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Leverage effects Revisited：Using the Dynamic Panel Analysis

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Abstract

This paper investigates the asymmetric response of volatility (so-called leverage effect) to innovations in the 29 individual firms whose options are listed on the London Stock Exchange and the extent to which such a behavior is explained by the leverage ratio. Leverage effects are observed for 27 firms. Controlling for the unobservable heterogeneity, the dynamic panel analysis based on the GMM reveals that the degree of asymmetry can be attributed to the degree of leverage ratio, in support of the "leverage effect hypothesis." In addition, the observed leverage effects are positively related to the firm size.

Keywords： Leverage effect; EGARCH; Dynamic panel model; GMM
JEL Classification:

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1. Introduction

Previous research has shown that individual firm's stock return volatility rises after stock prices fall (Black (1976), Christie (1982), Cheung and Ng (1992)). One of the most popular explanations for this well-known relation is the "leverage effect".[1] The leverage effect posits that a firm's stock price decline raises the firm's financial leverage, resulting in an increase in the volatility of equity.

Nelson (1991) formalizes the notion of a negative relation between stock return and volatility by developing an exponential ARCH-type model whereby, the conditional variance is an asymmetric function of past innovations. He finds that negative innovations increase stock return volatility more than positive ones thus confirming Christie's (1982) and Black's (1976) earlier findings. However, there is also evidence that foreign stock indices (e.q. Poon and Taylor (1992) and Koutmos (1992)) and exchange rate changes (e.q. Koutmos(1993)) also exhibit asymmetric volatility.

Koutmos and Saidi (KS) (1995) investigates the asymmetric response of volatility to innovations in the 30 individual companies included in the Dow Jones Industrial and the extent to which such a behavior is explained by the debt-to-equity ratio. They found that all stock returns, with one exception, exhibit asymmetric volatility in the sense that negative innovations increase volatility more than positive innovations of an equal magnitude. In addition, their cross-section analysis reveals that, to some extent, differences in the degree of asymmetry can be attributed to differences in the degree of leverage in support of Christie's (1982) and Black's (1976)

[1] Other possible explanations include volatility feedback (Campbell and Hentschel (1992)), time-varying risk premia (Pindyck (1984), French, Schwert and Stambaugh (1987)) and asymmetry in the volatility of macroeconomic variables (Schwert (1989)). Recently, a trading explanation for asymmetric effects in daily volatility at the level of the firm is investigated by Avramov, Chordia and Goyal (2004). Using transaction data in their study of 2232 NYSE firms, they show that selling activity governs the asymmetric effect. Their empirical results support their argument that "herding" or uninformed traders sell when prices fall, leading to an increase in volatility, while "contrarian" or informed traders sell after prices rise leading to a reduction in volatility.

earlier findings. On the other hand, Duffee (1995) uses simple methods applied to all 2494 firms included in the set of CRSP tapes to show that the degree of asymmetry is related to neither debt-to-equity ratios nor firm size.

Recently, Figlewski and Wang (FW) (2000) argue that the “leverage effect” is not a leverage effect! Their empirical evidence suggests that the “leverage effect” is really a “down market effect” that may have little direct connection to firm leverage. The true explanation for the “leverage effect” phenomenon is yet to be determined.

This paper re-examines the leverage effect and contributes to the literature by providing two new insights. First, it uses the implied volatility of stock option as a proxy of conditional volatility of stock returns for a few reasons as described in section 4. Second, it exploits the panel aspects of the data by incorporating dynamic effects as well as controlling for unobservable firm-specific effects and provides a more appropriate basis to analyze leverage effects. We use the Arellano and Bond (1991) two-step GMM estimator for our dynamic model, which allows for heteroskedasticity across firms. The use of panel data and GMM provide a more satisfactory basis for our purpose. It is argued that, by providing a large number of data points and blending characteristics of both cross-sectional and time-series data, panel data improves the efficiency of econometric estimates (Hsiao (1985)).

The rest of this paper is organized as follows. Section 2 first derives a theoretical model of leverage effect and proposes relevant hypotheses. Section 3 presents the EGARCH model and the measure of leverage effect. Section 4 defines the relevant variables used to estimate the leverage effects and section 5 reports the estimation results. Section 6 deals with the determinants of leverage effect and discusses empirical results. The final section concludes.

2. Theoretical Background of Leverage Effects and Hypotheses

Before examining the empirical analysis of leverage effects, a simple model of the theoretical relation between volatility, leverage and firm size is first explored. This is derived from the model developed by Galai and Masulis (1976), which relates the systematic risk of equity to that of the firm's asset value and uses the framework of Black and Scholes (1973).

Consider a simple firm that issues bonds with a face value of D and maturity T secured on the assets of the firm, V. It is assumed that investors agree on the following stochastic process describing the evolution of firm value

$$dV = \mu V dt + \sigma V dz \tag{1}$$

where μ and σ are the instantaneous mean and standard deviation, respectively, of the proportional change in firm value, (dV/V), and dz are increments to a standard Wiener process.

Given the current level V and volatility σ of assets, and the riskless rate r, equity value can be denoted by the Black-Scholes (1973) price of a European call option with strike price D and time to maturity (Merton (1974)). That is

$$E = VN(d_1) - D\exp(-rT)N(d_2) \tag{2}$$

where $D\exp(-rT)$ is the present value of the face value of the firm's debt, E is the market value of the firm's equity and $N(x)$ is the cumulative normal probability of the unit normal variate, x, $d_1 = \left[\ln(V/D) + (r_f + 0.5\sigma^2)T\right]/\sigma\sqrt{T}$ and $d_2 = d_1 - \sigma\sqrt{T}$.

Further, Ito's lemma can be applied to find the instantaneous standard deviation of the rate of return on equity (dE/E). That is,

$$\sigma_E = \sigma \frac{V}{E}\frac{\partial E}{\partial V} \tag{3}$$

where σ_E is the instantaneous standard deviation of (dE/E).

Using the equation (2) and the delta of call option, the following substitutions can be made for the value of equity, E, and for $\partial E/\partial V$ in equation (3),

$$\sigma_E = \frac{VN(d_1)}{VN(d_1) - De^{-rT}N(d_2)}\sigma \tag{4}$$

Equation (4) can be rearranged as

$$\sigma_E = \frac{1}{1-(D/V)e^{-rT}\left[N(d_2)/N(d_1)\right]}\sigma \tag{5}$$

Since $(D/V) \le 1$, $\exp(-rT) < 1$ and $N(d_2) \le N(d_1)$, the variance of return on equity must be greater than the variance of the proportional change in firm value, that is $\sigma_E > \sigma$. Further, as reductions in firm value reduce the ratio $N(d_2) \le N(d_1)$ proportionately less than the ratio (D/V) increases, equity return volatility will rise. Also, since $N(d_1) = \partial E/\partial V > 0$, reductions in firm value must also reduce the value of equity. Taken together, the risk and return on leverage equity will be negatively correlated. In other words, it exhibits a "leverage effect." Thus, we have the following hypothesis

H_1: A firm with leveraged equity exhibits a leverage effect.

Moreover, from equation (5), the higher the leverage ratio (D/V), the greater the change in σ_E given any change in σ. That is

$$\partial(\sigma_E/\sigma)\Big/\partial(D/V) = \frac{e^{-rT}\left[N(d_2)/N(d_1)\right]}{\left\{1-(D/V)e^{-rT}[N(d_2)/N(d_1)]\right\}^2} > 0$$

Thus, the second hypothesis is

H_2: Observed leverage effects are increasing functions of leverage ratios.

Finally, the leverage effect is, relative to larger firms, expected to be more intense for smaller firms (as changes in leverage are likely to contain more information) for two reasons. First, the observed leverage multiplier (σ_E/σ) is affected by the maturity (T) of the outstanding debt of the firms. The longer the maturity of the debt, then the smaller is the multiplier. That is

$$\partial(\sigma_E / \sigma) \Big/ \partial T = \frac{-re^{-rT}\left[N(d_2)/N(d_1)\right]}{\left\{1-(D/V)e^{-rT}[N(d_2)/N(d_1)]\right\}^2} < 0$$

Larger and more developed firms are more likely to have an established reputation in the corporate debt market than can be used to access longer term loans than smaller companies. Second, small firms' returns are characterized by the relative scarcity of information when they use the leverage ratio as a possible means of signaling the stochastic process generating firm value (Barry and Brown (1984)). This suggests that, holding other factors constant, the equity returns of smaller firms are more likely to experience larger leverage effects. Thus, we have

H_3: Observed leverage effects are decreasing functions of firm size.

In the following sections, we will present an empirical framework that is used to test these hypotheses.

3. Volatility Asymmetry

To efficiently model the leverage effect, we adopt the Exponential GARCH (EGARCH) model developed by Nelson (1991), which allows the conditional variance to depend on the magnitude as well as the sign of the innovation. This implies that the variance of stock returns is an asymmetric function of the past error terms or, equivalently, negative and positive innovations can have a different impact on volatility. Furthermore, unlike the linear GARCH, the EGARCH model imposes no constraints on the parameters to ensure nonnegativity of the conditional variance. This allows for random oscillatory behavior of the conditional variance.

Let R_t be the stock return at time t;

I_{t-1} the information set at time $t-1$;

μ_t the expected stock return at time t;

$\varepsilon_t = R_t - \mu_t$ the innovation at time t;

σ_t^2 the conditional variance of R_t;

$f(\cdot)$ the conditional density function of R_t;

The EGARCH (1,1) model can then be formulated as follows:

$$R_t = d_0 + d_1 R_{t-1} + \varepsilon_t \tag{6}$$

$$\varepsilon_t | I_{t-1} \sim f(\mu_t, \sigma_t^2) \tag{7}$$

$$\ln \sigma_t^2 = \varpi + \beta \ln \sigma_{t-1}^2 + \alpha \left[\frac{|\varepsilon_{t-1}|}{\sqrt{\sigma_{t-1}^2}} - \sqrt{2/\pi} + \gamma \frac{\varepsilon_{t-1}}{\sqrt{\sigma_{t-1}^2}} \right] \tag{8}$$

Let $Z_t = \varepsilon_t / \sigma_t$, the equation (8) can be standardized as[2]

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[2] There are various ways to express the conditional variance equation of EGARCH. In general, the conditional variance equation (9) in the EGARCH can be reexpressed as

$\ln \sigma_t^2 = \alpha_0 + \alpha_1 g(Z_{t-1}) + \phi \ln \sigma_{t-1}^2$

where g(.) is an asymmetric response function defined by

$g(Z_t) = \delta Z_t + (|Z_t| - E|Z_t|)$

and the last term $\left(|Z_{t-1}| - \sqrt{2/\pi}\right)$ is the mean deviation of Z_{t-1} since $E(|Z_t|) = \sqrt{2/\pi}$.

$$\ln \sigma_t^2 = \varpi + \beta \ln \sigma_{t-1}^2 + \alpha \left(|Z_{t-1}| - E|Z_{t-1}| + \gamma Z_{t-1} \right) \qquad (9)$$

where $E|Z_{t-1}| = \sqrt{2/\pi}$

Equation (9) specifies the logarithm of the conditional variance as an asymmetric function of last period's standardized innovation Z_{t-1} and the logarithm of last period's conditional variance. In this respect, the term $\left(|Z_{t-1}| - E|Z_{t-1}|\right)$ represents the magnitude effect and the term γZ_{t-1} represents the sign effect. The leverage effect is present if the coefficient $\alpha\gamma$ is negative and statistically significant.[3]

If the leverage effect is present, the contribution of a positive innovation $(Z_{t-1} > 0)$ in (9) is equal to $\alpha(\gamma + 1)Z_{t-1}$, while the contribution of a negative innovation $(Z_{t-1} < 0)$ is equal to $\alpha(\gamma - 1)Z_{t-1}$. Given positive α, if γ is negative, then the increase of equity volatility caused by the negative innovations (price declines) is larger than the decrease of equity volatility caused by the positive innovations (price advances). This is the so-called "leverage effect". Koutmos and Saidi (1995) suggests that it is appropriate to use the absolute value of the quantity, $\alpha\gamma$, as a measure for the degree of asymmetry (leverage effect) for each individual stock.[4]

The degree of volatility persistence in (8) depends on the size of coefficient β. For $\beta = 1$, the unconditional variance does not exist and the conditional variance is an integrated process of the first degree. If $\beta < 1$, the unconditional variance exists, and its logarithm is equal to $\alpha_0 / (1 - \beta)$. In this case, the conditional variance is a

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[3] More formally, leverage effect is typical for parameterizations with $\gamma < 0$, $0 \le \alpha < 1$ and $\alpha + \beta < 1$. For such parameter configurations, negative innovations have a larger effect on the conditional variance than positive innovations of the same size.

[4] An advantage of adopting the EGARCH formulation over other asymmetric GARCH specifications is due to the fact that the EGARCH is no need to artificially impose non-negative constraints on the model parameters. It thus allows the coefficient γ to adequately reflect the negative relationship between volatility and returns.

mean-reverting process.

4. Data and the Definition of Variables

In this study, we use a sample of 29 firms whose options are listed on the London Stock Exchange or the London International Financial Futures and Options Exchange. Table 1 provides the names of the companies, their corresponding Company Code (CNUM) and Industrial Code (DNUM). The data were obtained from the DATASTREAM and cover the period from 2000/1/25 to 2003/12/31. Financial data, such as debt-to-equity ratios and asset size, were obtained from the annual COMPUSTAT tapes.

To examine the leverage effect, the implied volatility of stock options is used as a proxy of conditional volatility of stock returns for several reasons. First, implied volatility is more responsive than stock return volatility, because it is absent of short-sales restrictions. Second, it is widely accepted that the implied volatility computed from the market price of an option is a good estimate of the market's expectation of the volatility of the underlying asset, and that market's expectation is informationally efficient. It contains reliable incremental information and outperforms past volatility in forecasting future return volatility (Christensen and Prabhala (1998), Mayhew and Stivers (2003)).

Let's define variables used in the EGARCH model as follows:

1. Implied Volatility (IV): Given any option price, we calculate the implied standard deviation (ISD) by inverting the Black and Scholes (1973) formula by using Newton-Raphson method. For each day, the ISD is estimated from near-term, at-the-money stock options for the 29 firms. The implied volatility is expressed on a daily basis by dividing ISD by the square root of 252 (the number of trading days in a year), that is $ISD/\sqrt{252}$. The three-month LIBOR is used as a proxy of riskless interest rate.

2. Innovations (ε_t): The first-difference of the log of stock prices are employed as proxies of innovations of stock price. That is, $\varepsilon_t = \left|\Delta \ln P_t\right|$.

3. Debt-to-equity ratio (D/E): The ratio of the long-term debt to market value of equity is used as the proxy of debt-to-equity (leverage) ratio.[5] The market value of equity is calculated as the stock price on the end of the year multiplied by the number of shares of common stock outstanding.

4. Firm size (A): The logarithm of total asset is used as a proxy for firm size.

As the implied volatility and the first-difference of the log of stock prices are regarded as proxies of conditional variance of stock returns and innovations of stock price, respectively, the equation (8) of EGARCH can be, following Simon (1997), rewritten as

$$\ln(IV_t^2) = \omega + \beta \ln(IV^2_{t-1}) + \alpha \left[\frac{\left|\Delta \ln P_t\right|}{\sqrt{IV^2_{t-1}}} - \sqrt{2/\pi} + \gamma \frac{\Delta \ln P_t}{\sqrt{IV^2_{t-1}}} \right] \quad (10)$$

or expressed as

$$\ln(IV_t^{\ 2}) = \beta_0 + \beta_1 \ln(IV_{t-1}^{\ 2}) + \beta_2 \left[\Delta \ln P_t^+ / \sqrt{IV_{t-1}^{\ 2}} \right] + \beta_3 \left[\Delta \ln P_t^- / \sqrt{IV_{t-1}^{\ 2}} \right] \quad (11)$$

where $\beta_2 = \alpha(\gamma + 1)$ and $\beta_3 = \alpha(\gamma - 1)$ denotes, respectively, the impact of positive and negative innovations.

In the above equation, IV_t is the estimated implied volatility at the close of trading on day t, expressed on a daily basis, $\Delta \ln P_t$ is the first-difference of the log of stock prices from the close of trading on day $t-1$ to day t, representing the daily innovations of stock prices, $\ln P_t^+$ and $\ln P_t^-$ denotes, respectively, the positive and

[5] For the debt-to-equity ratio, several widely used measures are calculated. Koutmos and Saidi (1995) used nine different measures of debt-to-equity ratios. Three of these measures are based on the book value and six are based on the market value of equity. The empirical results did not show significant difference as the different measures of debt-to-equity ratio are employed.

negative price changes. The logs of stock price are scaled by lagged implied volatility at the close of trading at day $t-1$, expressed on a daily basis by dividing by the square root of 252 (the number of trading days in a year).[6]

The above model is an asymmetric GARCH model which specifies that implied volatility at the close of day t is driven by its lagged value, and by separate variables for positive and negative scaled stock price changes from the close on day $t-1$ to the close on day t.[7] Separate variables for positive and negative stock price changes are included to determine whether implied volatility responds differently to positive and negative stock price changes. If both greater scaled stock price increases and decreases give rise to higher implied volatility, β_2 should be significantly positive and β_3 should be significantly negative. If implied volatility increases more in response to negative than positive stock price changes, then $|\beta_3| > |\beta_2|$.

The maximum likelihood estimates of the EGARCH (1,1) model for the 29 firms are reported in Table 2. The coefficients, γ, measuring the asymmetric impact of past innovations on current volatility (leverage effect) are statistically significant at least at the 1% level for 27 firms, with the exception of 2 firms (number 2 and 12). Their signs are negative in all cases with no exception. As mentioned above, this implies that negative innovations increase volatility more than positive innovations, supporting our first hypothesis that leverage effects are present. These results are consistent with Black (1976), Christie (1982) and Nelson (1991).

The coefficients, α, that links current volatility (conditional variance) to the asymmetric function of past innovations are significant at the 5% level for 22 firms.

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[6] If the log of daily stock price changes is normally distributed with a mean equal to zero and a standard deviation equal to estimated implied volatility expressed on a daily basis, then $\Delta \ln P_t /(IV_{t-1} / \sqrt{252}) \sim N(0,1)$

[7] The reason for scaling stock price changes is that market participants should revise their forecasts of volatility. Consequently, implied volatility changes should be greater when the magnitude of stock price changes diverges from that predicted by implied volatility.

Their signs are positive and their values are between zero and one in all cases. Likewise, the coefficients, β, that links current volatility to past volatility is statistically significant even at the 1% level for all firms. They are all lees than, but close to, one. The coefficient β is important because it measures the persistence of innovations on volatility. A more intuitive measure of persistence is the half-life of an innovation calculated as $\ln(0.5)/\ln(\beta)$. Using this measure, we can see that firm number 23 exhibits the shortest persistence with a half-life of 34 days and firm number 22 exhibits the longest persistence with a half-life of approximation 138 days.

5. Estimating time-varying leverage effects

The first stage of our empirical work involves estimating the EGARCH model (10) equation-by-equation for the 29 stock options. It is well documented that expected returns and risks for the underlying stocks can be time-varying. We explicitly incorporate these elements into our estimation. Given our sample of daily observations for 4 years, we estimate the following EGARCH with time-varying coefficients for 29 options individually using a maximum likelihood estimation procedure:

$$\ln(IV_t^2) = \sum_{n=1}^{4}\omega_n D_n + \sum_{n=1}^{4}\beta_n D_n \ln(IV^2{}_{t-1}) + \sum_{n=1}^{4}\alpha_n D_n \left[\frac{|\Delta \ln P_t|}{\sqrt{IV^2{}_{t-1}}} - \sqrt{2/\pi} + \gamma_n \frac{\Delta \ln P_t}{\sqrt{IV^2{}_{t-1}}} \right] \quad (12)$$

where the year dummy variables, D_n , as defined as follows:

$$D_n = \begin{cases} 1 & if \quad t \in year\, n \quad , \quad n = 1,2,3\, and\, 4 \\ 0 & otherwise \end{cases}$$

Our empirical procedure allows us to estimate a conditional measure of leverage effects for each option for each year, which we seek to explain in our panel regressions in the following section. The coefficients, $\alpha\gamma_{i,n}$, denote the time-varying asymmetries on firm i (from 1 to 29) for year n (from 1 to 4), which measure the leverage effects of firm i at year n . They are presented in Table 3. Those coefficients, with a total of 116, are used to examine the determinant of leverage effect in the following section.

6. The Determinant of Leverage Effects

6.1. The Pooled OLS

In the following analysis, we attempt to determine whether the estimated degree of asymmetry for each firm is related to some measure of financial leverage (debt/equity ratio)and firm size. We start with the following pooled OLS:

$$|\alpha\gamma|_{it} = \delta_0 + \delta_1 (D/V)_{it} + \delta_2 (A)_{it} + u_{it} \qquad for \quad i = 1,2,\cdots 29, \quad t = 1,2,3,4 \qquad (13)$$

where $|\alpha\gamma|_{it}$ is the absolute value of the degree of asymmetry of firm i on year t, as discussed earlier; $(D/V)_{it}$ is the debt-to-equity ratio of firm i on year t, representing the measure of financial leverage; $(A)_{it}$ is the asset size of firm i on year t; u_{it} is an error term and γ_0, γ_1 *and* γ_2 are coefficients to be estimated.

A positive and statistically significant δ_1 coefficient implies that variations in the asymmetric response of volatility to shocks can be attributed to variations in the financial leverage across firms. The variable $(A)_{it}$ is only used to account for possible heteroskedasticity in u_{it} due to firm-size difference.

6.2. The Fixed-effect Panel Model

The fundamental advantage of a panel data set over a cross-section is that it will allow the researcher greater flexibility in modeling differences in behavior across individuals. We consider a fixed-effect model in which the approach takes δ_{oi} , $i = 1,2,\cdots 29$ to be a firm-specific constant term in the regression model (13). That is,

$$(\alpha\gamma)^*_{it} = \delta_{0i} + \delta_1 (D/V)_{it} + \delta_2 (A)_{it} + u_{it} \qquad (14)$$

where $(\alpha\gamma)^*_{it} \equiv |\alpha\gamma|_{it}$. This formulation of the model assumes that differences across firm can be captured in differences in the constant term. Each δ_{oi} is treated as an unknown parameter to be estimated.

The results of pooled OLS and panel model are presented in the Table 4. In pooled OLS, only the coefficient of firm size (δ_2) is significantly (different from zero); however, in panel OLS, both coefficient δ_1 and δ_2 are significant at 1% level. As mentioned above, the panel data methodology has the great advantage of allowing us to control for unobservable heterogeneity through firm-specific effects δ_{0i}.[8] In panel OLS, the positive coefficient of δ_1 supports our second hypothesis and the positive coefficient of δ_2, however, contradicts our third hypothesis.

6.3. The Dynamic Panel Model and GMM

Panel data are well suited for examining dynamic effects, as in the first-order fixed-effect model

$$\alpha\gamma_{it}^{*} = \delta_{0i} + \theta\alpha\gamma_{it-1}^{*} + \delta_1 (D/V)_{it} + \delta_2 (A)_{it} + u_{it} \qquad for \quad i = 1,2,\cdots N, \quad t = 1,2,\cdots T \tag{15a}$$

In this case, $N = 29$ and $T = 4$. The set of right hand side variables now includes the lagged dependent variables, $\alpha\gamma_{it-1}^{*}$. Adding dynamics to the above model in this fashion is a major change in the interpretation of the equation. Without the lagged variable, the "independent variables" represent the full set of information that produce observed outcome $\alpha\gamma_{it}$. With the lagged variable, we now have in the equation, the entire history of the right hand side variables, so that any measured influence is conditioned on this history.

In a pure cross-sectional regression, the unobserved firm-specific effect is a part of the error term. Thus, a possible correlation between the unobservable firm-specific effect and the explanatory variables results in biased coefficient estimates. Therefore, we use a dynamic panel estimator that controls for the presence of unobserved

[8] Without control for the heterogeneity, we will run the risk of obtaining biased results, as shown by Moulton (1986, 1987).

firm-specific effects. The approach produces consistent and efficient estimates even when the firm-specific effect is correlated with the explanatory variables.

Before proceeding, we must somewhat get rid of the unobserved firm-specific effect. Nickell (1981) has shown that, for models with lagged dependent variables, treating firm-specific effects as constants to be estimated or used within transformation yields inconsistent estimates. The usual method of dealing with the firm-specific effect in the context of panel data has been to first-difference the regression (Anderson and Hsiao (1981); Arellano and Bond (1991)). In this way, the firm-specific effect is directly eliminated from the estimation process, which yields

$$\Delta\alpha\gamma_{it}^{*} = \hat{\theta}\Delta\alpha\gamma_{it-1}^{*} + \hat{\delta}_1\Delta(D/V)_{it} + \hat{\delta}_2\Delta(A)_{it} + \Delta u_{it} \tag{15b}$$

Since the difference of the lagged dependent variable is related to the errors, the OLS estimation is biased. In order to avoid this problem, we estimate our models by using the generalized method of moments (GMM), which allows us to control for problems of endogeneity by using instruments. The GMM, suggested by Arellano and Bond (1991), is employed here.

The orthogonal condition suggested by Arellano and Bond (1991) is

$$\begin{aligned} &E\left[\Delta u_{it}\alpha\gamma_{i,t-j}\right] = 0 \\ &E\left[\Delta u_{it}(D/V)_{i,t-j}\right] = 0 \quad \textit{for} \quad \forall j = 2,\cdots t-1; \quad t = 3,\cdots T \\ &E\left[\Delta u_{it}(A)_{i,t-j}\right] = 0 \end{aligned} \tag{16}$$

Thus, there are $(T-2)\times(T-1)/2$ orthogonal conditions. Each orthogonal condition can be further written in a compact for each firm, that is,

$$E\left[\Delta \underline{u}_{it} Z_i^{'}\right] = 0 \qquad i = 1,2,\cdots N \tag{17}$$

where $Z_i =$

$$\begin{bmatrix} [m1_{i1}, m2_{i1} \;\; m2_{i2} \;\; m3_{i1} \;\; m3_{i2}] & & & \\ & [m1_{i1} \;\; m1_{i2} \;\; m2_{i1} \;\; m2_{i2} \;\; m2_{i3} \;\; m3_{i1} \;\; m3_{i2} \;\; m3_{i3}] & & \\ & & \cdots & \\ & & & [m1_{i1}\cdots m1_{iT-2}, m2_{i1}\cdots m2_{iT-1}, m3_{i1}\cdots m3_{iT-1}] \end{bmatrix}$$

where $m1 = \alpha\gamma^{*}, m2 = (D/V), m3 = (A)$ and

$$\Delta\underline{u}_{it} = \left[\Delta u_{1t}, \Delta u_{2t}, \cdots, \Delta u_{Nt}\right]$$

Using these moment conditions, Arellano and Bond (1991) propose a two-step GMM estimator. In the first step, the error terms are assumed to be independent and homoskedastic across firms and over time. In the second step, the residuals obtained in the first step are used to construct a consistent estimate of the variance-covariance matrix, thus relaxing the assumptions of independence and homoskedasticity.

6.4. Empirical results

The result obtained seems to verify our hypothesis 2. As can be seen in Table 5, $\hat{\delta}_1$ is positive and significantly different from zero at 10% significance level. The result indicates that observed leverage effects are increasing functions of debt ratios.

On the contrary, the result contradicts the hypothesis 3. Although $\hat{\delta}_2$ is significantly different from zero at least at 10% significance level, its sign is positive. The result implies that observed leverage effects are also increasing functions of firm size. The equity returns in larger firms are more likely to experience larger leverage effects.

In order to check for potential misspecification of the models, we use the Sargan statistic of over-identifying restrictions, which tests for the hypothesis that the instrument variables used are not correlated with the error term. The p-values in Table 5, which fail to reject the null hypothesis, give support to the validity of our model.

Table 1

List of company names and industrial code in the sample

No.	Company	Industrial Code
1	ALLIANCE & LEICESTER PLC	6020
2	ALLIED DOMECQ PLC	2085
3	ANGLO AMERICAN PLC	6792
4	ASTRAZENECA PLC	2834
5	AVIVA PLC	6331
6	BP PLC	2911
7	BG GROUP PLC	1311
8	BRITISH SKY BCAST	4841
9	CENTRICA PLC	4932
10	DIAGEO PLC	2085
11	EMI GROUP	8900
12	GALLAHER GROUP PLC	2111
13	GLAXOSMITHKLINE PLC	2834
14	GUS PLC	5961
15	HANSON	3270
16	HILTON GROUP	7990
17	IMPERIAL TOBACCO GROUP	2111
18	KINGFISHER PLC	5211
19	MARKS & SPENCER GROUP PLC	5311
20	NATIONAL GRID TRNSCO PLC	4911
21	PRUDENTIAL PLC	6311
22	REED ELSEVIER PLC	2700
23	REUTERS GROUP PLC	7380
24	RIO TINTO GROUP	1000
25	ROLLS ROYCE GROUP PLC	3724
26	ROYAL & SUN ALLIANCE INS PLC	6331
27	SCOTTISH POWER PLC	4911
28	VODAFONE GROUP PLC	4812
29	WHITBREAD PLC	5810

Table 2

The Estimation of EGARCH parameters over the full sample period

No.	Company	ω	β	γ	α
1	ALLIANCE & LEICESTER	0.039	0.993***	-0.235***	0.077
		(0.405)	(0.000)	(0.000)	(0.209)
2	ALLIED DOMECQ PLC	0.041	0.987***	-0.056	0.097
		(0.395)	(0.000)	(0.190)	(0.125)
3	ANGLO AMERICAN	0.074	0.982***	-0.342***	0.152***
		(0.111)	(0.000)	(0.000)	(0.010)
4	ASTRAZENECA PLC	0.118***	0.986***	-0.450***	0.199***
		(0.009)	(0.000)	(0.000)	(0.001)
5	AVIVA	0.053	0.991***	-0.399***	0.097
		(0.278)	(0.000)	(0.000)	(0.135)
6	BP PLC	0.069	0.990***	-0.403***	0.124**
		(0.136)	(0.000)	(0.000)	(0.040)
7	BG GROUP	-0.013	0.986***	-0.158***	0.024
		(0.787)	(0.000)	(0.000)	(0.704)
8	BRITISH SKY BCAST	0.110***	0.993***	-0.363***	0.166***
		(0.008)	(0.000)	(0.000)	(0.003)
9	CENTRICA	0.183***	0.987***	-0.115***	0.280***
		(0.000)	(0.000)	(0.002)	(0.000)
10	DIAGEO	0.068*	0.990***	-0.260***	0.125**
		(0.100)	(0.000)	(0.000)	(0.021)
11	EMI GROUP	0.177***	0.983***	-0.124***	0.269***
		(0.000)	(0.000)	(0.000)	(0.000)
12	GALLAHER GROUP	0.051	0.990***	-0.062	0.098
		(0.287)	(0.000)	(0.151)	(0.115)
13	GLAXOSMITHKLINE	0.097	0.992***	-0.357***	0.155***
		(0.033)	(0.000)	(0.000)	(0.009)
14	GUS PLC	0.022	0.994***	-0.143***	0.047
		(0.501)	(0.000)	(0.000)	(0.259)
15	HANSON	0.077**	0.994***	-0.107***	0.121***
		(0.024)	(0.000)	(0.000)	(0.005)
16	HILTON	0.067*	0.988***	-0.188***	0.124**
		(0.094)	(0.000)	(0.000)	(0.017)

17	IMPERIAL TOBACCO GROUP	0.099**	0.991***	-0.190***	0.160***
		(0.032)	(0.000)	(0.000)	(0.007)
18	KINGFISHER	0.109**	0.982***	-0.171***	0.195***
		(0.023)	(0.000)	(0.000)	(0.002)
19	MARKS & SPENCER	0.034	0.991***	-0.235***	0.074**
		(0.399)	(0.000)	(0.000)	(0.161)
20	NATIONAL GRID TRNSCO	0.074	0.988***	-0.196***	0.139**
		(0.166)	(0.000)	(0.000)	(0.041)
21	PRUDENTIAL	0.108**	0.991***	-0.541***	0.171***
		(0.017)	(0.000)	(0.000)	(0.004)
22	REED ELSEVIER	0.063**	0.995***	-0.277***	0.098**
		(0.037)	(0.000)	(0.000)	(0.012)
23	REUTERS GROUP	0.085**	0.980***	-0.177***	0.148***
		(0.030)	(0.000)	(0.000)	(0.005)
24	RIO TINTO	0.084*	0.986***	-0.388***	0.153**
		(0.082)	(0.000)	(0.000)	(0.013)
25	ROLLS ROYCE	0.182***	0.983***	-0.177***	0.279***
		(0.000)	(0.000)	(0.000)	(0.000)
26	ROYAL & SUN ALLIANCE	0.125***	0.988***	-0.400***	0.193***
		(0.010)	(0.000)	(0.000)	(0.003)
27	SCOTTISH POWER	0.092*	0.983***	-0.207***	0.178***
		(0.074)	(0.000)	(0.000)	(0.008)
28	VODAFONE GROUP	0.082*	0.993***	-0.413***	0.128**
		(0.091)	(0.000)	(0.000)	(0.050)
29	WHITBREAD	0.007	0.990***	-0.262***	0.045
		(0.877)	(0.000)	(0.000)	(0.402)

Note: The numbers in parentheses are p-values and thus ***, ** and * denote, respectively, the significance of 1%, 5% and 10%.

Table 3

Estimation of Time-varying coefficients of EGARCH Model

No.	Company name	2000				2001				2002				2003			
		ω	β	γ	α	ω	β	γ	α	ω	β	γ	α	ω	β	γ	α
1	ALLIANCE & LEICESTER	-0.130	0.962***	0.042	-0.072	-0.140	0.973***	-0.182**	-0.097	0.230**	0.986***	-0.417***	0.347	0.084	0.995***	-0.436***	0.136
		(0.179)	(0.000)	(0.571)	(0.504)	(0.150)	（0.000）	(0.026)	(0.431)	(0.018)	(0.000)	(0.000)	(0.006)	(0.416)	(0.000)	(0.000)	(0.313)
2	ALLIED DOMECQ PLC	-0.005	0.927***	-0.018	0.162	-0.178	0.967***	-0.049	-0.124	0.082	0.983***	-0.158**	0.169	0.123	0.992***	0.011	0.192
		(0.960)	(0.000)	(0.842)	(0.239)	(0.113)	（0.000）	(0.594)	(0.379)	(0.356)	(0.000)	(0.035)	(0.122)	(0.207)	(0.000)	(0.899)	(0.136)
3	ANGLO AMERICAN	-0.044	0.971***	-0.130	0.018	0.095	0.979***	-0.335***	0.183*	0.129	0.972***	-0.435***	0.248*	0.030	0.955***	-0.468***	0.196
		(0.669)	(0.000)	(0.104)	(0.883)	(0.272)	（0.000）	(0.000)	(0.083)	(0.203)	(0.000)	(0.000)	(0.066)	(0.766)	(0.000)	(0.000)	(0.113)
4	ASTRAZENECA PLC	-0.059	0.939***	-0.212***	0.098	0.075	0.953***	-0.079	0.248**	0.113	0.988***	-0.743***	0.184*	0.172*	0.996***	-0.727***	0.247*
		(0.533)	(0.000)	(0.004)	(0.371)	(0.433)	（0.000）	(0.318)	(0.033)	(0.157)	(0.000)	(0.000)	(0.084)	(0.080)	(0.000)	(0.000)	(0.056)
5	AVIVA	-0.242**	0.912***	-0.191**	-0.087	0.140	0.972***	-0.088	0.266**	0.076	0.994***	-0.499***	0.119	0.029	1.001***	-0.779***	0.047
		(0.038)	(0.000)	(0.042)	(0.547)	(0.152)	（0.000）	(0.290)	(0.039)	(0.353)	(0.000)	(0.000)	(0.286)	(0.799)	(0.000)	(0.000)	(0.751)
6	BP PLC	-0.113	0.978***	-0.024	-0.090	0.195**	0.969***	-0.224***	0.356***	0.031	0.986***	-0.704***	0.083	-0.034	0.991***	-0.663***	-0.005
		(0.237)	(0.000)	(0.754)	(0.455)	(0.024)	（0.000）	(0.001)	(0.001)	(0.715)	(0.000)	(0.000)	(0.452)	(0.757)	(0.000)	(0.000)	(0.972)

7	BG GROUP	0.016	0.981***	-0.054	0.064	-0.083	0.966***	-0.303***	-0.007	0.005	0.985***	-0.179**	0.053	-0.101	0.977***	0.002***	-0.061
		(0.880)	(0.000)	(0.547)	(0.641)	(0.413)	（0.000）	(0.000)	(0.952)	(0.954)	(0.000)	(0.013)	(0.639)	(0.411)	(0.000)	(0.984)	(0.704)
8	BRITISH SKY BCAST	0.134*	0.982***	-0.088	0.209**	0.017	0.956***	-0.184***	0.124	0.027	0.994***	-0.786***	0.055	0.146	0.986***	-0.447***	0.241*
		(0.062)	(0.000)	(0.165)	(0.031)	(0.838)	（0.000）	(0.007)	(0.230)	(0.734)	(0.000)	(0.000)	(0.611)	(0.153)	(0.000)	(0.000)	(0.075)
9	CENTRICA	-0.169	0.896***	-0.144*	0.004	0.024	0.952***	0.035	0.175	0.495***	0.991***	-0.110	0.687***	0.014	0.976***	-0.151**	0.092
		(0.105)	(0.000)	(0.055)	(0.967)	(0.821)	（0.000）	(0.652)	(0.143)	(0.000)	(0.000)	(0.108)	(0.000)	(0.890)	(0.000)	(0.067)	(0.497)
10	DIAGEO	-0.002	0.975***	-0.030	0.069	-0.039	0.959***	-0.026	0.084	0.168**	0.980***	-0.547***	0.288***	-0.041	0.994***	-0.448***	-0.022
		(0.980)	(0.000)	(0.664)	(0.503)	(0.689)	（0.000）	(0.723)	(0.438)	(0.025)	(0.000)	(0.000)	(0.003)	(0.662)	(0.000)	(0.000)	(0.854)
11	EMI GROUP	-0.115	0.936***	-0.053	-0.043	0.306***	0.967***	-0.044	0.483***	0.111	0.980***	-0.145**	0.191**	0.079	0.960***	-0.131*	0.166
		(0.181)	(0.000)	(0.448)	(0.671)	(0.000)	（0.000）	(0.440)	(0.000)	(0.131)	(0.000)	(0.018)	(0.043)	(0.328)	(0.000)	(0.058)	(0.113)
12	GALLAHER GROUP	-0.171	0.913***	0.039	-0.022	-0.080	0.972***	-0.004	-0.018	0.198*	0.988***	-0.140	0.293**	0.123	0.978***	-0.256**	0.246
		(0.114)	(0.000)	(0.616)	(0.836)	(0.465)	（0.000）	(0.962)	(0.885)	(0.060)	(0.000)	(0.111)	(0.030)	(0.295)	(0.000)	(0.010)	(0.106)
13	GLAXOSMITH KLINE	-0.095	0.966***	-0.099	-0.029	0.161*	0.967***	-0.135*	0.320***	0.089	0.995***	-0.551***	0.136	0.055	0.997***	-0.615***	0.091
		(0.326)	(0.000)	(0.185)	(0.815)	(0.073)	（0.000）	(0.074)	(0.005)	(0.273)	(0.000)	(0.000)	(0.202)	(0.575)	(0.000)	(0.000)	(0.480)
14	GUS PLC	0.036	0.987***	-0.103	0.079	-0.020	0.975***	-0.055	0.043	0.017	0.989***	-0.205***	0.056	0.031	0.996***	-0.228***	0.059
		(0.610)	(0.000)	(0.102)	(0.383)	(0.734)	（0.000）	(0.274)	(0.539)	(0.809)	(0.000)	(0.000)	(0.534)	(0.664)	(0.000)	(0.000)	(0.537)
15	HANSON	0.071	0.981***	0.161***	0.137*	0.012	0.969***	-0.265***	0.105	0.011	0.984***	-0.198***	0.065	0.066	1.008***	-0.148**	0.071
		(0.283)	(0.000)	(0.005)	(0.092)	(0.885)	（0.000）	(0.000)	(0.280)	(0.860)	(0.000)	(0.000)	(0.413)	(0.376)	(0.000)	(0.020)	(0.464)
16	HILTON	-0.019	0.966***	0.023	0.051	0.116	0.987***	-0.058	0.193**	0.102	0.985***	-0.354***	0.178	0.144	0.988***	-0.486***	0.225
		(0.827)	(0.000)	(0.765)	(0.631)	(0.106)	（0.000）	(0.429)	(0.030)	(0.283)	(0.000)	(0.000)	(0.154)	(0.182)	(0.000)	(0.000)	(0.118)

17	IMPERIAL TOBACCO GROUP	-0.040	0.893***	-0.120*	0.215**	0.018	0.979***	-0.142	0.091	-0.060	0.968***	-0.102	0.024	0.043	0.992***	-0.425***	0.095
		(0.696)	(0.000)	(0.099)	(0.047)	(0.867)	（0.000）	(0.110)	(0.484)	(0.510)	(0.000)	(0.170)	(0.829)	(0.678)	(0.000)	(0.000)	(0.473)
18	KINGFISHER	0.048	0.969***	0.387***	0.136	0.033	0.972***	-0.060	0.120	0.207**	0.982***	-0.558***	0.330**	0.056	0.985***	-0.537***	0.121
		(0.593)	(0.000)	(0.000)	(0.237)	(0.727)	（0.000）	(0.463)	(0.297)	(0.031)	(0.000)	(0.000)	(0.011)	(0.594)	(0.000)	(0.000)	(0.389)
19	MARKS & SPENCER	-0.078	0.976***	0.033	-0.056	-0.102	0.960***	0.054	-0.022	0.045	0.984***	-0.486***	0.111	-0.019	0.986***	-0.384***	0.026
		(0.324)	(0.000)	(0.648)	(0.584)	(0.268)	（0.000）	(0.487)	(0.848)	(0.558)	(0.000)	(0.000)	(0.266)	(0.819)	(0.000)	(0.000)	(0.810)
20	NATIONAL GRID TRNSCO	-0.070	0.913***	-0.091	0.135	0.055	0.971***	-0.035	0.163	-0.053	0.959***	-0.243**	0.084	0.093	0.985***	-0.409***	0.187
		(0.535)	(0.000)	(0.336)	(0.324)	(0.592)	（0.000）	(0.681)	(0.183)	(0.653)	(0.000)	(0.011)	(0.569)	(0.389)	(0.000)	(0.000)	(0.182)
21	PRUDENTIAL	0.065	0.948***	-0.203**	0.208	0.128	0.973***	-0.482***	0.249**	0.062	0.997***	-0.755***	0.093	0.080	0.999***	-0.612***	0.118
		(0.548)	(0.000)	(0.030)	(0.127)	(0.109)	（0.000）	(0.000)	(0.017)	(0.497)	(0.000)	(0.000)	(0.445)	(0.392)	(0.000)	(0.000)	(0.343)
22	REED ELSEVIER	0.002	0.991***	-0.084	0.022	0.069	0.980***	-0.015	0.147*	0.150**	0.994***	-0.519***	0.216***	-0.077	0.995***	-0.475***	-0.083
		(0.978)	(0.000)	(0.133)	(0.782)	(0.300)	（0.000）	(0.768)	(0.052)	(0.014)	(0.000)	(0.000)	(0.007)	(0.185)	(0.000)	(0.000)	(0.271)
23	REUTERS GROUP	0.149**	0.959***	-0.036	0.258***	0.080	0.930***	-0.114	0.228**	-0.133	0.990***	-0.429***	-0.158	-0.011	0.989***	-0.258***	0.014
		(0.042)	(0.000)	(0.587)	(0.009)	(0.354)	（0.000）	(0.106)	(0.040)	(0.107)	(0.000)	(0.000)	(0.151)	(0.899)	(0.000)	(0.000)	(0.903)
24	RIO TINTO	0.011	0.962***	-0.208***	0.102	-0.003	0.954***	0.003	0.119	0.071	0.979***	-0.620***	0.158	0.025	0.948***	-0.642***	0.223*
		(0.912)	(0.000)	(0.008)	(0.401)	(0.975)	（0.000）	(0.969)	(0.335)	(0.450)	(0.000)	(0.000)	(0.193)	(0.804)	(0.000)	(0.000)	(0.059)

25	ROLLS ROYCE	0.143	0.930***	0.111	0.355***	0.360***	0.961***	-0.124	0.580***	0.038	0.985***	-0.424***	0.080	0.148	0.988***	-0.267**	0.221
		(0.212)	(0.000)	(0.259)	(0.004)	(0.000)	（0.000）	(0.106)	(0.000)	(0.729)	(0.000)	(0.000)	(0.569)	(0.235)	(0.000)	(0.016)	(0.179)
26	ROYAL & SUN ALLIANCE	0.037	0.961***	-0.087	0.134	0.114	0.971***	-0.402***	0.236**	0.138	0.994***	-0.374***	0.195	0.098	0.975***	-0.639***	0.177
		(0.770)	(0.000)	(0.417)	(0.412)	(0.176)	（0.000）	(0.000)	(0.036)	(0.158)	(0.000)	(0.000)	(0.138)	(0.341)	(0.000)	(0.000)	(0.199)
27	SCOTTISH POWER	-0.022	0.958***	0.075	0.085	0.194**	0.966***	-0.057	0.364***	0.041	0.969***	-0.317***	0.153	-0.002	0.982***	-0.421***	0.069
		(0.860)	(0.000)	(0.487)	(0.613)	(0.050)	（0.000）	(0.513)	(0.002)	(0.662)	(0.000)	(0.000)	(0.202)	(0.987)	(0.000)	(0.000)	(0.672)
28	VODAFONE GROUP	-0.049	0.951***	-0.189**	0.014	0.012	0.984***	-0.217***	0.053	0.057	0.983***	-0.609***	0.108	0.255**	0.985***	-0.699***	0.387***
		(0.609)	(0.000)	(0.011)	(0.909)	(0.903)	（0.000）	(0.006)	(0.688)	(0.533)	(0.000)	(0.000)	(0.375)	(0.026)	(0.000)	(0.000)	(0.009)
29	WHITBREAD	0.010	0.980***	0.050	0.072	-0.048	0.971***	-0.195***	0.044	-0.047	0.986***	-0.586***	-0.014	0.027	0.991***	-0.348***	0.072
		(0.910)	(0.000)	(0.481)	(0.508)	(0.599)	（0.000）	(0.005)	(0.639)	(0.586)	(0.000)	(0.000)	(0.895)	(0.775)	(0.000)	(0.000)	(0.556)

Note: The numbers in parentheses are p-values and thus ***, ** and * denote, respectively, the significance of 1%, 5% and 10%.

Table 4

Determinant of leverage effect: Pooled versus Panel OLS

Estimation model	Intercept (δ_{0i})	Debt ratio (δ_1)	Firm size (δ_2)
Pooled OLS	-0.482*** (0.005)	-0.002 (0.734)	0.075*** (0.000)
Fixed-effect Panel OLS	See note 1	0.035*** (0.003)	0.292*** (0.004)

Note: 1. The firm-specific constant terms, with a total of 29, are omitted.

2. The numbers in parentheses are p-values and thus ***, **, and * denote the significance of 1%, 5%, and 10%, respectively.

Table 5

Determinant of leverage effect: Using Dynamic Panel GMM

Explanatory variables	One-step estimation	Two-step estimation
One-period lag	-0.602	-0.296
($\hat{\theta}$)	(0.197)	(0.232)
Debt ratio	0.042*	0.026*
($\hat{\delta}_1$)	(0.094)	(0.091)
Firm Size	0.436*	0.341**
($\hat{\delta}_2$)	(0.062)	(0.047)
Sargan Test p-value	0.493	0.527

Note: 1. The numbers in parentheses are p-values and thus ***, **, and * denote the significance of 1%, 5%, and 10%, respectively.

2. Sargan test is a test of over-identifying restrictions, asymptotically distributed as χ^2 under the null hypothesis.

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