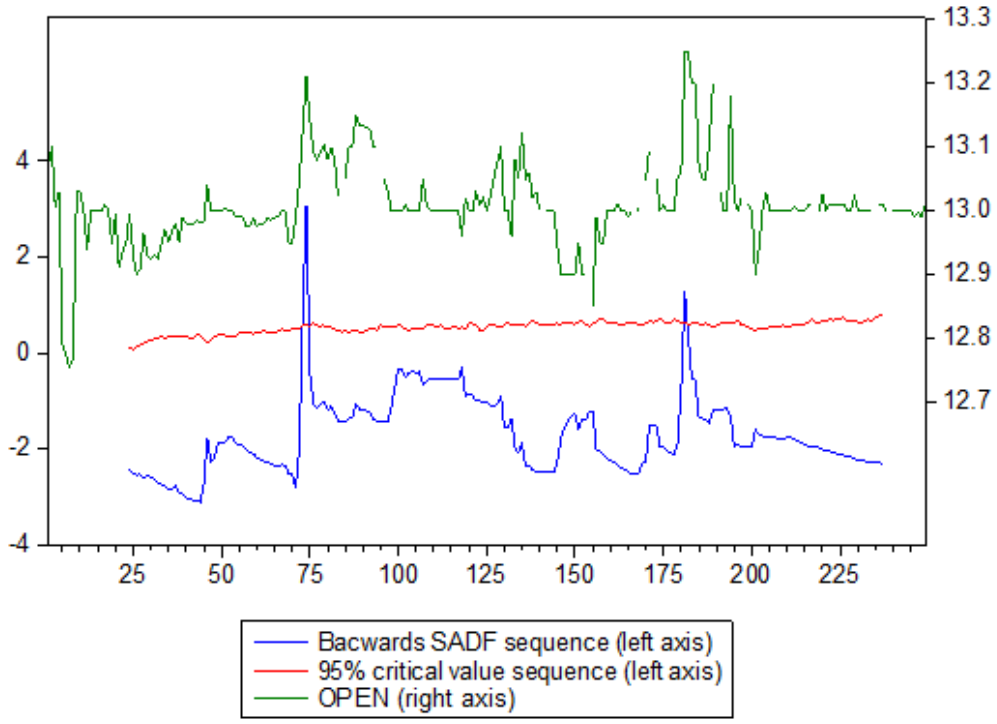

Figure 4 Time series of Loxo Oncology Inc. stock price and the corresponding sequence of ADF_t t-statistics

6.2. ReWalk Robotics Ltd

A GSADF test result of 2.223700 is larger than the 2.212489 5% significance level, meaning that there is enough statistical evidence to reject the null hypothesis of non-explosiveness at a 5% significance level. Considering the times series performance of the stock price and the corresponding sequence of ADF_t statistics, shown in figure 5, it is possible to conclude that we are in presence of exuberant behaviour throughout the initial 41 periods of 5 minutes, therefore consistent with the evolution of the stock price that started at an IPO price of 12 dollars and increased to 25.60 and 38.40 dollars in the first and second day of trading, which is an appreciation of

ReWalk Robotics Ltd	t-statistic
GSADF	2.223700
CV 1%	2.930040
CV 5%	2.212489
CV 10%	1.995492

Table 3 Tests for explosive behaviour in ReWalk Robotics Ltd stock price after IPO

113.33% and 220%, respectively, relative to the initial IPO price. Moreover, during the first day it reached a maximum of 29.048, 142% above the IPO price. This price performance suggests that the IPO was underpriced, which will be the object of my analysis in section 7.

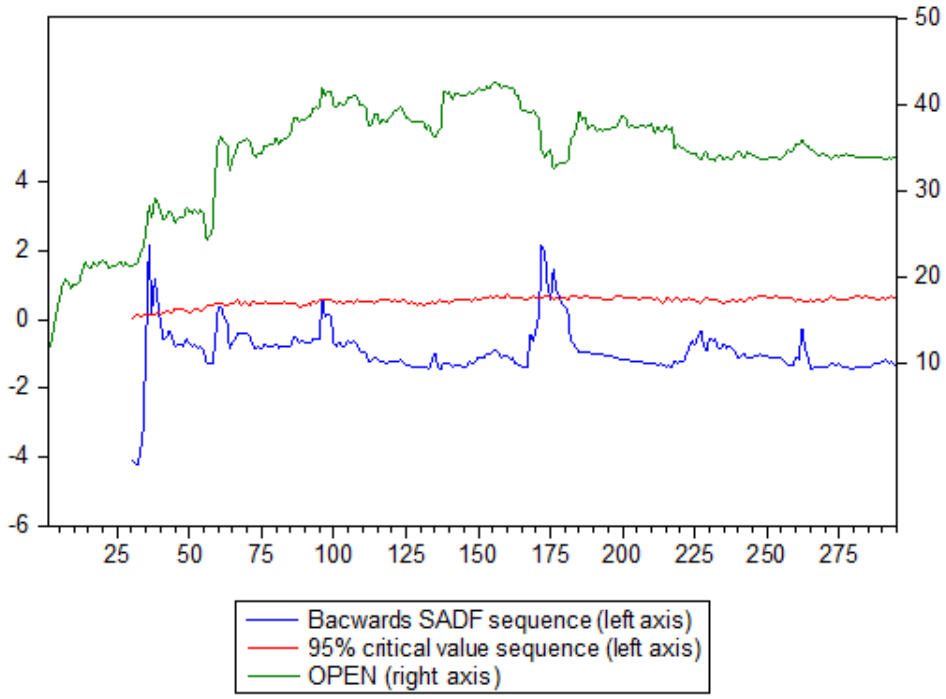

Figure 5 Time series of ReWalk Robotics Ltd stock price and the corresponding sequence of ADF_t t-statistics

6.3. Tokai Pharmaceuticals Inc.

In this case there is enough statistical evidence not to reject the null hypothesis of non-explosive behaviour, given that the GSADF test is lower than the 10% critical value, as shown in table 4. Moreover, 25 minutes after the IPO the

Tokai Pharmaceuticals Inc.	t-statistic
GSADF	1.362959
CV 1%	2.922230
CV 5%	2.263685
CV 10%	2.025750

Table 4 Tests for explosive behaviour in Tokai Pharmaceuticals Inc. stock price after IPO

stock price reached 30 dollars, a significant variation when compared with the IPO price of 18.63 dollars[1], however undetected by the GSADF test.

6.4. Affimed NV

Judging from the GSADF test shown in table 5, there is enough statistical evidence to reject the null hypothesis of non-explosiveness at a 5% significance level, however after analysing the times series of the stock price in figure 6, it is possible to say that we are not in the presence of a bubble, given that the price has a downward sloping trend from the 6.95 dollars IPO price, suggesting that the IPO was overpriced.

Affimed NV	t-statistic
GSADF	2.717232
CV 1%	2.987469
CV 5%	2.275646
CV 10%	2.023454

Table 5 Tests for explosive behaviour in Affimed NV stock price after IPO

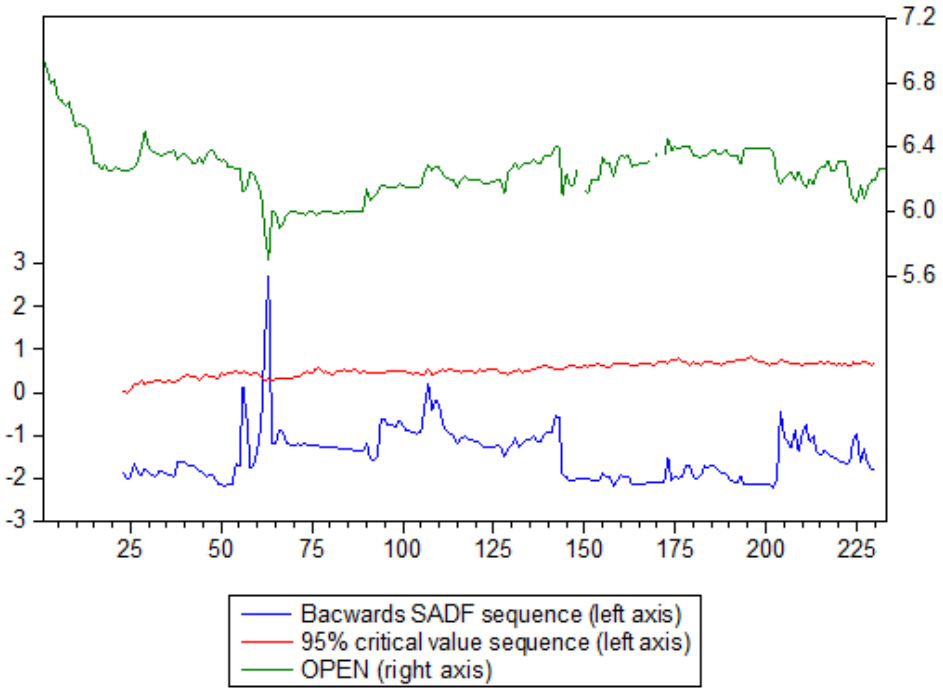

Figure 6 Time series of Affimed NV stock price and the corresponding sequence of ADF_t t-statistics

[1] Time series of Tokai Pharmaceuticals Inc.'s stock price and the corresponding sequence of ADF_t t-statistics are shown in the Appendix

6.5. Alibaba Group Holding Ltd

The Alibaba's GSADF test is higher than the 5% significance level, so there is enough statistical evidence to reject the null hypothesis of non-explosiveness in the stock price. By observing figure 7 though, it is possible to observe that 15 minutes after the IPO, the stock price almost reaches 100 dollars, from an IPO price of 92 dollars, but 5 minutes later drops to 93 dollars and continues a downward trend after that until in stabilizes at 88 dollars, showing evidence of an overpriced IPO, therefore it is not possible to claim the existence of a bubble.

Alibaba Group Holding Ltd	t-statistic
GSADF	2.809650
CV 1%	2.927949
CV 5%	2.243015
CV 10%	1.994326

Table 6 Tests for explosive behaviour in Alibaba Group Holding Ltd stock price after IPO

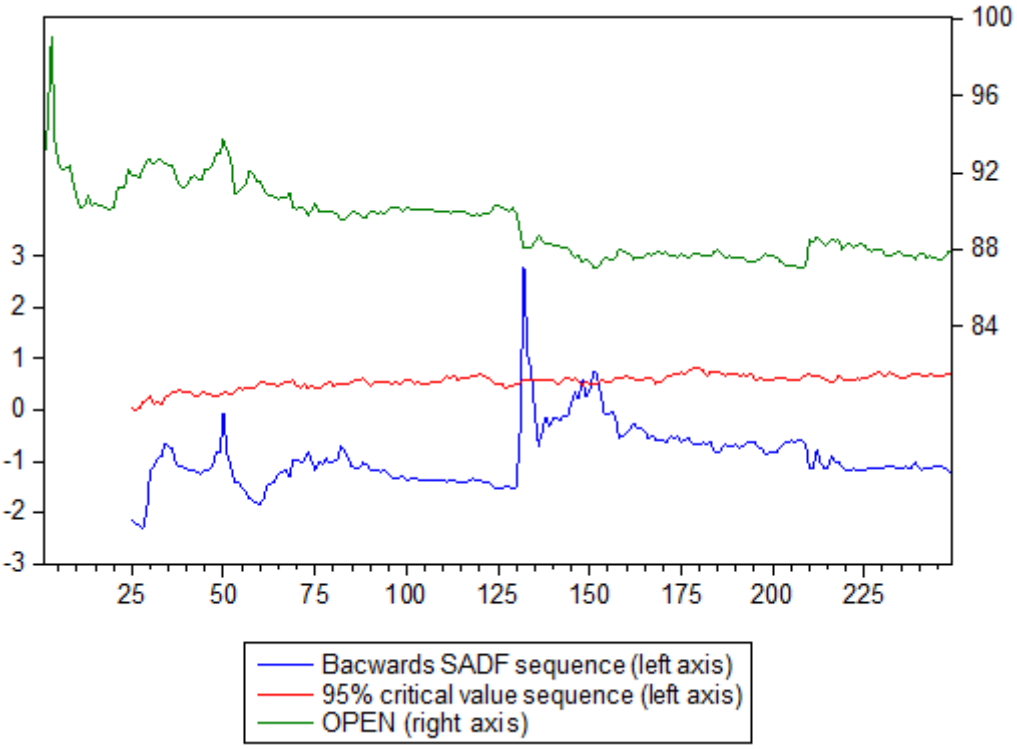

Figure 7 Time series of Alibaba Group Holding Ltd stock price and the corresponding sequence of ADF_t t-statistics

6.6. Vascular Biogenics Ltd

According to table 7 where it is possible to see that a GSADF test of 4.8 is higher than the 1% significance level of 2.849, there is enough statistical evidence to reject the null hypothesis of non-explosiveness in the stock price. When analysing the time series of the stock price and the corresponding sequence of ADF_t t-statistics, shown in figure 8, there is evidence of an exuberant behaviour during the sixth day of trading, where the stock price goes from a relatively stable price of 6 dollars to a price of 7.29 dollars. However, the price stabilizes later in the 6 dollars, which suggests that the IPO was fairly priced.

Vascular Biogenics Ltd	t-statistic
GSADF	4.805509
CV 1%	2.848864
CV 5%	2.274936
CV 10%	2.028087

Table 7 Tests for explosive behaviour in Vascular Biogenics Ltd stock price after IPO

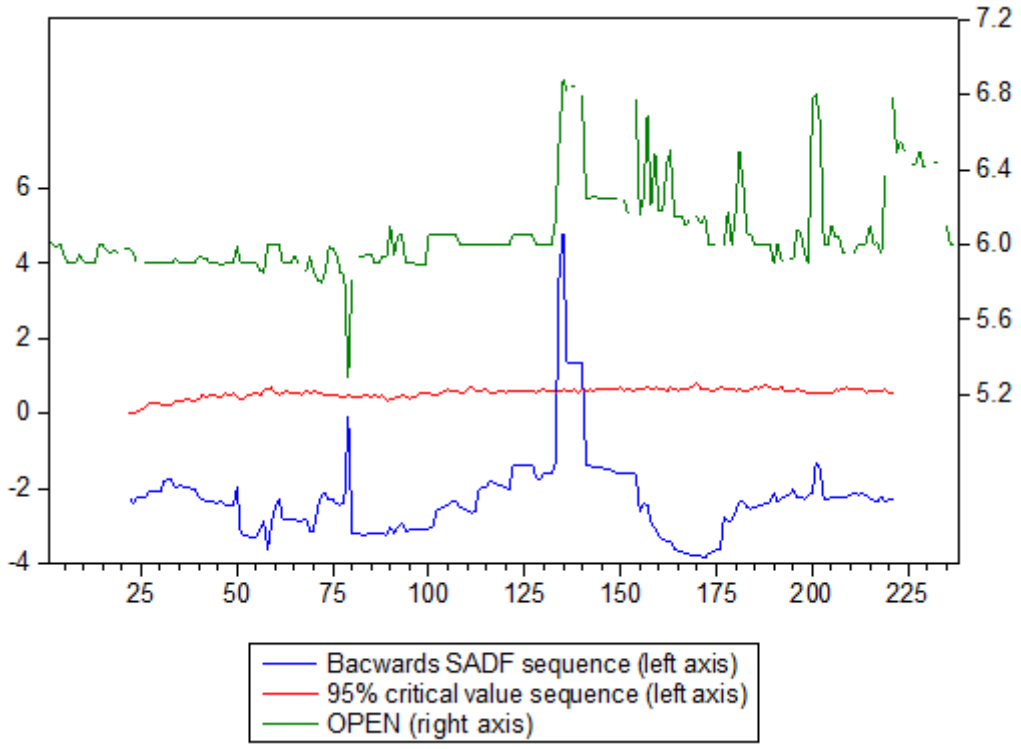

Figure 8 Time series of Vascular Biogenics Ltd stock price and the corresponding sequence of ADF_t t-statistics

6.7. Vivint Solar Inc.

In the Vivint Solar Inc. case there is enough statistical evidence to not reject the null hypothesis of non-explosiveness in the stock price, given that the GSADF test is lower than the 10% significance level, observable in table 8. In fact, the stock price at the end of the sample was of 13 dollars, 30% less than the IPO price of 17 dollars[2], suggesting that the IPO was overpriced.

Vivint Solar Inc.	t-statistic
GSADF	1.725490
CV 1%	2.927949
CV 5%	2.243015
CV 10%	1.994326

Table 8 Tests for explosive behaviour in Vivint Solar Inc. stock price after IPO

6.8. Mobileye NV

In the same line with the previous case, Mobileye NV GSADF test presented in table 9 is lower than the 10% significance level, thus there is enough statistical evidence to not reject the null hypothesis of non-explosiveness in the stock price. Even though the stock price showed an erratic behaviour[3], the relative price has not changed significantly and finished the period in analysis close to the IPO price, suggesting that the IPO was fairly priced.

Mobileye NV	t-statistic
GSADF	1.540790
CV 1%	2.927949
CV 5%	2.244302
CV 10%	1.994326

Table 9 Tests for explosive behaviour in Mobileye NV stock price after IPO

[2] Time series of Vivint Solar Inc.'s stock price and the corresponding sequence of ADF_t t-statistics are shown in the Appendix

[3] Time series of Mobileye NV's stock price and the corresponding sequence of ADF_t t-statistics are shown in the Appendix

6.9. Cyberark Software Ltd

Cyberark Software Ltd shows signs of the presence of bubbles, having a GSADF test higher than a 1% significance level, as illustrated in Table 10, thus there is enough statistical evidence to reject the null hypothesis of non-explosiveness in the stock price after the IPO. Figure 9, clarifies that there was an episode of exuberance in the first 24 hours, where the price increased 40%, from 25 to 35.2 dollars, followed by equilibrium in the 32 dollars mark. This suggests the existence of a bubble and that the IPO was underpriced.

Cyberark Software Ltd	t-statistic
GSADF	3.025236
CV 1%	2.927949
CV 5%	2.243015
CV 10%	1.994326

Table 10 Tests for explosive behaviour in Cyberark Software Ltd stock price after IPO

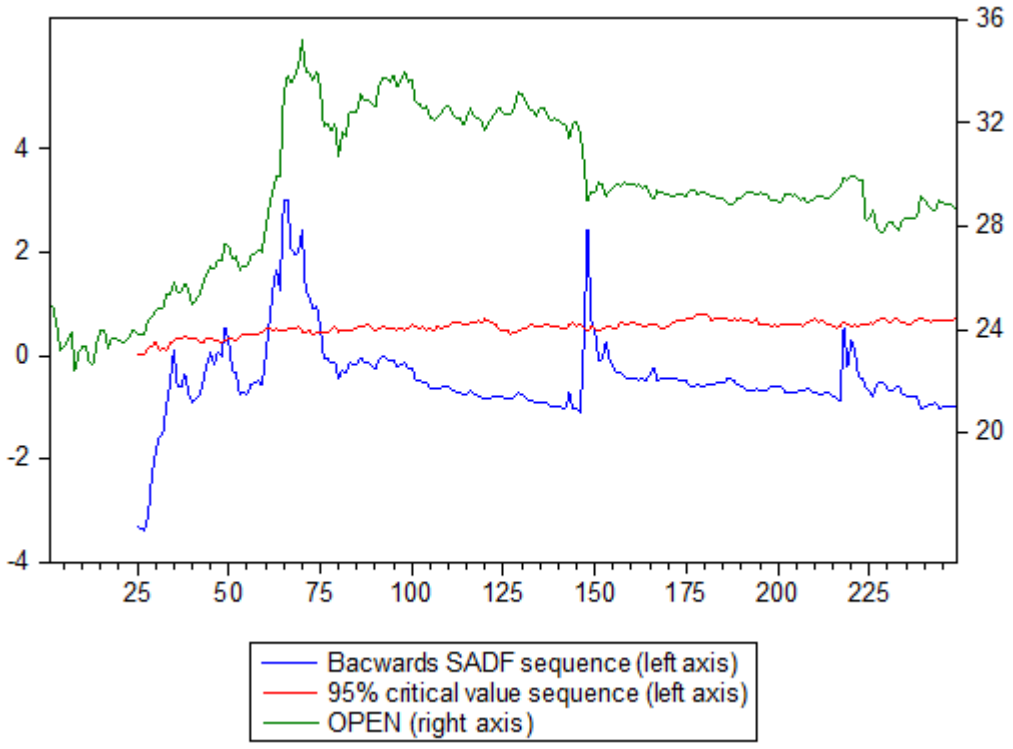

Figure 9 Time series of Cyberark Software Ltd stock price and the corresponding sequence of ADF_t t-statistics

7. Case Study: ReWalk Robotics Ltd

In the previous section I conclude that there is statistical evidence of exuberant behaviour in the stock price of ReWalk Robotics Ltd. Therefore, I will make a further analysis about the stock behaviour after the IPO of this company in order to determine if the initial overshooting was justified or not.

ReWalk Robotics Ltd[4] was founded in 2001 by Dr Amit Goffer[5], who was involved in an accident that left him paralyzed, is an Israeli emerging medical device company that develops, advertises and sells its proprietary wearable robotic exoskeletons (as seen on figure 10) for individuals with spinal cord injury. The company only sells two products, the ReWalk Rehabilitation, adjustable for different patients and indicated for use in a clinical rehabilitation environment, and the ReWalk Personal, suitable for home and community use, that can help people sit, stand, and walk with the assistance of a trained companion.

Figure 10 ReWalk R (Source: Company presentation)

On September 12, 2014, ReWalk Robotics Ltd raised 36 million dollars on NASDAQ, selling 3 million shares for 12 dollars each at a company value of 136 million dollars. According to Globes Online (2014), an Israeli business news agency, the company's IPO price and number of shares sold was lower than initially anticipated since they were aiming at a company value between 250 and 300 million dollars, through an IPO price between 13 and 14 dollars and a

[4] formerly Argo Medical Technologies Ltd

[5] Amit Goffer currently holds a 3.7% stake in ReWalk

number of shares sold of 4 million, raising therefore around 56 million dollars. On the other hand, Bidness Etc, a financial media platform, estimates that the company expected gross IPO proceeds of 50 million dollars, selling 3.4 million shares at a price range of 14 to 16 dollars. They argue that the company reviewed their expectations due to an expected muted demand from retail and institutional investors.

Financial data prior to the IPO was limited and it is difficult to justify a market valuation of 136 million dollars given that the company had a revenue of 1.6 million dollars and a loss of 12.2 million in 2013, making it an unprofitable business with very low level of revenue. Therefore it is possible to conclude that ReWalk Robotics Ltd is an emerging company and this valuation can only be supported by the belief that their business will grow and investors expect the price to increase in the long term. For that reason, I will make a SWOT analysis in order to understand the current Strengths and Weaknesses of the company and their position in the market and I will analyse the Opportunities and Threats that it will face with the intention to become a mature company and reward the investors. This SWOT analysis is supported by the analyst reports from Barclays Capital Inc., Canaccord Genuity Inc., and Jefferies Group LLC, in their published reports of October 7, 2014[6].

7.1. Strengths

The biggest strength ReWalk Robotics Ltd has is being the first to receive approval from the Food and Drug Administration (FDA) for its personal device, which gives them the "first-mover" advantage in the US market, where the personal use market is significantly larger than the rehabilitation market.

[6] Barclays Capital Inc. and Jefferies Group LLC served as book runners for the IPO of ReWalk Robotics Ltd and collectively have an option to buy 450,000 shares

In addition, the ReWalk device is considered to be better and cheaper than the competitive products, having incorporated a patented tilt-sensor technology that gives patients a natural ambulatory motion, thus not requiring tethers or switches for walking. The device is also building clinical evidence of improvement in various related conditions including reduction in pain and spasticity, improving bowel and urinary tract function, increase in lean muscle mass, decrease in fat, reduced hospitalization, and less dependence on medications, thus not only improving the mobility of the patient, but also his quality of living.

Their strategic alliance with Yaskawa Electronic Corporation and the contract with Sanmina Corporation, allows them to cover the Asian market and scale the manufacture of devices with an expert in medical devices.

7.2. Weaknesses

The few studies conducted show that the ReWalk device can provide clinical benefits and help patients to improve function, however the number of studies and cohorts that benefited from the device is still very small and there are limited published data on the industry, which will result in costly and time consuming studies in order to convince private insurers and individuals of the benefits of the device. Moreover, the device costs between 60,000 and 70,000 dollars, therefore requiring a reimbursement policy, given that the patients who would have the financial capacity to purchase this device are a reduced part of the target group.

Furthermore, ReWalk's business is quite training intensive, since it requires not only medical and rehabilitation centres to be trained on the devices before they can train and certify patients, but also train and adapt each equipment to the patient, a process that can demand dozens of sessions.

7.3. Opportunities

On July 2014, the Bronx Veterans Affairs (Bronx VA) announced they would support the procurement of ReWalk Personal and would provide staff the support needed for all eligible veterans with paraplegia due to a Spinal Cord Injury (SCI), being the first VA to adopt this measure. The company has the opportunity to spread around the rest of the VAs, reaching a target of around 42,000 veterans eligible for medical care. Additionally, a major German insurer is willing to cover ReWalk devices on a case-by-case basis, which creates a precedent that could lead to the reimbursement from other private insurers.

In order to grow at a rapid pace, ReWalk must capitalise their "first-mover" advantage in the personal use market, thus accelerating the reimbursement agreements and their presence in the markets outside the United States.

There is also room for the adaptation of the device to other patients with mobility impairment that resulted from quadriplegia, stoke, multiple sclerosis and cerebral palsy.

7.4. Threats

The main threat for ReWalk Robotics Ltd is the uncertainty around reimbursement, given that there is no common policy of coverage and reimbursement in place among third party payers in the US and outside the US. With the exception of the Bronx VA, there has been a case in Germany where a private insurer agreed to provide the device on a case-by-case basis. If a case-by-case decision becomes the only way of reimbursement for the patients, then it will become costly for the company to prove in each individual case the benefits of the device, which would force the company to find a different payment method, such as leasing, resulting in lower gross margin and revenue streams in the first years. In order to overcome the scepticism from insurers,

ReWalk are likely to engage in additional studies and longer term follow up to build clinical and cost-effectiveness arguments for those devices.

The high costs and time consuming penetration in the market might also give the opportunity for the competitors to develop equally suitable equipment at a lower cost, which would negatively affect ReWalk efforts of gaining a significant market share.

After analysing the strengths, weaknesses, opportunities and threats of ReWalk Robotics Ltd it is possible to conclude that there are many variables and stakeholders they cannot control and it may impact their ability to prosper in a new market, however they are the company furthest along in the exoskeleton market and in a leading position, therefore it might require investors some years before they can capitalise their investment.

7.5. The Stock Behaviour after the IPO

As seen in figure 11, in the first day of trading the share price more than doubled, having an appreciation of 113.33% to a value of 25.60 dollars per share. In the second day it was trading at a price of 38.40 dollars, 220% more than its IPO price and 230% at the end of three days. This initial price behaviour gave reasons to believe that the IPO was underpriced, which was the initial reaction of the financial media. The financial news analysts StreetInsiders.com, pointed out on an article published on the second trading day, that the ReWalk Robotics IPO was the best performing IPO of 2014, an opinion shared by Bidness Etc, surpassing GoPro's IPO that had an overshooting of 191%. However, StreetInsiders.com was predicting already that the stock price of ReWalk had the first signs of a bubble.

Figure 11 Time series close price of ReWalk Robotics Ltd

Initially, the analysts from Barclays advocated a price target of 28 dollars, and Canaccord and Jefferies a target price of 26 and 39 dollars, respectively. They also estimated that the company would become profitable in 2017 and revenues would grow at a three digit rate in the upcoming years.

On the subsequent reports that followed quarterly result announcements, the three groups of analysts negatively reviewed their estimates, downgrading their price target, profitability predictions and revenue growth, which is consistent with the stock behaviour that went from a maximum of 38.40 dollars to a price lower than the IPO price, stabilizing around 10 dollars per share. The main reason for this downgrading was the slower growth of revenue, which was primarily a result of lower profit margins and subsequently of the decrease of unit sales. This underachieving performance was caused by the longer than expected selling cycle and the scepticism from the insurers in reimbursing their patients for the purchase of the devices, making ReWalk concede leases, in order to sell more products and increase their sample for clinical studies. The reimbursement policies were still made case-by-case, resulting in a higher cost of goods sold for the company and a lower price.

Consequently, the estimates from the analysts became less optimistic and they were still estimating an unprofitability scenario at least until 2018, with a slower revenue growth rate. On August 7, 2015, Barclays was the most

pessimistic about ReWalk, having a target price of 10 dollars, while Canaccord and Jefferies had a target price of 16 and 27 dollars, respectively. In the same report, Barclays noted that with the current level of cash and the respective burn rate ReWalk would have cash available for 4 additional quarters.

8. Conclusion

The purpose of this dissertation has been to examine the price performance of newly listed companies, by determining if their IPO price was overvalued or undervalued. Given that the consensus tells us that IPO firms are on average underpriced on a short term basis and underperform in the long run, I wanted to test if it possible to predict the price behaviour through the detection of exuberant behaviour in the first trading days. I chose to use intraday data and restrict the analysis to the first 5 to 6 days due to having limited access to intraday data and to the fact that many authors argue that the reaction that can be directly attributed to the IPO are observed in the first 6 to 15 days. After that period there is a wider number of factors that can influence the price performance of the company, therefore it is possible to determine if the IPO was underpriced or overpriced within the first 5 to 6 days.

This dissertation introduces a new recursive right tailed unit roots testing procedure and data stamping algorithm that detects multiple bubble events, which is a method never before used in the IPO market, but I believe that if it can be used in a stock index to detect multiple bubbles, it can also be used in a case-by-case price performance to detect bubble events in the IPO market.

This new testing procedure provides investors with a predictive power tool that they may use when investing in IPO firms and it allows regulators to take action in order to ensure a smooth collapse of the bubble, since they can anticipate it. However, this test of explosiveness cannot be used in order to determine investment strategies, given that they need a minimum of historical prices, therefore this test is not useful to assess whether to invest or not in an IPO firm before the first issue of stocks. This testing mechanism also does not take into account an initial period of observations.

From the 9 IPO firms in study, I concluded that 3 firms shown an explosive behaviour in one or more sub-periods of the sample, having ReWalk Robotics Ltd shown the widest period of explosive behaviour, where the price more than tripled in the first 3 trading days, suggesting a huge underpricing. Also Cyberark Software Ltd presented some evidence of the presence of a bubble, having the price increased by 40% in the first 24 hours, and Vascular Biogenics Ltd had a small sub-period of explosive sequence. However, the GSADF test detected a bubble in Affimed NV price performance, which was not expected since they had a consistent price underperformance throughout the sample in analysis.

Finally, I made a more comprehensive analysis on the ReWalk Robotics Ltd, considered the most successful IPO in 2014, throughout their first year as a listed company. I found that the company's financial history of residual revenues and consistent losses does not support the optimist of investors, thus I made a deeper analysis of the business and even though they have a competitive advantage and a product that can revolutionize the market, they are having some difficulties with the reimbursement policy of insurance companies, which is making them underperform to a price below the IPO price.

This test procedure can be further explored in future research. Not only can it be applied to different markets, such as SEOs or CDSs, but it also can be further adapted to the IPO market, by testing more companies and maybe increasing the sample window.

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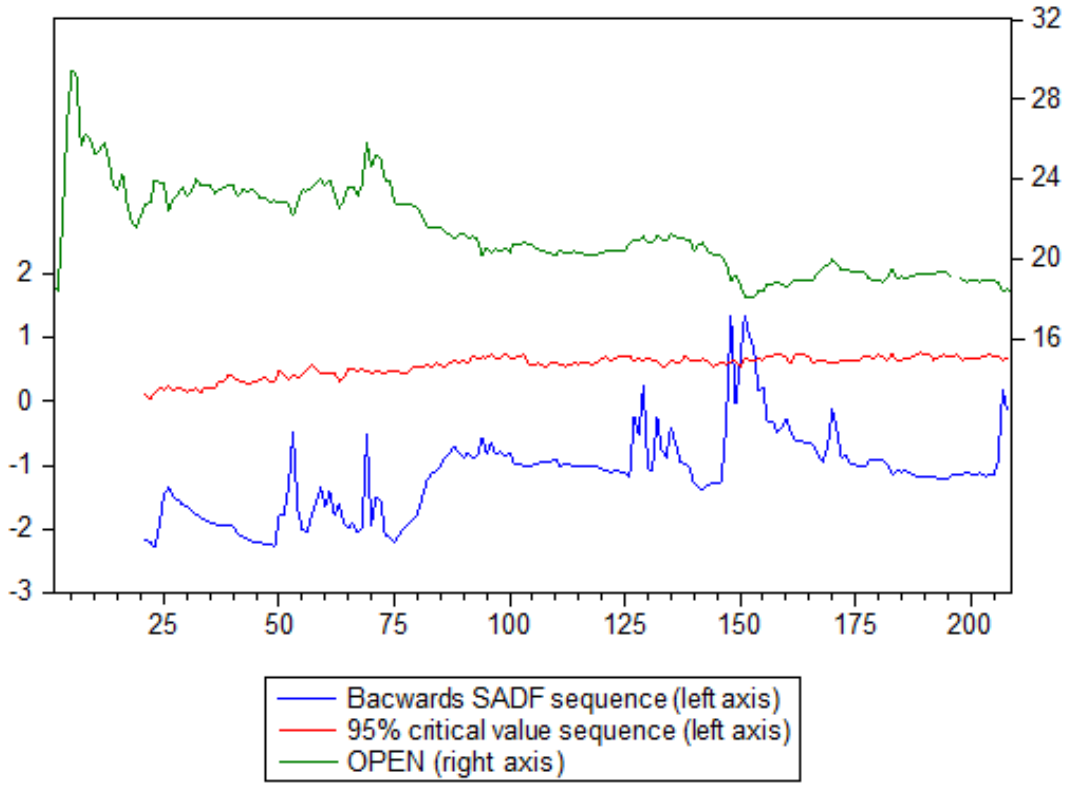
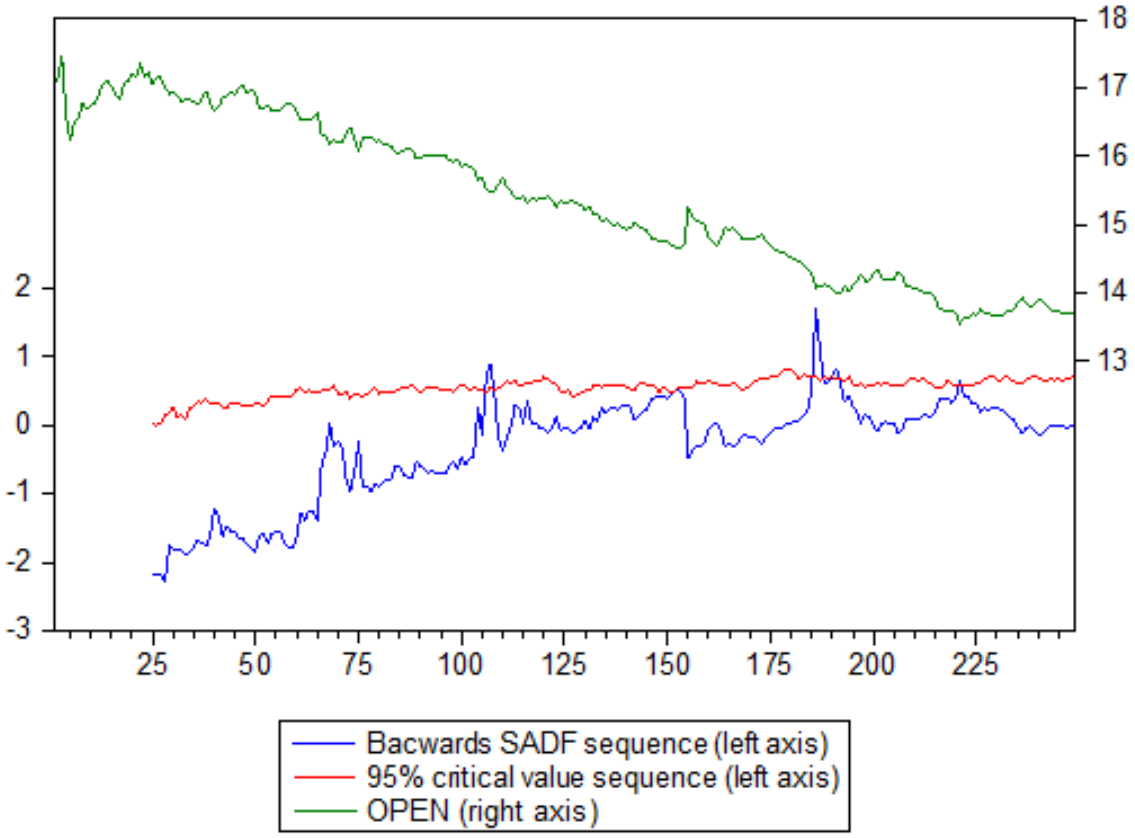
10. Appendix

10.1 Time series of Tokai Pharmaceuticals Inc. stock price and the corresponding sequence of ADF_t t-statistics



10.2 Time series of Vivint Solar Inc. stock price and the corresponding sequence of ADF_t t-statistics



10.3 Time series of Mobileye NV stock price and the corresponding sequence of ADF_t t-statistics