Online Appendix

to accompany

Event Study Testing with Cross-Sectional Correlation of Abnormal Returns

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This Online Appendix contains additional materials related to "Event Study Testing with Cross-Sectional Correlation of Abnormal Returns" in the following order:

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Appendix A. Event studies with potential event date clustering published in leading finance journals

Study	Main issue	Key finding	Variance[a]	Correlation[b]
A. Regulatory, government, and legal events				
Aktas, de Bodt, and Roll (2004)	Regulatory intervention in mergers	AR(0) = 1.02% for combinations	BMP	Portfolio/Other
Arslanalp and Henry (2005)	Brady Plan impact on countries	CAR(-3, 0) = 4.90% in the months prior	GLS	GLS
Bhagat (1986)	Utility stocks and Rule 50	AR(0) = -2.30% for group difference	GLS	GLS
Bittlingmayer and Hazlett (2000)	Federal antitrust actions against Microsoft	AR(0) = -0.26% for 29 events	Sign	Portfolio
Black, Fields, and Schweitzer (1990)	Interstate banking laws	AR(0) = 0.69% for 51 banks	None	Portfolio
Cornett and Tehranian (1990)	Garn-St. Germain Act of 1982 effects	CAR(-1, 0) = 1.96% large S&Ls	GLS	GLS
Desai, Dyck, and Zingales (2007)	Tax enforcements on Russian oil firms	CAR(-1,+9) = -2.35%	Sign	Portfolio
Dowdell, Govindaraj, and Jain (1992)	Tylenol incident and regulatory changes	AR(0) = 0.63%	None	Portfolio
Henry (2002)	Disinflation programs in countries	AR(0) = 12.2% in high inflation periods	GLS	GLS
Hill and Schneeweis (1983)	Three Mile Island nuclear accident	AR(0) = -5.0% utilities in month 0	Patell	Portfolio
Lakonishok and Sadan (1981)	Major economic reforms in Israel in 1977	CAR(0, + 2) = 6% for firms benefiting	None	Portfolio
McQueen and Roley (1993)	Macroeconomic news announcements	AR(0) = -0.455% for PPI	GLS	GLS
Mitchell and Netter (1989)	Antitakeover provisions by government	AR = -1.43% on October 14, 1987	Other/Sign	Portfolio
Park (2002)	1989 FIRREA banking regulations	CAR(0,+30) = -0.22% for thrifts in June	Rank	Portfolio
Stillman (1983)	Antitrust enforcement actions and mergers	Two out of 18 merger events significant	GLS	GLS
B. Takeover events				
Agrawal and Mandelker (1990)	Antitakeover charter amendments	CAR(-40,1) = -2.60%	Sign	Portfolio
Asquith (1983)	Merger takeover bids	CAR(-1,0) = 6.2% for successful targets	Patell	Portfolio
Betton and Eckbo (2000)	Takeovers	CAR(-60,0) = 30.13% targets in initial bid	GLS	GLS
Chang (1998)	Takeovers of privately held targets	CAR(-1,0) = 2.64% for stock offers	Patell	Portfolio
Chaplinsky and Niehaus (1994)	ESOPs and takeover contests	CAR(0,+1) = -3.05% for ESOP changes	None	Portfolio
Linn and McConnell (1983)	Antitakeover amendments	CAR(0,+90) = 4.11%	Patell/Sign	Portfolio
McWilliams (1990)	Antitakeover amendment proposals	AR(0) = 0.49% low insider ownership	Sign	Portfolio
Travlos (1987)	Takeover bidder reaction	AR(0) = -0.69% for common stock offers	Patell	Portfolio
C. Mergers and acquisition events				
Dodd (1980)	Merger proposals	AR(0) = 4.30% for targets	None	Portfolio
Eckbo (1983)	Horizontal mergers in industries	AR(0) =3.13% for targets	Sign	Portfolio
Eckbo and Thorburn (2000)	Mergers and bidder firm gains	AR(0) = 1.27% in month 0 TSE bidders	None	Portfolio
Faccio, McConnell, and Stolin (2006)	Acquisition of listed and unlisted targets	CAR(-2,+2) = 1.86% for unlisted targets	Sign	Portfolio
Fuller, Netter, and Stegemoller (2002)	Active acquiring firms from 1990 to 2000	CAR(-2,+2) = 2.08% private firm targets	None	Portfolio
Hansen and Lott (1996)	Acquisition of public vs private targets	AR(0) = 1.15% for private targets	None	Portfolio
Holmén and Knopf (2004)	Bidder and target firms in mergers	AR(0) = 0.96% for targets	Rank	Portfolio
Hubbard and Palia (1999)	Bidder firms involved in acquisitions	AR(0) = 1.62% for related mergers	Patell/Rank	Portfolio

Study	Main issue	Key finding	Variance[a]	Correlation[b]
Kang, Shivdasani, and Yamade (2000)	Japanese mergers	CAR(-1,+1) = 5.37% for acquirers	Sign	Portfolio
Kaplan and Weisbach (1992)	Acquisitions and divestitures	CAR(-5,+5) = -1.49% for acquirers	None	Portfolio
Leeth and Borg (2000)	Targets and acquirers in 1920s mergers	AR(0) = 6.74% for targets	Sign	Portfolio
Salinger (1992)	Mergers in months from 1976 to 1978	AR(0) = -2.6% using monthly returns	GLS/Other	GLS
Saunders and Smirlock (1987)	Bank of America and Charles Schwab	AR(0) = -2.11% for securities firms	GLS/Rank	GLS
Wansley, Roenfeldt, and Cooley (1983)	Firms with a high probability of merging	AR(6) = 2.15% six months from time 0	None	Portfolio
D. Bankruptcy and financial distress events				
Bae, Kang, and Lim (2002)	Bankruptcies and effects on banks	CAR(-1,+1) = -2.81% for bankruptcies	Other	Portfolio
Dahiya, Saunders, and Srinivasan (2003)	Bankruptcy events and bank lending	CAR(-1,+1) = -0.49% for lead banks	None	Portfolio
Dawkins and Bamber (1998)	Bankruptcy petition filing dates	AR(0)= 12.24% for the total sample	None	Portfolio
Denis and Denis (1995)	Leverage and financial distress	CAR(-1,+1) range from -6.15% to 0.33%	Sign	Portfolio
Jorion and Zhang (2007)	Intra-industry responses to credit events	CAR(-1,+1) = -0.56% for 170 events	None	Portfolio
Kaen and Tehranian (1990)	Bankruptcy of electric utilities	CAR(0,+1) = -2.06% for n = 9	None	Portfolio
O’Hara and Shaw (1990)	Deposit insurance and bank failures	AR(0) = 1.31% for 10 banks	None	Portfolio
Ongena, Smith, and Michalsen (2003)	Borrowing firms and bank distress	CAR(-1, +1) = -1.7% for all firms	GLS	GLS
Slovin, Sushka, and Polonchek (1999)	Contagion and banking industry	CAR(-1,0) = -9.51% for 62 banks	Patell	Portfolio
E. Newly listed and delisted stock events				
Beneish and Gardner (1995)	DJIA stocks newly listed or delisted	CAR(+1) = 1.04% for portfolios	Rank	Portfolio
Harris and Gurel (1986)	Changes in the S&P 500 list	AR(1) = 1.52%	None	Portfolio
Sanger and McConnell (1986)	OTC stocks listed on the NYSE	AR(0) = 0.88% using weekly returns	Patell/Sign	Portfolio
Sanger and Peterson (1990)	Delisting firms from stock exchanges	AR(0) = -8.51%	Sign	Portfolio
F. Securities markets events				
Amihud, Mendelson, and Lauterbach (1997)	Trading mechanism improvements	CAR(0,+1) = 3.04% for 17 events	GLS	GLS
Barber and Loeffler (1993)	Stock pros’ picks versus dartboard	AR(0) = 3.53% for pros	GLS	GLS
Bjerring, Lakonishok, and Vermaelen (1983)	Brokerage stock recommendations	AR(0) = 1.80% in week 0	Patell	Portfolio
Boardman, Dark, and Lease (1986)	Listing announcements of corporate debt	CAR(-1,0) = -0.01% for 50 listings	Sign	Portfolio
Bradley, Jordon, and Ritter (2003)	Expiration of the IPO quiet period	CAR(-2,+2)) = 4.10% for initiated firms	Sign	Portfolio
Cowan, Nayar, and Singh (1990)	Convertible bond calls of firms	CAR (-61,-2) = -72.62% using months	Patell/Sign	Portfolio/Other
Damodaran (1989)	Earnings and dividend news on Fridays	AR(0) = -0.1156% on Fridays	None	Portfolio
Datta and Dhillon (1993)	Unexpected earnings announcements	AR(0) = 1.02% for earnings increases	Patell/Sign	Portfolio
Denis and Sarin (2001)	Earnings announcements	AR(0) = 0.16% after equity offerings	None	Portfolio
Field and Hanka (2001)	IPO lockup expiration effects	CAR(-1,+1) = -1.50%	Sign	Portfolio
Gemmill (1996)	Block trade and market transparency	AR(0) = 0.31% in month 0	Sign	Portfolio
Greene and Smart (1999)	Analyst recommendations in the WSJ	AR(0) = 3.00%	GLS	GLS
Henry (2000)	Foreign investors in emerging markets	AR(0) = 6.5% in month 0	None	Portfolio
Hertzel (1991)	Stock repurchases and rival firms	CAR(-5,+5) = -1.17% for rivals	None	Portfolio
Ivković and Jegadeesh (2004)	Earnings forecast revisions	CAR(0,+2) = 1.02% for upward revisions	None	Portfolio

Study	Main issue	Key finding	Variance[a]	Correlation[b]
Kim and Kim (2003)	Quarterly earnings announcements	CAR(0,+1) = 0.23% Fama French model	None	Portfolio
Klein, and Rosenfeld (1987)	Nonclustered events in bull/bear markets	CAR(-1,0) = 2.37% in bull markets.	None	Other
Senchack and Starks (1993)	Short-interest announcements	AR(0) = -02.2%	GLS/Patell	GLS
G. Other events				
Carleton, Nelson, and Weisbach (1998)	Corporate governance and TIAA-CREF	CAR(-1, +2) = -2.10%	Sign	Portfolio
Chen and Merville (1986)	Breakup of AT&T and spillover effects	CAR(0,+20) significant for 6 of 9 firms	None	None
Cooper, Dimitrov, and Rau (2001)	Internet-related dotcom name changes	CAR(0,+1) = 18%	Rank	Portfolio
Firth (1996)	Intra-industry effect of dividend changes	CAR(-1, 0) = 0.37% among similar firms	Patell	Portfolio
Jain (1985)	Voluntary sell-off activities	AR(0) = 0.09% for sellers	None	Other
Kracaw and Zenner (1996)	Bank financing announcements	CAR(-1, 0) = -0.27% among 15 banks	Sign	Portfolio
Sundaram, John, and John (1996)	R&D spending on firms and rival firms	CAR(0, +1) = -0.16%	GLS/Other	GLS

[a] Variance inflation is taken into account by researchers via parametric BMP and Patell tests, nonparametric sign and rank tests (e.g., Wilcoxon statistics), GLS (generalized least squares), and other approaches (e.g., doubling the variance in the pre-event period, testing for variance shifts, etc.).

[b] Cross-correlation is addressed by means of the portfolio approach, GLS (generalized least squares), and other approaches (e.g., sampling or statistical methods

Appendix B. Asymptotic distributions of PORT, ADJ-PATELL, and ADJ-BMP statistics

1. Definitions

We denote the event date as day $t = 0$, the estimation period is from $t_1 + 1$ to t_2, and the event period is $t_2 + 1$ to t_3, such that $t_1 + 1 < t_2 < 0 < t_3$. The length of the estimation period is $m = t_2 - t_1$. Denote the factor model to define the abnormal returns as

$$r_{it} = x_t'\beta_i + u_{it}, \tag{B1}$$

where r_{it} is the return of asset i, x_t is a $p + 1$ -vector of common factors augmented with the intercept dummy with prime for transpose, $i = 1, \dots, n$, and n is the number of firms. Let Σ_n denote the cross-covariance matrix of residual returns $u_{1t}, \dots, u_{nt}$, which is constant for all t. The estimated OLS parameters of factor model (B1) are obtained using estimation period returns. The event day abnormal return is defined as

$$AR_{i0} = r_{i0}^* - x_0^{*\prime}\hat{\beta}_i, \tag{B2}$$

where r_{i0}^* is the event day return of stock i, and x_0^* is the event day factor return vector. Scaled abnormal returns are defined as

$$A_{i0} = \frac{AR_{i0}}{s_i\sqrt{1 + x_0^{*\prime}(X'X)^{-1}x_0^*}}, \tag{B3}$$

where X is the matrix of estimation period observations of the common factors with a vector of ones in the first column, and

$$s_i = \sqrt{\frac{1}{m-p-1}\sum_{t=t_1+1}^{t_2}\left(r_{it} - x_t'\hat{\beta}_i\right)^2} \tag{B4}$$

is the standard deviation of the OLS residuals where p is the number of explanatory variables (factors) in factor model (B1).

It is assumed that $plim_{m\to\infty} X'X/m \to Q$, a positive definite matrix, where "$plim$" denotes convergence in probability.

The test statistics considered are as follows:

Portfolio method (PORT):

$$t_{pf} = \frac{\widehat{AR}_0}{s\sqrt{1+x_0^{*\prime}(X'X)^{-1}x_0^*}}, \tag{B5}$$

where $\widehat{AR}_0 = \bar{r}_0^* - x_0^{*\prime}\hat{\beta}$ with $\bar{r}_0^* = \sum_i^n r_{i0}^*/n$, $\hat{\beta}$ is the OLS estimator of the portfolio abnormal return model $\bar{r}_t = x_t'\beta + u_t$, and $s = \sqrt{\frac{1}{n-p-1}\sum_t\left(\bar{r}_t - x_t'\hat{\beta}\right)^2}$ is the residual standard error.

Adjusted Patell (ADJ-PATELL):

$$t_{AP} = \frac{\bar{A}_0\sqrt{n}}{\sqrt{1+(n-1)\hat{\bar{\rho}}_n}}, \tag{B6}$$

where $\bar{A}_0 = \sum_i A_{i0}/n$, and $\hat{\bar{\rho}}_n$ is the average cross-correlation of the OLS residuals $\hat{u}_{it} = r_{it} - x_t'\hat{\beta}_i$, $i = 1 \ldots, n$.

Adjusted BMP (ADJ-BMP):

$$t_{AB} = \frac{A_0\sqrt{n}}{s_A\sqrt{1+(n-1)\hat{\bar{\rho}}_n}}, \tag{B7}$$

where $s_A = \sqrt{\sum_i(A_{i0} - \bar{A}_0)^2/(n-1)} \,/\, \sqrt{1 - \hat{\bar{\rho}}_n}$ is the cross-sectional standard deviation of the abnormal returns corrected for cross-correlation.

Rank statistic (RANK):

$$t_R = \frac{\left(\bar{U}_0 - \frac{1}{2}\right)\sqrt{n}}{s_u}, \tag{B8}$$

where

$$s_u = \sqrt{\frac{1}{M}\sum_{t=t_1+1}^{t_3} n_t\left(\bar{U}_t - \frac{1}{2}\right)^2}, \tag{B9}$$

such that $s_u/\sqrt{n}$ is the standard error of the event day average scaled rank $\overline{U}_0$, $\overline{U}_t = \sum_i^{n_t} U_{it}/n_t$ are the average scaled ranks for $t = t_1 + 1, \dots, t_3$, and M is the total number of observations in the combined estimation and event periods. The scaled ranks are defined as

$$U_{it} = \text{rank}(A_{it}^*)/(M_i + 1), \tag{B10}$$

where M_i is the total number of non-missing returns in the combined estimation and event periods for stock i, and

$$A_{it}^* = \begin{cases} A_{it} \text{ for } t \neq 0 \\ A_{i0}/s_A \text{ for } t = 0 \end{cases} \tag{B11}$$

are scaled abnormal returns that are rescaled for the event day with the cross-sectional standard deviation.

2. Assumptions

Assumption B1: Asset returns $r_{1t}, r_{2t}, \dots, r_{nt}$ of *n* firms for calendar time period *t* are serially independently multivariate normally distributed random variables with constant mean and constant covariance matrix for all *t* (see Campbell, Lo and MacKinlay (1997, Section 4.3)).

Assumption B2: Event-induced volatility is proportional to the variance of stocks' residual return volatility, such that the event-induced cross-covariance matrix is of the form $\Omega_n = \omega^2\Sigma_n$, where ω is a scalar.

3. Main Results

Theorem B1: *Under Assumption B1, for any fixed n number of firms, and with no event-induced variance, the null-distributions of PORT defined in equation (B5) and ADJ-PATELL defined in equation (B6) converge to the standard normal distribution as $m \to \infty$, where m is the length of the estimation period*.

Proof: We first prove this result for the ADJ-PATELL statistic. Given that $plim\ X'X/m = Q$

(a positive definite matrix) as $m \to \infty$, $plim\ (1 + x_t^{*\prime}(X'X)^{-1}x_t^*) = 1$. Under general regularity conditions, the properties of OLS estimators imply $plim_{m\to\infty}\ \hat{\beta}_i = \beta_i$ and $plim_{m\to\infty}\ s_i = \sigma_i = \sqrt{var[u_{it}]}$. Thus, $plim_{m\to\infty}\ A_{i0} = (r_{i0}^* - x_0^{*\prime}\beta_i)/\sigma_i \equiv Z_{i0}$, which due to Assumption B1 is $N(0,1)$ distributed under the null hypothesis of no event effect. Because convergence in probability implies convergence in distribution, asymptotically $A_{i0} \sim N(0,1)$. Furthermore, for the pair-wise residual correlations, or $\rho_{ij} = corr[u_{it}, u_{jt}]$, estimated by the sample correlations

$$\hat{\rho}_{ij} = \frac{\sum_t \hat{u}_{it}\hat{u}_{jt}}{\sqrt{\left(\sum_t \hat{u}_{it}^2\right)\left(\sum_t \hat{u}_{jt}^2\right)}}, \qquad \text{(B12)}$$

again $plim_{m\to\infty}\ \hat{\rho}_{ij} = \rho_{ij}$. Due to Assumption B1, the scaled abnormal returns are asymptotically multivariate normal with covariance matrix equal to the correlation matrix. Thus, it follows that $\bar{A}_0 = \sum_i A_{i0}\ /n$ is asymptotically normal with variance $\lim_{m\to\infty} var[\bar{A}_0] = (1 + (n-1)\bar{\rho}_n)/n$, where $\bar{\rho}_n$ is the average cross-correlation of the residuals. Utilizing these results, for the null distribution of the ADJ-PATELL statistic we have

$$t_{AP} = \frac{\bar{A}_0\sqrt{n}}{\sqrt{1+(n-1)\hat{\bar{\rho}}_n}} \to \frac{\bar{Z}_0\sqrt{n}}{\sqrt{1+(n-1)\bar{\rho}_n}} \sim N(0,1) \qquad \text{(B13)}$$

as $m \to \infty$, where $\bar{Z}_0 = plim_{m\to\infty}\ \bar{A}_0$. Using similar arguments for non-scaled returns, we get

$$t_{pf} = \frac{\widehat{AR}_0}{s\sqrt{1+x_0^{*\prime}(X'X)^{-1}x_0^*}} \to \frac{r_0^* - x_0^{*\prime}\beta}{\sigma} \sim N(0,1), \qquad \text{(B14)}$$

where $plim_{m\to\infty}\ s = \sigma = \sqrt{var(r_0^* - x_0^{*\prime}\beta)}$. QED.

Remark B1: Under Assumption B1 the finite sample null-distribution of the portfolio method is the *t*-distribution with $m - p - 1$ degrees of freedom. Notably, this result is not dependent on the number of firms in the portfolios. Furthermore, if the normality assumption does not hold, the finite sample distribution property breaks down and the asymptotic distribution is not normal (without additional assumptions), a fact which seems to be overlooked in application.

Theorem B2: (see Lehmann and Romano (2005, Lemma 11.3.1)) *Assume that for each fixed number of firms n, the length of the estimation period m is allowed to go to infinity, such that* $plim\ \hat{\bar{\rho}}_n \to \bar{\rho}_n$. *Assume further that*

$$\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1,j\neq i}^{n}\rho_{ij} = (n-1)\bar{\rho}_n \to \gamma \tag{B15}$$

and

$$\frac{1}{n^2}\sum_{i=1}^{n}\sum_{j=1,j\neq i}^{n}\rho_{ij}^2 \to 0 \tag{B16}$$

as $n \to \infty$. *Then under assumptions B1 and B2 the null-distribution of ADJ-BMP defined in equation (B6) tends to the normal distribution* $N(0,1)$.

Proof: With the same arguments as in the proof of Theorem B1, for any fixed n, $plim_{m\to\infty}\ \bar{A}_0 = \bar{Z}_{0,n}$, where $\bar{Z}_{0,n}$ is normally distributed with variance

$$var\left[\bar{Z}_{0,n}\right] = \omega^2(1 + (n-1)\bar{\rho}_n)/[n(1-\bar{\rho}_n)]. \tag{B17}$$

Thus, $var\left[\sqrt{n}\ \bar{A}_0\right] \to var\left[\sqrt{n}\ \bar{Z}_{0,n}\right] = \omega^2(1 + (n-1)\bar{\rho}_n)/(1-\bar{\rho}_n)$ as $m \to \infty$. Due to the normality of the returns, the asymptotic distribution of $\sqrt{n}\ \bar{A}_0$ for fixed n as $m \to \infty$ is normal with variance $\omega^2(1 + (n-1)\bar{\rho}_n)/(1-\bar{\rho}_n)$. Formula (B15) implies that $\bar{\rho}_n \to 0$ as $n \to \infty$. Furthermore, limiting behavior in formula (B15) implies together with (B16) that

$$plim_{n\to\infty}\left(plim_{m\to\infty} s_A\right) = plim_{n\to\infty}\left(plim_{m\to\infty}\sqrt{\frac{1}{n-1}\sum_i\frac{(A_i-\bar{A})^2}{1-\hat{\bar{\rho}}_n}}\right) = \omega\sqrt{1+\gamma}. \tag{B18}$$

Given equation (B17), $var\left[\bar{Z}_{0,n}\right] \to 0$ as $n \to \infty$, which implies that $plim_{n\to\infty}(plim_{m\to\infty}\bar{A}_0) = plim_{n\to\infty}\bar{Z}_{0,n} = 0$. Thus, utilizing these results, we finally obtain the result that the null distribution of the ADJ-BMP statistic in equation (B7) tends to the normal distribution $N(0,1)$.

QED.

Remark B2: Based on the assumptions of Theorem B2, similar properties hold for the variance and expected value of the RANK statistic, such that under the null hypothesis asymptotically the mean is zero and variance is finite. Unfortunately, these may not be sufficient conditions for asymptotic normality in the case of cross-correlation. However, as noted in Lehmann (1999, p. 107), it will frequently continue to be true that asymptotic normality holds if the two first moments converge to some finite values.

Appendix C. Simulation results for the banking industry

Because the cross-correlation problem is expected to be especially problematic when firms are in the same industry [Brown and Warner (1985)], this appendix repeats the marketwide analyses of the main text for a single industry. We use the banking industry in the 48-industry definitions on Kenneth French's website. Given similar results for different adjusted return approaches, we focus on the results for FF INDUSTRY MODEL adjusted returns. Table C1 provides sample statistics for $n = 50$ firms from 1,000 simulations with no event effect. The average return cross-correlation is 0.092, which again is considerably larger than the average residual cross-correlation of 0.024. The standard deviations of the UNADJ, PATELL, and BMP *t*-statistics are from 1.4 to 1.6 times the theoretical value of one. Thus, even though the FF INDUSTRY MODEL maximally extracts common correlation from the returns, again disregarding even small remaining average cross-correlation can substantially bias the distributional properties of the test statistics via underestimation of the true (residual) return variability. Average standard deviations for the PORT, ADJ-PATELL,ADJ-BMP, and RANK tests that take into account cross-correlation are close to the theoretical value of unity. As before, however, the distributions of the test statistics appear to be skewed as well as leptokurtic.

[TABLE C1]

1. Industry Type I Error Rates

Here we present Type I error rejection rates of the test statistics under the null hypothesis of no event effect and possible event-induced variance. Results are shown for $n = 50$, $n = 30$, and $n = 10$ securities to demonstrate sample size effects. As shown in column 2 of Table C2, with no variance increase cross-correlations instigate the UNADJ, PATELL, and BMP *t*-statistics to over-reject the null hypothesis at rates typically two-to-four times the nominal rate of 0.05. As predicted by theory (see Table 2 in the main text), over-rejections noticeably increase as sample sizes increase from 10 to 50 securities. For n = 50 the two-tailed rejection rates for the PATELL and BMP statistics are 0.208 and 0.214, respectively, while for n = 30 they are 0.104 and 0.111.

[TABLE C2]

The remaining columns in Table C2 report the results with event-induced variability. For different sample sizes, as variance increases, over-rejections worsen for the UNADJ and PATELL tests but not for the BMP test. The results are also mixed for test statistics that take into account cross-correlation, with increasing rejection rates for the PORT and ADJ-PATELL tests but no change for the ADJ-BMP and RANK tests. We infer that, given event-induced variability, the ADJ-BMP and RANK statistics remove the cross-correlation bias from the rejection rates for the most part and are robust to event-induced variance.[1]

2. Industry Type II Error Rates

We next evaluate industry rejection rates of test statistics that take into account cross-correlation under different levels of abnormal returns (i.e., power analyses) with n = 50 securities using FF INDUSTRY MODEL, FF MODEL, OLS MODEL, and INDUSTRY adjusted returns. The latter case simulates the availability of data only in the event period (i.e., 21 days) for rescaling purposes. The results in Table C3 and accompanying Figure C1 are similar to the marketwide results. A notable difference is the INDUSTRY adjusted counterpart of MARKET adjusted returns. Contrary to the latter, the average cross-correlation in simulations of INDUSTRY adjusted returns is unexpectedly high, even higher than the industry average. This suggests that the individual company returns have relatively low correlations with the industry index and, hence, INDUSTRY adjustment is not a recommended choice for an abnormal return model.

Even so, all test statistics reject the null hypothesis of no mean event effect and are reasonably close to the correct rate of 0.05 (i.e., the bold faced zero abnormal return line in Panel D of Figure C1 with 95 percent confidence interval [0.036, 0.064]). Thus, these tests are robust in this situation also. The major effect of cross-correlation is substantially weakened power (or increase of Type II error) of the tests compared to the other abnormal return models. Like Figure 1 in the main text, as residual cross-correlations increase when fewer relevant factors are extracted from returns, Figure C1 shows that the power of the tests suffers (e.g., OLS MODEL and INDUSTRY adjusted returns have lower powers of test statistics than multi-factor adjusted returns). In each case, however, the ADJ-PATELL, ADJ-BMP, and RANK tests again have higher power than the PORT test.

[TABLE C3]

[FIGURE C1]

References

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Footnotes

1. To further investigate the issue of skewness, we split the 1,000 simulations according to the upper 75th percent quartile of cross-correlations (i.e., above 0.0177) and collect 250 simulation results for these high correlations. In this subsample the mean and median residual cross-correlations are both 0.075. In general, the results are similar to those in Table C2. For the subsample with residual cross-correlations below the 75th percent quartile, the distribution of the average cross-correlation is again fairly symmetric with mean and median equal to 0.007 and 0.006, respectively. We found that, even in this case of trivial cross-correlation, there is a tendency to over-reject in the UNADJ, PATELL and BMP tests with no variance inflation. Also, when variance is increased, the simulated rejection rates are close to the nominal rate of 0.05 for the ADJ-BMP and RANK tests.

Table C1
Banking industry sample statistics in event tests based on 1,000 random portfolios of *n* = 50 securities with no event effect when the residual returns are correlated

	Mean	Median	Std dev	Skew-ness	Excess kurtosis	Min	Max
Average return cross-correlation	0.092*	0.084*	0.033	1.185*	1.306*	0.034	0.227
Average residual cross-correlation	0.024*	0.009*	0.035	1.926*	2.886*	-0.008	0.195
UNADJ test	-0.058	0.001	1.432	-0.818*	7.560*	-10.675	7.427
PATELL test	-0.054	-0.022	1.573	-0.936*	7.727*	-12.567	7.405
BMP test	-0.060	-0.024	1.533	-0.324*	2.166*	-6.861	5.329
PORT test	-0.042	0.010	0.989	-0.750*	5.856*	-8.442	3.469
ADJ-PATELL test	-0.035	-0.017	1.072	-1.067*	9.354*	-10.495	2.906
ADJ-BMP test	-0.039	-0.016	1.012	-0.187*	0.851*	-5.704	3.033
RANK test	-0.038	-0.008	1.031	-0.154*	0.467*	-5.051	3.304

The sample period covers January 3, 1990 through December 31, 2005 with daily returns for banking industry stocks (i.e., a total of 1,828 return series). Average correlations are computed for n = 50 securities in 1,000 simulations. Residuals are FF INDUSTRY MODEL adjusted returns: $AR_{it} = r_{it}^e - \alpha_i - \beta_{im} r_{mt}^e - \beta_{i,smb} SMB_t - \beta_{i,hml} HML_t - \beta_{i,bank} I_{bank,t}^e$, where r_i^e is the excess return of stock i, r_m^e is the value weighted market excess return, *SMB* is the small-minus-big market capitalization factor, *HML* is the high-minus-low book equity/market equity factor, and I_{bank}^e is the banking industry excess return (see Kenneth French's website). Asterisks indicate significant differences from zero at the 5 percent level or smaller.

Table C2
Banking industry two-tailed average rejection rates for different test statistics at the 0.05 significance level for the null hypothesis of no mean event effect in the presence of event-induced variance-covariance based on 1,000 random portfolios of *n* = 50, 30, and 10 securities

	Average event-induced variance-covariance factor c			
	$c = 1.0$	$c = 1.5$	$c = 2.0$	$c = 3.0$
Panel A. $n = 50$ securities				
UNADJ test	0.143	0.224	0.281	0.370
PATELL test	0.208	0.277	0.346	0.432
BMP test	0.214	0.214	0.215	0.213
PORT test	0.061	0.094	0.139	0.232
ADJ-PATELL test	0.061	0.115	0.168	0.250
ADJ-BMP test	0.057	0.056	0.059	0.058
RANK test	0.062	0.059	0.064	0.059
Panel B. $n = 30$ securities				
UNADJ test	0.098	0.158	0.208	0.300
PATELL test	0.104	0.178	0.247	0.336
BMP test	0.111	0.115	0.112	0.114
PORT test	0.061	0.100	0.136	0.205
ADJ-PATELL test	0.067	0.111	0.169	0.255
ADJ-BMP test	0.055	0.049	0.053	0.054
RANK test	0.061	0.057	0.061	0.060
Panel C. $n = 10$ securities				
UNADJ test	0.066	0.124	0.166	0.256
PATELL test	0.068	0.135	0.188	0.268
BMP test	0.123	0.123	0.122	0.122
PORT test	0.040	0.085	0.130	0.206
ADJ-PATELL test	0.053	0.109	0.167	0.251
ADJ-BMP test	0.094	0.094	0.091	0.094
RANK test	0.088	0.089	0.089	0.090

The variance (covariances) are increased according to the magnitudes of different volatility increasing designs. The no volatility effect is when the factor *c* is a constant equal to 1. In the three other designs, each event day (day 0) return $r_{i,0}$ is multiplied by $\sqrt{c}$, where *c* are random deviates drawn from the appropriate uniform distribution, *U*(1, 2), *U*(1.5, 2.5), or *U*(2.5, 3.5), with means 1.5, 2.0, and 3.0, respectively, depending on the design. Thus, the highest volatility with *c* drawn from *U*(2.5, 3.5) corresponds to an average variance that is 3 times the non-event variance, or $\sqrt{3} \approx 1.7$ times the non-event standard deviation. The correlations of the returns remain unchanged. Abnormal returns are the FF INDUSTRY MODEL adjusted returns: $AR_{it} = r_{it}^e - \alpha_i - \beta_{im} r_{mt}^e - \beta_{i,smb} SMB_t - \beta_{i,hml} HML_t - \beta_{i,bank} I_{bank,t}^e$, where r_i^e is the excess return of stock *i*, r_m^e is the value weighted market excess return, *SMB* is the small-minus-big market capitalization factor, *HML* is the high-minus-low book equity/market equity factor, and I_{bank}^e is the banking industry excess return (see Kenneth French's website).

With a true rejection rate of 5 percent (i.e., 0.05), the 95 percent confidence interval for the average rejection rates in 1,000 replicates is [0.036, 0.064]. The rejection rates indicate the fractions by which the test statistics exceed in 1,000 simulations the nominal cutoffs at the 5 percent level (i.e., 1.96 in the two-tailed test).

Table C3
Banking industry two-tailed average rejection rates at the 0.05 significance level for selected test statistics sampled from 1,000 random portfolios of *n* = 50 securities with abnormal returns ranging from -3.0 to +3.0 percent in different abnormal return models

Abnormal return (%)	PORT	ADJ-PATELL	ADJ-BMP	RANK
Panel A: FF INDUSTRY MODEL (average residual cross-correlation of 0.024)				
-3.0	0.994	0.999	0.995	0.999
-2.0	0.935	0.981	0.969	0.982
-1.0	0.515	0.720	0.716	0.767
-0.5	0.198	0.327	0.350	0.386
0.0	**0.068**	**0.064**	**0.056**	**0.054**
+0.5	0.166	0.288	0.319	0.375
+1.0	0.509	0.751	0.738	0.787
+2.0	0.933	0.974	0.963	0.974
+3.0	0.995	1.000	0.991	0.994
Panel B: FF MODEL (average residual cross-correlation of 0.033)				
-3.0	0.990	0.996	0.991	0.993
-2.0	0.915	0.971	0.961	0.970
-1.0	0.475	0.661	0.664	0.729
-0.5	0.168	0.253	0.273	0.309
0.0	**0.061**	**0.061**	**0.057**	**0.064**
+0.5	0.137	0.213	0.233	0.274
+1.0	0.451	0.636	0.627	0.706
+2.0	0.922	0.973	0.962	0.973
+3.0	0.997	1.000	0.998	1.000
Panel C: OLS MODEL (average residual cross-correlation of 0.044)				
-3.0	0.985	0.996	0.987	0.988
-2.0	0.872	0.941	0.929	0.953
-1.0	0.394	0.541	0.583	0.635
-0.5	0.135	0.187	0.212	0.248
0.0	**0.051**	**0.061**	**0.045**	**0.053**
+0.5	0.140	0.189	0.205	0.260
+1.0	0.412	0.575	0.595	0.674
+2.0	0.893	0.955	0.941	0.965
+3.0	0.994	1.000	0.990	0.997
PANEL D: INDUSTRY Adjusted Returns (average residual cross-correlation of 0.135)				
-3.0	0.820	0.851	0.864	0.792
-2.0	0.634	0.689	0.727	0.655
-1.0	0.281	0.349	0.411	0.303
-0.5	0.123	0.124	0.186	0.111
0.0	**0.053**	**0.038**	**0.062**	**0.034**
+0.5	0.094	0.094	0.143	0.092
+1.0	0.235	0.287	0.362	0.269
+2.0	0.607	0.674	0.724	0.637
+3.0	0.816	0.834	0.856	0.801

The abnormal return models are summarized in Table 1 of the main text. In panels A, B, and C the parameters are estimated from the 239 day estimation period. In panel D only the event period (21 days) observations are used in the estimation.

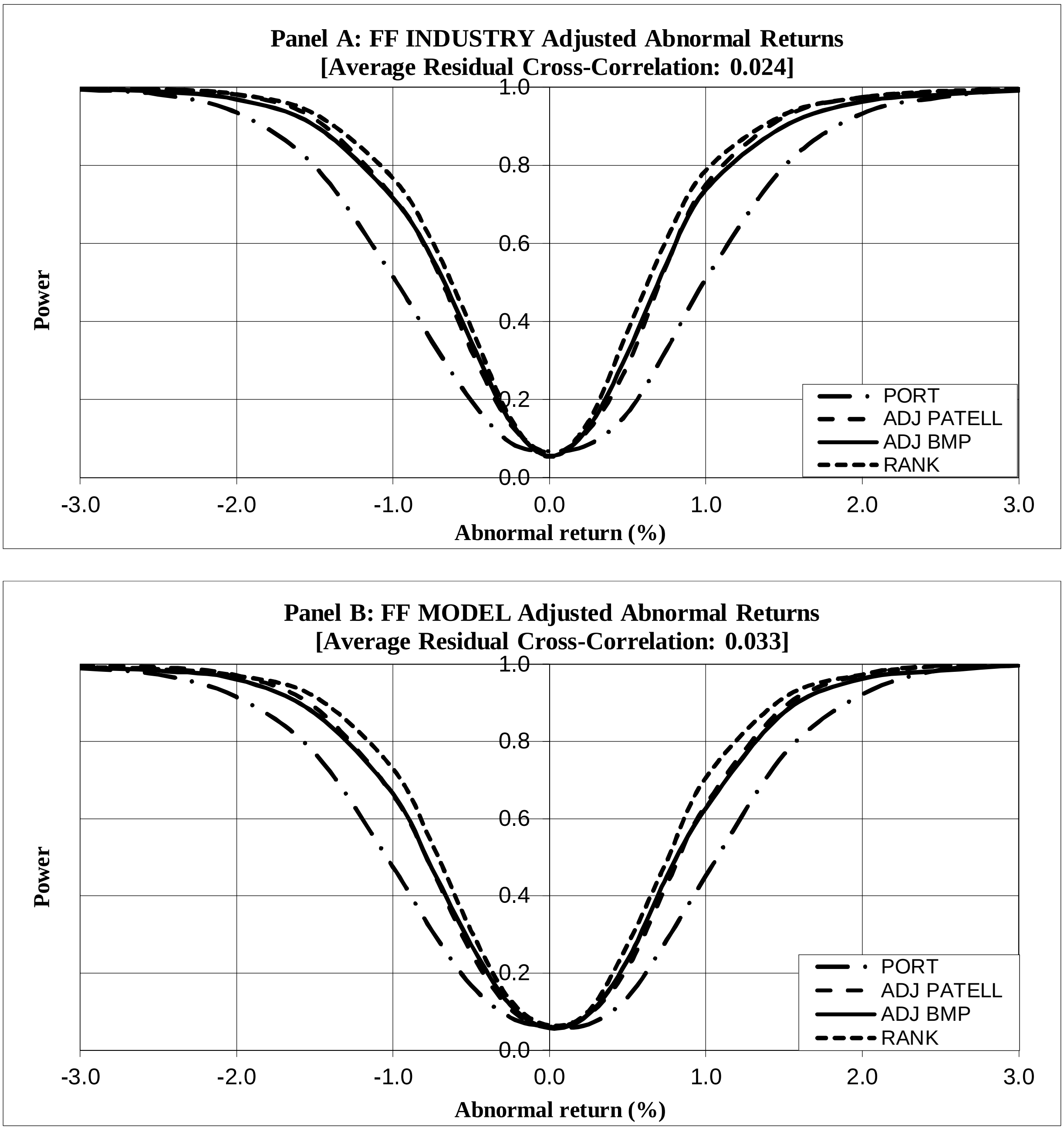
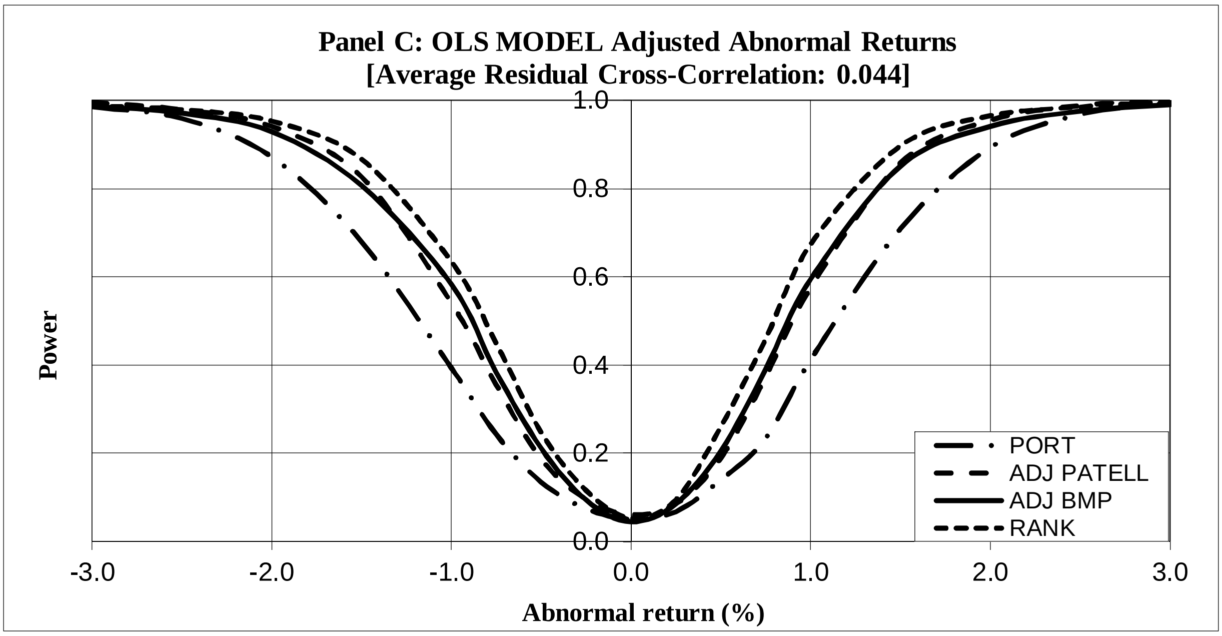


Figure C1

Estimated power functions with different abnormal return definitions for the PORT, ADJ-PATELL, ADJ-BMP, and RANK tests based on 1,000 samples of n = 50 security portfolios from the Fama-French banking industry: Two-sided tests, significance level 0.05, and no event-induced variance.

The sample period covers January 3, 1990 through December 31, 2005 with daily returns for firms in the Fama-French banking industry (i.e., a total of 1,828 return series). The abnormal returns are generated by adding a constant ranging from 0% to 3.0% to the abnormal returns. Panel A contains results for FF INDUSTRY MODEL adjusted returns augmented with a banking industry index:

$AR_{it} = r_{it}^{e} - \alpha_i - \beta_{im} r_{mt}^{e} - \beta_{i,smb} SMB_t - \beta_{i,hml} HML_t - \beta_{i,bank} I_{bank,t}^{e}$, where r_{it}^{e} is the stock excess return, r_{mt}^{e} is the value-weighted market excess return from Professor French's database, *SMB* is the small-minus-big market capitalization factor, *HML* is the high-minus-low book equity/market equity factor, and $I_{bank,t}^{e}$ is the excess banking industry return. Panel B is the same model as in panel A without the industry factor. Panel C employs OLS MODEL adjusted returns: $AR_{it} = r_{it}^{e} - \alpha_i - \beta_{im} r_{mt}^{e}$. Panel D utilizes INDUSTRY adjusted returns: $AR_{it} = r_{it} - I_{bank,t}$. In panel D the needed parameters are estimated from the 21-day event period, while for other panels the estimation period contains 239 days prior to the event period.



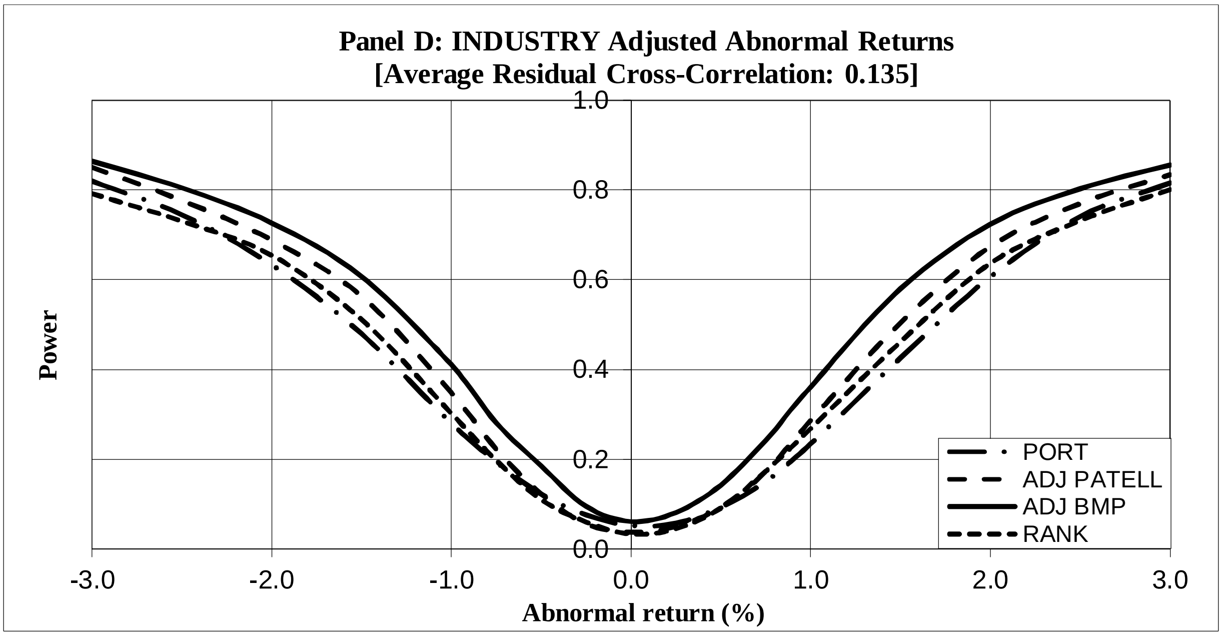


Figure C1
Continued