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Equity option listing in the UK: a comparison of market-based research methodologies

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Abstract

This study compares the results generated from a range of parametric models and two classes of non-parametric models used in event studies. The models are applied to test the information content of equity option listing in the UK. The results indicate that Corrado's [Journal of Financial Economics 23 (1989) 385] rank test or bootstrapping the market model should be adopted in conjunction with parametric methodologies in the computation of mean abnormal returns. When computing cumulative abnormal returns, the ZD test is recommended. It would appear that the equity optioning effect in the UK has diminished over time. This result may be explained by the market completion hypothesis. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Following the stock market crash in 1987, derivative securities were singled out as being a major contributory factor. The media's perception was that index futures and options were culpable (see Lee and Ohk, 1992). Derivative securities image have been further tarnished by the huge losses which some financial institutions and their corporate clients have suffered from trading in recent times

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(see Sinkey and Carter, 1999). The issue that academics, practitioners and the regulatory community are concerned about is whether or not trading in derivative securities impacts upon the underlying cash markets.

1.1. Equity options literature

Black and Scholes (1973) option pricing model (OPM) provides the foundation for the study of equity options. In their OPM, equity option listing cannot have an effect on the price of the underlying security since an option payoff can be exactly replicated from the pool of existing financial instruments, and is therefore, a redundant security. Cao (1999) points out that when the assumptions of complete competitive and frictionless markets are relaxed, the optioning of equities may affect the price of the underlying asset. A number of theories have been proposed to explain such effects.

Detemple and Selden (1991) provide theoretical justification for an increase in the equilibrium price of the stock and a decrease in the volatility of its rate of return with the introduction of an option. They demonstrate that when the market is incomplete the option market and the cash market will, in general, interact so that the valuation of the optioned stock and the option is a simultaneous pricing problem. Conrad (1989) analyses a price effect surrounding optioning of stocks in relation to the trading behaviour of dealers in the context of the model proposed by Shleifer (1986). A temporary price effect would be consistent with a liquidity/supply related price pressure. Alternatively, a permanent price effect would support the 'imperfect substitutes' or 'market segmentation' hypothesis. Cao (1999) demonstrates that introducing derivative assets increases the incentive to acquire private information. This increased informational efficiency causing the price of the underlying asset to be higher on average in the more complete market. Consequently, the market becomes more complete with the introduction of options. This model also predicts that the impact on the cash market diminishes with subsequent listings of options.

Conrad (1989), Detemple and Jorion (1990) and Sorescu (1999) provide empirical evidence for price effects surrounding the optioning of stocks in the US Conrad examines the period 1974–1980, reporting that the introduction of options causes a permanent price increase. Detemple and Jorion contribute to the debate by analysing a much larger sample over an extended sample period: 1973–1986. They confirm the significant positive price effect reported by Conrad. In addition, they examine the persistence of the observed price effect. Their analysis suggests that the price effect diminishes over time, a result which they contribute to market completion following the introduction of options on stock indices in 1982. Sorescu (1999) reports positive abnormal returns for options listed during 1973 to 1980 and negative abnormal returns for options listed in 1981 and later. This result is consistent with the market completion hypothesis suggested by Detemple and Jorion.

Watt et al. (1992) contribute to the literature by providing UK evidence. They report that option listing is associated with a temporary price increase immediately prior to listing, lower unsystematic risk, lower total risk, an increase in the efficiency with which prices adjust to new information and a significant decline was observed in skewness of returns.

1.2. Event study methodologies

Event study methodology has been employed extensively in the accounting and finance literature since the seminal papers of Ball and Brown (1968) and Fama et al. (1969). Campbell et al. (1997) identify an early example of this type of methodology as far back as Dolley (1933). The validity of event studies has received considerable academic attention, with the result that a considerable number of refinements and additional tests have been proposed to reinforce the basic model. One school of thought argues that even though the Ball and Brown approach, with the single index market model as the returns generating metric, tends to violates the econometric assumption which the model is rooted in, such violations generally do not alter qualitative outcomes. Empirical evidence to support this argument is provided by Brown and Warner (1985), Chandra et al. (1990, 1995) and Burnett et al. (1995).

A more pessimistic view regarding the performance of the standard event study methodology and Patell's (1976) standardised residual test is adopted by Coutts et al. (1994). In response to the econometric weaknesses documented in Coutts et al. (1994), Coutts et al. (1995) propose the ZD test. They clearly demonstrate that accounting for multiple mis-specification of the market model leads to significantly different results than would be obtained when computing cumulative abnormal returns vis-à-vis Patell's standardised residual test.

An approach that has been adopted by researchers to reinforce conclusions drawn from event studies has been to adopt a non-parametric rank test in conjunction with the basic model (see Opong, 1995; Walmsley et al., 1992). A non-parametric technique that has not been adopted to a great degree, in the context of event studies, is bootstrapping. Though it has been applied in other finance contexts (see Pan et al., 1997; Brock et al., 1992; Malliaropulos and Priestly, 1999). This approach differs significantly from the rank-based tests. Whereas rank tests utilise abnormal returns which are generated from a potentially mis-specified beta, bootstrapping and robust regression adjust the beta estimate which in turn produces the abnormal returns.

The current study re-examines the price effect associated with equity option listing in the UK. It is distinct in terms of the methodologies employed and the time period studied. Also, it aims to make a contribution to the event study literature by comparing various methodologies which have been adopted.

The remainder of this paper is organised as follows. Section 2 outlines UK data set studied. Section 3 outlines the classes of parametric and non-parametric methodologies. Section 4 reports the empirical results. A belief conclusion summarising the main findings is contained in Section 5.

2. Sample

The sample spans the period 1978 to 1997, which includes the amalgamation of the London Traded Options Market (LTOM) and the London International Financial Futures Exchange (LIFFE) in 1992. Over this period there were 115 equity option listings between the two exchanges. Listing dates were provided by LIFFE. The study includes equities that had Puts and Calls listed simultaneously, this did not occur on LTOM until 1981. As a consequence, 21 equity options were deleted from the sample for the period 1978–1981. In line with the findings of Peel et al. (1993), with respect to the crash of October 1987, five listings that occurred within 6 weeks at either side of the crash were removed so as to minimise the influence of unrepresentative equities. Of the remaining 89 listings 16 were removed due to the non-availability of data. A further 25 listings were deleted as there was not enough data available to employ an event study methodology with a 230-day estimation period. Two companies were lost due to bankruptcy and unrepresentative trading characteristics which left 49 equity option listings.

3. Methodology

The methodologies employed in the study is made up of a number of parametric and non-parametric event study models. The tests, listed below, have been employed in the empirical literature to varying degrees for the last three decades. They have been classified in terms of computing mean abnormal returns and cumulative abnormal returns.

3.1. Methodologies used for computing mean abnormal returns

Market-based research, or event study methodology, popularised by Beaver (1968) and Ball and Brown (1968), is an empirical investigation into the relationship between security prices and an economic event. Initially, this methodology requires the calculation of returns. For this study, daily dividend adjusted share prices were downloaded from Datastream, from which daily logarithmic returns were calculated using:

$$y_{i,t} = \ln\left[\left(P_{i,t} + D_{i,t}\right)/\left(P_{i,t-1}\right)\right]$$

$$x_{i,t} = \ln\left(P_{m,t}\right) - \ln\left(P_{m,t-1}\right)$$

where $P_{i,t}$ is the price of security i on day t; $D_{i,t}$ is the dividends paid during period t; $P_{i,t-1}$ is the price of security i at the end of period $t-1$; and $P_{m,t}$ is the price of the market index on day t.

The returns generating process, or benchmark, used to assess whether or not an economic event results in ‘abnormal’ returns, is the single-index market model. It posits a linear relationship between the returns on a given security and a market portfolio: given by

$$y_{it} = \alpha_i + \beta_i x_{it} + u_{it} \quad i = 1,\ldots,N, \quad t = 1,\ldots,T. \tag{1}$$

The α_i and β_i coefficients are security specific Ordinary Least Squares estimates, u_{it} is the unpredictable component of the return y_{it}. Empirical analysis involves collecting returns data for N securities over the estimation and test period, all of which experienced the same event.

In this study, $T = 140$ trading days, while $e = 151$ (event day) and the last day in the event period $(T+m)$ is $T = 161$. Fisher (1966) pointed out the problems that are caused by non-synchronous prices in the calculation of returns. This problem is magnified with shorter differencing intervals and thinly traded equities. Cohen et al. (1986) provide a general specification for the calculation of beta, adjusted for non-synchronous prices. Their beta estimator is calculated as follows:

$$\beta_i = \frac{\left(\sum_{+n=1}^{+N} \beta_i^{+n} + \beta_i^0 + \sum_{-n=1}^{-N} \beta_i^{-n} \right)}{1 + 2 \sum_{+n=1}^{+N} \rho_{+n}} \tag{2}$$

where $+N$ is the number of leads in the estimator; $-N$ is the number of lags in the estimator; β_i^{+n} is the lead security beta; β_i^{-n} is the lagged security beta; and ρ_n is the autocorrelation coefficient of the market index.

For each of the above models the bias associated with thin trading is adjusted for with maximum lags/leads set to ± 2. This is equivalent to Scholes and Williams (1977) and Fowler and Rorke (1983) asynchronous trading adjustments, respectively. The parameters from the estimated market model are used to generate forecasts of the security returns for the event period: days $T+1$ to $T+m$ in Fig. 1. Calculate the intercept coefficient (α_i) for firm i:

$$\alpha_i = \bar{y}_i - \beta_i \bar{x}_i \tag{3}$$

where $\bar{y}_t$ denotes the return on firm i averaged over the estimation period and $\bar{x}_i$ denotes the return on the market averaged over the estimation period. The

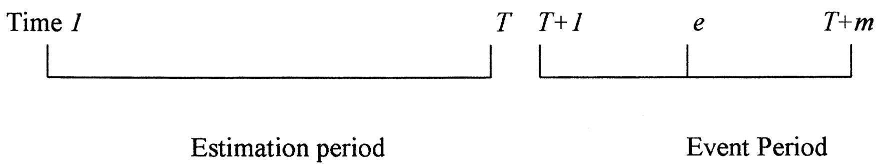

Fig. 1. Estimation and event periods.

abnormal returns for the estimation and event period are calculated as the difference between the predicted and actual returns:

$$u_{it} = y_{it} - \alpha_i - \beta_i x_{it} \tag{4}$$

$$u_{i\tau} = y_{i\tau} - \alpha_i - \beta_i x_{i\tau} \tag{5}$$

where $y_{i,t}$ and $x_{i,t}$ are actual returns over the estimation period and $y_{l,\tau}$ and $x_{i,\tau}$ are the actual returns over the test period. u_{it} and $u_{i\tau}$ are the individual securities abnormal return over the estimation and event period, respectively. Averaging the abnormal returns across all securities:

$$\mathrm{AR}_\tau = N^{-1} \sum_{i=1}^{N} u_{i\tau} \tag{6}$$

$$\mathrm{AR}_t = N^{-1} \sum_{i=1}^{N} u_{it} \tag{7}$$

The abnormal returns over the event period (AR_τ) are used to investigate whether equity option listing has resulted in significant abnormal returns. To test the hypothesis:

$$\mathrm{H}_0 : \mathrm{AR}\tau = 0 \quad \text{for all } \tau$$

versus

$$\mathrm{H}_1 : \mathrm{AR}\tau \neq 0 \quad \text{for some } \tau$$

we use the statistic:

$$t_\tau = \frac{\mathrm{AR}_\tau}{\sigma} \tag{8}$$

where σ is the standard deviation of the estimation period abnormal returns (AR_t), which under general conditions has a t distribution with $T-2$ df.

Rejection of the null hypothesis would indicate a significant price effect, which could possibly be either temporary or permanent. There is no prior theory to predict a reversal in the price effect reported by Watt et al. (1992) from being temporary to permanent. Therefore, a priori, we would expect that rejection of H_0 would indicate a persistent temporary price effect. Failure to reject H_0 may be explained by the market completion hypothesis. The sample period in this study encompasses the introduction of options on FT-SE 100 index. The London International Financial Futures and Options Exchange (LIFFE) launched a European style contract on the FT-SE 100 Index on 1st February 1990 with American style and flexible style contracts being launched on the same index in 1994 and 1995, respectively. In conjunction with the conventional event study methodology, outlined above, we also test H_0 with a range of parametric and non-parametric methodologies. These include:

(A) Patell's (1976) methodology;
(B) Coutts et al. (1995) ZD-test;
(C) Three group resistant line robust regression (see for example, Coutts et al., 1996);
(D) Test based on the Binomial distribution (see for example, Opong, 1995);
(E) Corrado's (1989) rank test;
(F) Walmsley et al. (1992) rank test;
(G) Bootstrapping (see for example, Malliaropulos and Priestly, 1999).

It would be cumbersome and detract from the clarity of the paper to outline each methodology in detail. The bootstrapping algorithm, with non-synchronous trading adjustments, is detailed in Appendix A as this modification is not available in the literature.

3.2. Methodologies used for computing cumulative abnormal returns

Coutts et al. (1995) provide an alternative specification to Patell's methodology, which they demonstrate does not have the correct standard error. However, an errata in Coutts et al.'s methodology makes it difficult to replicate their ZD test. The methodology presented here remedies these errors. Fig. 1 outlines the notation used for the estimation and test period. Again, as in Eq. (1), we have the single-index market model written in vector form as:

$$y_{it} = \mathbf{x}_{it}\beta_i + u_{it} \tag{9}$$

where $\mathbf{x}_{it} = (1,\ x_{it})$ and $\beta_i' = (\alpha_i,\ \beta_i)$ or, in matrix form as:

$$\mathbf{y}_i = \mathbf{X}_i\beta_i + \mathbf{u}_i \tag{10}$$

where $\mathbf{y}_i' = (y_{i1},\dots,y_{iT})$, $\mathbf{u}_i' = (u_{i1},\dots,u_{iT})$, and

$$\mathbf{X}_i' = (\mathbf{x}_{i1}',\dots,\mathbf{x}_{iT}') = \begin{bmatrix} 1,\dots,1 \\ x_{i1},\dots,x_{iT} \end{bmatrix}.$$

The estimated model is used to forecast m future observations $y_i^{*\prime} = (y_{i,T+1,\dots,}y_{i,T+m})$ using the matrix of future observations;

$$\mathbf{X}_i^{*\prime} = (\mathbf{x}_{i,T+1}^{*\prime},\dots,\mathbf{x}_{i,T+m}^{*\prime}) = \begin{bmatrix} 1,\dots,1 \\ x_{i,T+1,\dots,}x_{i,T+m} \end{bmatrix}$$

and the Ordinary Least Squares (OLS) estimator $\hat{\beta}_i = (\mathbf{X}_i'\mathbf{X}_i)^{-1}\mathbf{X}_i'\mathbf{y}_i$.

The vector of prediction errors is then $\mathbf{u}_i^{*\prime} = (\hat{u}_{i,T+1},\ldots,\hat{u}_{i,T+m})$, obtained from:

$$\mathbf{u}_i^* = \mathbf{y}_i^* - \mathbf{X}_i^* \hat{\beta}_i \tag{11}$$

where $\mathbf{y}_i^*$ is the return on the firm over the test period, $\mathbf{X}_i^*$ is a typical $m \times 2$ OLS matrix of market returns over the test period and $\hat{\beta}_i$ is the vector of OLS estimated parameters. The cumulative sum of forecast errors over the event window $(T+m_1, T+m_2)$ is:

$$\sum_{\tau=T+m_1}^{T+m_2} \hat{u}_{i\tau} = \mathbf{C}\mathbf{u}_i^* \tag{12}$$

where $\mathbf{C}$ is an appropriately designed $1 \times n$ selection vector, as opposed to a $m \times 1$ selection factor in the original article, which has the elements taking the value unity if $\hat{u}_{i\tau}$ is contained in the event window and zero if it is not. The covariance matrix is given by:

$$\mathbf{D}_i = (\mathbf{X}_i'\mathbf{X}_i/T)^{-1}\mathbf{Q}_i(\mathbf{X}_i'\mathbf{X}_i/T)^{-1} \tag{13}$$

where $\mathbf{Q}_i$ is an estimate of $\mathbf{E}\ (\mathbf{X}_i'\mathbf{u}_i\mathbf{u}_i'\mathbf{X}_i/T)$ which can be approximated by:

$$\hat{\mathbf{Q}}_i = T^{-1}\sum_{t=1}^{T}\mathbf{x}_{it}'\mathbf{x}_{it}\hat{u}_{it}^2 + T^{-1}\sum_{s=1}^{p}\sum_{t=s+1}^{T}(\mathbf{x}_{it}'\mathbf{x}_{i,t-s} + \mathbf{x}_{i,t-s}\mathbf{x}_{it})\hat{u}_{it}\hat{u}_{i,t-s} \tag{14}$$

for p chosen to be approximately $T^{1/3}$; p should be increased until the truncations become trivial. $\hat{\mathbf{Q}}_i$ is thus an estimate of the average of the variances of $\mathbf{x}_{it}'u_{it}$ plus a term that takes into account the covariances between $\mathbf{x}_{it}'u_{it}$ and $\mathbf{x}_{i,t-s}'u_{i,t-s}$, the number of covariances being truncated at $s=p$ through the assumption of mixing (see, Mills, 1993, Chap. 5). In these circumtances, we have:

$$\mathbf{E}(\mathbf{C}\mathbf{u}_i^*\,\mathbf{u}_i^{*\prime}\mathbf{C}') = \sigma_i^2\mathbf{C}\mathbf{C}' + \mathbf{C}\mathbf{X}_i^*\,\mathbf{D}_i\mathbf{X}_i^{*\prime}\mathbf{C}'/T = \mathbf{V}_{\mathrm{D}i} \tag{15}$$

where:

$$\sigma_i^2 = \frac{\mathbf{u}_i'\mathbf{u}_i}{(T-2)}.$$

The Cumulative Abnormal Return (CAR) over the event window is:

$$\mathrm{CAR}_{m1,m2} = N^{-1}\sum_{i=1}^{N}\mathbf{C}\mathbf{u}_i^* \tag{16}$$

and using the expression in Eqs. (15) and (16) we have:

$$Z_{\mathrm{D}} = N \times \mathrm{CAR}_{m1,m2} \times \mathbf{V}_{\mathrm{D}}^{-1/2} \sim N(0,1) \tag{17}$$

where

$$\mathbf{V}_{\mathrm{D}} = \sum_{i=1}^{N}\mathbf{V}_{\mathrm{D}i}.$$

Eq. (15) does not include an erroneous **X** term, which is in the original formula for $\mathbf{V}_{\mathrm{D}i}$ in Coutts et al. The statistic Z_{D} can be used to test the hypothesis:

$$H_0\colon \mathrm{CAR}_{m1,m2} = 0$$

versus

$$H_1\colon \mathrm{CAR}_{m1,m2} \neq 0$$

Rejection of H_0 would indicate a persistent temporary price effect. Failure to reject H_0 may be explained by the market completion hypothesis. In addition to Coutts et al.'s ZD test, the significance of the CAR's is also computed using variance estimates from their Z test, which is nested in the ZD test, and Ruback's (1982) and Patell's (1976) variance estimates. The hypothesis being tested for each of these tests is the same as H_0.

4. Discussion of results

4.1. Parametric models

A concise summary of the results for parametric event study methodologies and robust regression with Scholes and Williams (1977) thin trading adjustment are reported in Table 1.[1] Fowler and Rorke (1983) results are omitted as they did not provide any additional insights.

These estimates provide the basis for testing whether the optioning of equities impacted upon their cash market securities on the days around listing. It is evident from Table 1 that there is a degree of consistency in the results produced by Ball and Brown approach, Patell's standardised residual test and the ZD test. Column 2 contains the mean abnormal returns from days -10 to 10 relative to option introduction. The mean excess returns were identical for each parametric model. Therefore, any difference in the reported test statistics is a consequence of differing variance estimates. When we compare the test statistics produced from Ball and Brown's and Patell's methodologies, it is evident that there is a small degree of divergence. For example, day -1, which produces the largest test statistic relative to the other days reported, is 1.49 for the Ball and Brown, 1.53 for Patell's methodology. When we compare the results from Patell's methodology and the ZD test we see that the test statistics are practically identical for each day in the test period.

Adopting three group resistant lines robust regression, as opposed to Ordinary Least Squares (OLS), for estimating the market model parameters does not produce any significant results for any of the days in the test period. Three group resistant line estimation of beta produces a mean abnormal return of 0.0038 for

[1] We also conducted our analysis for the same estimation and event period as Watt et al. (1992). We found no significant differences that would lead us to alter our conclusions.

Table 1
Results from parametric event study methodologies and robust regression[a]

Day	Mean abnormal returns	B&B *t*-test	PSR test	ZD test	R-L robust regression
−10	−0.0002	−0.07	−0.07	−0.07	0.14
−9	0.0003	0.12	0.13	0.13	0.29
−8	0.0029	1.11	1.14	1.14	1.13
−7	0.0022	0.84	0.87	0.86	1.19
−6	0.0024	0.92	0.95	0.93	0.61
−5	−0.0022	−0.84	−0.86	−0.86	−0.87
−4	−0.0002	−0.06	−0.06	−0.06	0.21
−3	−0.0030	−1.17	−1.20	−1.19	−0.79
−2	−0.0016	−0.61	−0.63	−0.63	−0.84
−1	0.0038	1.49	1.53	1.52	1.27
0	−0.0012	−0.47	−0.49	−0.49	−0.44
1	0.0020	0.79	0.81	0.80	0.65
2	−0.0022	−0.83	−0.86	−0.85	−0.77
3	0.0008	0.33	0.34	0.33	0.20
4	0.0024	0.94	0.96	0.95	0.69
5	−0.0010	−0.40	−0.41	−0.41	−0.39
6	−0.0040	−1.57	−1.61	−1.58	−1.39
7	−0.0012	−0.47	−0.49	−0.49	−0.27
8	0.0002	0.08	0.08	0.08	−0.04
9	−0.0014	−0.56	−0.58	−0.57	−0.41
10	−0.0024	−0.91	−0.94	−0.93	−0.67

[a] The mean excess returns have been generated from Scholes and Williams (1977) beta estimates adjusted for thin trading bias. B&B is the Ball and Brown standard event study methodology. PSR is Patell's standardised residual test. ZD is Coutts et al. (1995) ZD test. R-L is the test statistic generated from estimating the market model via three group resistant line robust regression.

day −1 with an associated test statistic of 1.27. This compares to a mean abnormal return of 0.0036 for the standard event study methodology with an associated test statistic of 1.49, whereas the ZD test produces a test statistic of 1.52 for day −1. This result demonstrates the arbitrary nature of the results produced from adopting robust regression, which mitigates the impact of excessively kurtotic data. Overall, the results reported in Table 1 indicate failure to reject the hypothesis that $AR_\tau = 0$ for all τ at the 95% level. This finding is consistent with the results reported by Watt et al. (1992) for mean abnormal returns. At this point it is not possible to state that failure to reject the null hypothesis is supportive of the market completion hypothesis. The temporary price effect reported by Watt et al. was based on significant cumulative abnormal returns around equity option listing.

4.2. Non-parametric models: rank tests

Table 2 reports a concise summary of results from three rank test commonly adopted in events studies. The non-parametric approaches considered here are free

Table 2
Concise summary of the results for non-parametric models 1[a]

Model		Days						
		−10	−6	−2	−1	+6	+7	+10
BIN	S&W			5	5			
	F&R	5			5			
WYR	S&W			+5	+5		−1	−5
	F&R			+1	+5		−5	−5
Cor	S&W					−5		
	F&R		+5			−5		

[a]Scholes and Williams adjustment for thin trading. F&R: Fowler and Rorke adjustment for thin trading. Bin: Binomial test. WYR: Walmsey, Yadav and Rees rank test. Cor: Corrado's rank test. +5 indicates a positive-significant test statistic at the 0.05 level. Additional numbers are defined analogously.

of specific assumptions concerning the distribution of returns. Typically, non-parametric tests are used in conjunction with their parametric counterparts, enabling one to check the robustness of conclusions based on the parametric tests. Subsequently, if the null hypothesis $AR_\tau = 0$ for all τ is rejected by both, a parametric and non-parametric methodology for the same event period day additional validity is given to the result. Campbell and Wasley (1993) demonstrate the value of this approach in event studies.

We can see from the results reported in Table 2 that there is a considerable variation in the results reported. Each of the rank tests rejects the null hypothesis at the 95% level, or less, for a number of event period days. However, given the lack of consistency with the results reported in Table 1, we have little evidence of a significant price effect around equity option listing. One feature of the results is a degree of dependence upon the choice of thin trading adjustment. Both the Binomial test and Corrado's test are affected. There appears to be a degree of consistency between the results produced by the Binomial Test and the test proposed by Walmsley et al. (1992) test around days −2 and −1. Probably the most striking result contained in Table 2 is the lack of consistency in the results produced by Corrado's test and the other two rank tests. In a situation where the data set under study produces highly significant results, it is probable that the Binomial model and the test proposed by Walmsley et al. would simply be stating the obvious. In a situation where the results from a given data set are marginally significant, the value of these two tests is questionable.

In general, the results from the parametric models and the rank based non-parametric models would lead to the recommendation that when testing the significance of mean abnormal returns the ZD methodology should be adopted. Whether or not the ZD test leads to a significant difference in the results produced from the traditional Ball and Brown approach is an empirical issue. However, the ZD test is the theoretically superior model. Mitigating the influence of outliers through estimating the market model via robust regression (Three group resistant line) is not recommended. If the researcher chooses to adopt a rank test, Corrado's (1989) rank test should contribute to the validity of their findings.

4.3. Bootstrapping

Table 3 reports the results from bootstrapping the market model. The bootstrap is a distribution-free randomisation technique, which can be used to estimate the sampling distribution of both estimators and test statistics. The results reported in Table 3 fail to reject H_0 for any of the days surrounding the introduction of equity option contracts for each of the bootstrapping techniques employed at the 95% level. This result is consistent with the results reported in Table 1.

A priori, it would not have been anticipated that the sample in this study would have been affected by thin trading. The majority of firms in our data set are amongst the largest firms quoted on the London Stock Exchange. However, bootstrapping betas, with adjustment for thin trading, may prove to be a valuable exercise for data sets comprised of smaller firms.

4.4. Testing cumulative abnormal returns

The results for the Cumulative Abnormal Returns (CARs) over various holding periods are reported in Table 4.

The test statistics for Rubac's estimate and the Z test are virtually identical. The difference between these two tests is the ability of the Z test to account for higher order serial correlation, whereas Rubac's test accounts for first-order serial correlation. This indicates that this data set is characterised by low-order serial correlation. When we compare the test statistics for the Z and ZD test, it is evident that heterokedasticity and non-normality have resulted in slightly differing variance estimates. If you compare CAR holding period from -10 to -6 you have a test statistic for the Z test of 1.34 and 1.28 for the ZD test. Though small, at 0.06, this difference is large enough to be of importance at marginal critical values. Patell's methodology produces test statistics which are inconsistent with our theoretically superior benchmark, the ZD test. Table 4 demonstrates the variability in the results produced from the methodologies considered. Consequently, the result of this empirical exercise would be to recommend the adoption of the ZD test when computing CAR's in event studies. This result is given added significance when we consider that event study methodology is still used extensively in the literature whilst the ZD test has not been adopted to any great degree by empiricists.

The results reported in Table 4 fail to reject the hypothesis that $\mathrm{CAR}_{m1,m2} = 0$ at the 95% level. The temporary price effect reported by Watt et al. (1992) was based on significant CAR's. Failure to reject the null hypothesis may be explained by the market completion hypothesis. The results reported here encompass a

Table 3
Results from bootstrapping the market model[a]

Day	Mean abnormal returns generated from bootstrapped beta estimate	*t*-Statistic	Mean abnormal returns generated from bootstrapped Scholes and Williams beta estimates	*t*-Statistic	Mean abnormal returns generated from bootstrapped Fowler and Rorke beta estimates	*t*-Statistic
−10	0.0001	0.05	0.0001	0.03	−0.0007	−0.27
−9	0.0007	0.29	0.0007	0.28	0.0012	0.47
−8	0.0033	1.28	0.0029	1.10	0.0028	1.06
−7	0.0023	0.92	0.0027	1.01	0.0025	0.94
−6	0.0025	0.99	0.0024	0.90	0.0028	1.07
−5	−0.0024	−0.95	−0.0029	−1.10	−0.0030	−1.14
−4	0.0001	0.05	−0.0004	−0.15	−0.0006	−0.21
−3	−0.0033	−1.29	−0.0023	−0.87	−0.0026	−0.99
−2	−0.0016	−0.62	−0.0022	−0.83	−0.0023	−0.87
−1	0.0039	1.53	0.0041	1.55	0.0038	1.47
0	−0.0012	−0.47	−0.0014	−0.54	−0.0010	−0.39
1	0.0022	0.85	0.0016	0.61	0.0012	0.46
2	−0.0018	−0.71	−0.0018	−0.69	−0.0018	−0.69
3	0.0005	0.19	0.0006	0.23	0.0004	0.17
4	0.0024	0.92	0.0018	0.68	0.0013	0.49
5	−0.0009	−0.37	−0.0009	−0.36	−0.0014	−0.54
6	−0.0036	−1.39	−0.0039	−1.49	−0.0047	−1.81
7	−0.0011	−0.42	−0.0012	−0.46	−0.0019	−0.71
8	−0.0002	−0.08	0.0004	0.16	0.0003	0.10
9	−0.0018	−0.69	−0.0017	−0.66	−0.0018	−0.69
10	−0.0023	−0.88	−0.0024	−0.92	−0.0024	−0.92

[a] All bootstrapped estimates generated from 1000 replications.

Table 4
Concise summary of results from testing the significance of Cumulative Abnormal Returns (CAR's) with Scholes and Williams adjustment for asynchronous trading

Holding period$_{m1,m2}$	Rubac's variance estimate[a]	Patell's methodology[b]	Z-test[b]	ZD-test[b]
−10	−0.07	−0.07	−0.07	−0.07
−10, −9	0.04	0.03	0.04	0.04
−10, −8	0.69	0.26	0.69	0.67
−10, −7	1.03	0.45	1.03	0.99
−10, −6	1.35	0.66	1.34	1.28
−10, −5	0.88	0.47	0.87	0.83
−10, −4	0.79	0.46	0.78	0.74
−10, −3	0.32	0.20	0.31	0.29
−10, −2	0.09	0.06	0.09	0.08
−10, −1	0.57	0.39	0.56	0.52
−10, 0	0.40	0.29	0.39	0.36
−10, 1	0.62	0.46	0.60	0.55
−10, 2	0.35	0.28	0.34	0.31
−10, 3	0.43	0.35	0.41	0.37
−10, 4	0.66	0.56	0.64	0.57
−10, 5	0.54	0.47	0.52	0.46
−10, 6	0.13	0.12	0.13	0.11
−10, 7	0.01	0.01	0.01	0.01
−10, 8	0.03	0.03	0.03	0.03
−10, 9	−0.01	−0.10	−0.10	−0.08
−10, 10	−0.30	−0.30	−0.29	−0.25

[a] The test statistics for Rubac's test follows a t-distribution.
[b] The test statistics for Patell, the Z and ZD tests are distributed $N(0,1)$.

period that includes the introduction of option contracts on the FT-SE 100 index, from 1990 onward. The results from the ZD test indicate that the temporary price effect documented for the UK has diminished to the extent that it is no longer significant at a reasonable probability level.

5. Conclusions

This paper examines the impact of equity option listing on the underlying cash market security in the UK. The results from this study indicate that the impact of this economic event has diminished over time, to the point that equity option listing no longer has a significant impact on the optioned equity. This result may be explained by the market completion hypothesis. Comparisons of the results produced from various methodologies demonstrate that there is potential for considerable variation when computing the significance of mean abnormal returns and cumulative abnormal returns. We would recommend that Corrado's (1989) rank test or bootstrapping the market model be adopted in conjunction with parametric methodologies in the computation of mean abnormal returns. When computing cumulative abnormal returns, the ZD test is recommended.

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Appendix A. Bootstrapping

In the context of event study methodology, there are two approaches which may be adopted. The first is outlined by Marias (1984) and involves bootstrapping the estimation period abnormal returns, which are used to reconstruct the single index market model. Underlying this approach is the assumption that the distribution of the abnormal returns (error term) is the same for all values of the return on the firm (dependant variable). Given the documented mis-specification of the market model by Coutts et al. (1995), it is unlikely that this assumption is valid in practice. Therefore, the second approach, bootstrapping the data vectors, is adopted here. Brabazon (1997) outlines an algorithm for re-sampling data vectors for a simple regression model. The following algorithm incorporates bootstrapped estimates of the parameters necessary to compute Fowler and Rorke (1983) thin trading adjustments. This algorithm nests Scholes and William's adjustment and the matched market model regression.

A.1. Bootstrap algorithm for computing beta with Fowler and Rorke's adjustment for thin trading

Step 1: Notation in relation to Fig. 1.

For firm i $(i = 1,\ldots,N)$, where N is the number of sample firms, create four new data matrices from the original data set. Resulting in five sets $= (y_{it}, x_{it})$, $(y_{it}\, x_{i,t-1})$, $(y_{it}, x_{i,t-2})$, $(y_{it}, x_{i,t+1})$ and (y_{it}, x_{t+2}).

y_{it} = return on the firm in the estimation period; and

x_{it} = return on the market index in the estimation period.

$t = 1,\ldots,T$

$\tau = T+1,\ldots,T+m$

where T is equal to the number of observations in the estimation period.

Step 2: From each of the five data matrices create a new data matrix (bootstrapped data matrix) by re-sampling T paired rows with replacement.

Step 3: Calculate the first-order Autocorrelation Function (ACF(1)) and second-order Autocorrelation Function (ACF(2)) from the matched bootstrapped data matrix x_{it} vector of observations (market index). Calculate the OLS regression coefficients for each of the five bootstrapped data matrices.

Step 4: Bootstrap **M** times (typically **M** = 1000: see Pan et al., 1997; Brock et al., 1992 and reference contained therein), and find **M** sets of five regression coefficients and **M** sets of two Autocorrelation Function values from each replication of the matched bootstrapped data matrix:

$\beta_{m,k}$ where $k = 1,2,\ldots 5$, and $m = 1$ to $\mathbf{M}$.

$\rho_{m,l}$ where $l = 1$ to 2, and $m = 1$ to $\mathbf{M}$.

Step 5: Calculate the mean coefficients:

$$\bar{\beta}_k = \frac{1}{m}\sum_{i=1}^{m}\beta_k \text{ and } \bar{\rho}_l = \frac{1}{m}\sum_{i=1}^{m}\rho_l$$

Step 6: From the mean coefficients in step 5, calculate the bootstrapped Fowler and Rorke beta estimate for firm i:

$$\beta_i = \frac{\sum_{k=1}^{5}\bar{\beta}_k}{1 + 2\sum_{l=1}^{2}\bar{\rho}_l}$$

Step 7: Calculate the intercept coefficient (α_i) for firm i.

$$\alpha_i = \bar{y}_i - \beta_i \bar{x}_i$$

where $\bar{y}_i$ denotes the return on firm i averaged over the estimation period and $\bar{x}_i$ denotes the return on the market averaged over the estimation period for the matched, original, data set from step 1.

Step 8: Compute the abnormal returns for the estimation and test period:

$$u_{it} = y_{it} - \alpha_i - \beta_i x_{it},$$
$$u_{i\tau} = y_{i\tau} - \alpha_i - \beta_i x_{i\tau},$$

where $y_{i,t}$ and $x_{i,t}$ are actual returns over the estimation period and $y_{i,\tau}$ and $x_{i,\tau}$ are the actual returns over the test period.

Step 9: Compute test statistic:

$$\mathrm{AR}_\tau = N^{-1}\sum_{i=1}^{N} u_{i\tau},$$

$$\mathrm{AR}_t = N^{-1}\sum_{i=1}^{N} u_{it},$$

$$t_\tau = \frac{\mathrm{AR}_\tau}{\sigma}$$

where σ is the standard deviation of AR_t.

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