THE HAMADA AND CONINE LEVERAGE ADJUSTMENTS AND THE ESTIMATION OF SYSTEMATIC RISK FOR MULTISEGMENT FIRMS

KIRT C. BUTLER, ROSANNE M. MOHR AND RICHARD R. SIMONDS*

INTRODUCTION

The Capital Asset Pricing Model (CAPM) identifies beta (or systematic risk) as the only firm-specific determinant of expected return. The key role of beta within the CAPM has led to a considerable body of theoretical beta decomposition research. In general, this research has used a variety of assumptions to model the corporate determinants of beta. The theoretical research has, of course, been accompanied by related empirical work. Typically, the empirical studies have used publicly-available data to examine the ability of the operationalized models to explain and/or predict beta and equity returns.

This study extends the model estimation and beta measurement literature. Using the theoretical work of Hamada (1969 and 1972), Conine (1980), and Rubinstein (1973), this study compares the relative ability of several beta estimates to explain and predict the equity returns of a sample of multisegment firms. The estimation issues associated with the Hamada and Conine financial leverage adjustments are emphasized. As such, this research provides a more complete examination of the issues raised by Fuller and Kerr (1981) and Conine and Tamarkin (1985) as to the appropriateness of financial leverage adjustments in the estimation of divisional and multisegment firm risk.

The remainder of this paper is organized as follows. The next section describes the related theoretical and empirical research. The estimation issues and measurement procedures are discussed in the third section and the empirical results are presented in the fourth section. The final section contains the research conclusions and recommendations.

RELATED THEORETICAL AND EMPIRICAL RESEARCH

The inaugural decomposition of beta into its corporate determinants was reported by Hamada (1969 and 1972). Using an assumption of risk-free corporate

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debt, Hamada derived the following relationship:

$$\beta_{LHAM} = \beta_U (1 + (1 - T)(D_L/S_L)),$$

(1)

where $\beta_{LHAM} =$ market-based beta of the levered firm $L$,

$\beta_U =$ market-based beta of the unlevered firm $U$ (an all-equity firm with the same assets as firm $L$),

$T =$ corporate tax rate,

$D_L =$ total market value of firm $L$ debt,

$S_L =$ total market value of firm $L$ common stock.

From expression (1), it is evident that Hamada’s analysis divided the firm’s market-based beta into two components: (1) a financial leverage component, $(1 - T)(D_L/S_L)$, and (2) an operating or business risk component, $\beta_U$. Significantly, the separateness of these two components follows from Modigliani and Miller’s (1958 and 1963) leverage irrelevance result.

Conine (1980) extended Hamada’s analysis by incorporating risky corporate debt into the levered beta relationship. Conine concluded that:

$$\beta_{LCON} = \beta_U (1 + (1 - T)(D_L/S_L)) - \beta_{DEBT} (1 - T)(D_L/S_L),$$

(2)

where $\beta_{DEBT}$ is a CAPM risky-debt covariability measure. From expression (2), it is apparent that the introduction of risky corporate debt reduces the systematic risk of the levered firm’s equity securities. This result is intuitively plausible since ‘the risk in net operating income is now shared by both debt and equity claimants’ (Conine, 1980, p. 1035).

Finally, the $\beta_U$ (or business risk) analysis of Rubinstein (1973) can be used to apply the above results to the multisegment firm. Rubinstein’s analysis can be reduced to:

$$\beta_{USEG} = \sum_{i=1}^{I} x_i \beta_{Ui},$$

(3)

where $\beta_{USEG} =$ unlevered beta of a multisegment firm,

$x_i =$ relative market value of the multisegment firm’s investment in each of $I$ industries ($\sum_{i=1}^{I} x_i = 1$),

$\beta_{Ui} =$ covariability or systematic risk of the unlevered returns to industry $i$.

Expression (3) highlights the impact of relative industry involvement ($x_i$) and systematic industry risk ($\beta_{Ui}$) on the operating beta of a multisegment firm. The expression also clearly indicates that the operating risk of a multisegment firm can be viewed as a value-weighted portfolio of the risks associated with each of its activities.

Substituting the multisegment firm’s unlevered beta ($\beta_{USEG}$) into the
Hamada (expression (1)) or Conine (expression (2)) relationships provides a very flexible model for estimating the systematic risk of a multisegment firm. The resulting leverage-adjusted relationships are:

\[
\beta_{\text{HAM}} = \left( \sum_{i=1}^{I} x_i \beta_{ui} \right) \left( 1 + (1 - T)(D_L/S_L) \right)
\]  

(4)

and

\[
\beta_{\text{CON}} = \left( \sum_{i=1}^{I} x_i \beta_{ui} \right) \left( 1 + (1 - T)(D_L/S_L) \right) - \beta_{\text{DEBT}} (1 - T)(D_L/S_L).
\]  

(5)

Using these relationships, a multisegment firm can, for example, remix its industry betas \((\beta_{ui})\) according to a newly-proposed investment strategy. Then, the beta effects of possible capital structure changes can be measured with either the Hamada or Conine leverage adjustments. In addition, a practical advantage of the foregoing beta models arises from the construction of \(\beta_{\text{USEG}}\) as a portfolio beta. It has been well documented that estimated portfolio betas exhibit greater efficiency and more stability than other types of beta estimates.

The potential advantages of the theoretical models can, however, only be realized if the models can be empirically estimated. An initial empirical test of the Hamada model was conducted by Fuller and Kerr (1981). These researchers examined the pure-play technique, an approach whereby the market-based betas of single-activity publicly-traded firms are used to estimate the systematic risk of untraded industry segments or divisions. For a sample of 60 multisegment firms, Fuller and Kerr matched pure-play firms with industry segments on the basis of industry class, size, and geographical location. Then, without any specific adjustment for the financial leverage of the multisegment firm, the researchers compared multisegment firms’ published Value Line betas to portfolio betas constructed as a weighted average of the levered pure-play firms. This comparison relied on the assumption that the segment’s debt/equity structure was the same as that of its matched pure-play; or, equivalently, that

\[
\beta_{\text{SEG}} = \sum_{i=1}^{I} x_i \beta_{Li},
\]  

(6)

where \(\beta_{\text{SEG}}\) is the beta of a levered multisegment firm \(L\). Fuller and Kerr’s results supported expression (6), and the researchers concluded that the pure-play technique without a specific financial leverage adjustment provided suitable estimates of multisegment firm risk.

Fuller and Kerr did, however, also test the appropriateness of a firm-specific leverage adjustment by examining the Hamada (expression (4)) model. Measures of \(\beta_{\text{LHAM}}\) were obtained by unlevering the pure-play betas with the
debt/equity ratios of the pure-play firms, and then relevering the weighted portfolio betas \( \beta_{USEG} = \sum_{i=1}^{S_L} x_i \beta_{UL} \) according to the tax rate \( T \) and financial leverage \( (D_L/S_L) \) of the multisegment firm \( L \). The statistical tests comparing \( \beta_{LHAM} \) (expression (4)) to the published Value Line betas were not, however, as supportive as the expression (6) results, and Fuller and Kerr concluded that 'the adjusted pure-play betas provided better approximations of the multidivision firm betas than did the leverage adjusted pure-play betas' (1981, p.1007).

Conine and Tamarkin (1985) provided additional research on the financial leverage adjustment issue. These authors recognized that the risk-free corporate debt assumption of Hamada could have introduced a systematic upward bias into the Fuller and Kerr leverage-adjusted betas. Conine and Tamarkin thus proceeded to re-examine the Fuller and Kerr sample by unleveraging and releveraging with the Conine (1980) (expression (2)) financial leverage relationship. Using somewhat crude estimation techniques, the researchers observed 'substantial improvement' in the beta estimates. They still found, however, that Fuller and Kerr's initial unadjusted \( \beta_{LSEG} \) estimates (expression (6)) were most closely related to the published Value Line betas. In view of this result, the researchers suggested that, 'Further empirical research is warranted' (1985, p.57).

The study reported in this paper provides a more complete examination of the beta estimation and leverage adjustment issues raised by Fuller and Kerr (1981) and Conine and Tamarkin (1985). It extends the earlier research by employing a larger sample of multisegment firms, by using financial leverage and risky debt measures with recent empirical support, and by incorporating alternative corporate tax rates. In addition, the earlier research suggested that the leverage-adjusted betas were more biased and less efficient than the unadjusted estimates. Given this foreknowledge, the error decomposition procedure of Theil (1966) was used to adjust the beta estimates for statistical bias and inefficiency. Finally, this study moved beyond the correlation statistics of the previous studies to an examination of the relative ability of the various beta estimates to both explain and predict observed security returns.

VARIABLE MEASUREMENT AND ESTIMATION ISSUES

The performance comparisons of this study required estimates of \( \beta_{LHAM}, \beta_{LCON}, \beta_{USEG}, \) and \( \beta_{OLS} \) (an ordinary least squares beta) for a sample of multisegment firms. The procedures used to select the sample and to measure the various beta components involved several estimation issues and problems. The discussion which follows will highlight those issues and, as such, provide insight into the practical problems of using real-world data to operationalize the theoretical beta models. Such insight is an important prelude to a more complete understanding of the empirical results reported both in this study and in the previous empirical research.
## Table 1

Percentage of Sales in Primary Segment

<table>
<thead>
<tr>
<th>Multisegment Industrial Firms</th>
<th>Total Industrial Firms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10% 20% 30% 40% 50% 60%</td>
</tr>
<tr>
<td>1979</td>
<td>0 0 6 49 84 106</td>
</tr>
<tr>
<td>1980</td>
<td>0 0 10 58 109 138</td>
</tr>
<tr>
<td>1981</td>
<td>0 0 13 66 101 135</td>
</tr>
<tr>
<td>1982</td>
<td>0 0 16 62 95 140</td>
</tr>
</tbody>
</table>

**Note:** Cell entries represent number of firms from the Value Line database.

### Sample Selection

The Value Line database provides line-of-business data for a four-year period. Table 1 was constructed from the Value Line data for the years 1979—1982. As indicated in the table, the sample of multisegment firms was defined as those Value Line firms that had at most 60 percent of sales in a primary segment. A 60 percent threshold was chosen to maximize the size of the multisegment firm sample while simultaneously excluding firms dominated by a single segment. The sample was also limited to nonfinancial firms and by data availability. The final sample consisted of 179 multisegment industrial firms.

### Hamada and Conine Leverage Adjustments

Empirical examination of the Hamada and Conine leverage adjustments requires estimates of $D^*_L/S_L$ (leverage position), $T$ (corporate tax rate), and $\beta^*_{DEBT}$ (risky debt covariability measure).

**Leverage Position ($D_L/S_L$)**

Fuller and Kerr (1981) calculated both market and book value measures of $D_L/S_L$. These researchers reported that book value measures provided better leverage-adjusted beta estimates. Conine and Tamarkin (1985, p.57), in re-examining the Fuller and Kerr sample, noted that the ‘book value data were not available’ and, as such, used only market value measures. Recognizing the practical problems of obtaining the theoretically-based market value data, Bowman (1980) conducted an extensive examination of the market vs. book value issue. He concluded that a mixed measure of the form $D_{L,BOOK}/S_{L,MKT}$ was most closely associated with the firm’s market-based beta. In accord with this evidence, the $D_L$ of this study was measured as the book value of ‘Total Reported Liabilities’; $S_L$ was calculated as the average annual market value of common equity. The $D_L/S_L$ ratio was updated annually for each sample firm.
Tax Rate ($T$)
The selection of a tax rate posed further estimation issues. Both the Hamada and Conine models are based on an assumption of perpetual cash flows. The tax rate used to operationalize these models should be the rate on continuing operations and should exclude unusual and nonrecurring items. In their examination of the Hamada adjustment, Fuller and Kerr (1981) measured $T$ as the tax rate reported in the firm’s financial statements. Also, as noted by the researchers, ‘Appropriate adjustments were made for the cases where the firm had . . . no effective tax rate because of deficit earnings’ (1981, p. 1004).

The Value Line amount for ‘Income Tax Rate’ represents the reported tax rate on pretax accounting income. An examination of these rates indicated wide variation across firms and over the four-year sample period. While the average reported tax rate for the multisegment firms was 37.5 percent, the actual range of rates varied from 1406 percent to $-856$ percent, with most firms reporting rates between 20 and 60 percent. Since tax rates greater than 60 percent and less than zero are likely to be associated with nonrecurring or unusual items, reported rates outside of this range were set equal to 40 percent. This assumption was necessary for approximately 15 percent of the sample firms. Again, this measure of $T$ was updated annually for each sample firm.

Finally, given the variability of the reported tax rates, the models were also estimated by assuming a 40 percent tax rate for all firms. This assumption is consistent with viewing 40 percent as the marginal tax rate applicable to the continuing operations of all corporate entities. The constant $T$ estimates are reported as $\beta_{LHAM T}$ and $\beta_{LCON T}$.

Risky Debt Beta ($\beta_{DEBT}$)
In general, it is impractical to estimate CAPM betas for the bonds of each firm. As noted by Alexander (1980) and others, the estimation of bond betas is beset with problems of untraded issues, non-normality of returns, and non-stationarity of estimated betas. As such, some proxy measure of $\beta_{DEBT}$ is needed to operationalize the Conine result.

Fortunately, the choice of an appropriate proxy is simplified by the fact that bond prices tend to move together and the systematic risk of corporate debt appears to depend primarily on changes in the level of interest rates and not on the default risk of a particular bond issue. Weinstein (1981), for example, concluded that various issues of investment grade bonds (Moody’s Baa and above) exhibited similar levels of systematic risk. Lower-rated bonds with higher levels of default risk had slightly higher levels of systematic risk. Since Value Line follows larger and generally higher grade investments, a $\beta_{DEBT}$ of 0.3 was assumed for all of the firms examined in this study. This estimate is representative of the average corporate bond betas reported in previous studies that used large publicly-traded firms and a market index similar to the one employed here.
Unlevered Operating Risk \( \beta_{USEG} = \sum_{i=1}^{l} x_i \beta_{U_i} \)

An examination of the Hamada and Conine relationships for a sample of multi-segment firms requires the substitution of \( \beta_{USEG} \) (expression (3)) for the \( \beta_U \) (or business risk component) of expressions (1) and (2). The estimation of \( \beta_{USEG} \) requires measures of its two components: \( x_i \), the relative 'weights', and \( \beta_{U_i} \), the unlevered industry betas.

Relative Market Value Measures (\( x_i \))
In the Rubinstein (1973) analysis, \( x_i \) was defined as the proportional market value of the firm's assets that are devoted to activity \( i \). While proportional market values are not generally available, reported line-of-business data do suggest several surrogate measures. A surrogate measure that has been successfully utilized in other studies (e.g., Fuller and Kerr, 1981; and Mohr, 1985) is: \( x_i = \text{sales of segment } i / \text{total firms sales} \), or a proportional 'sales weight'. Sales-based weights, calculated from Value Line line-of-business data, were also used in this study.

Unlevered Industry Betas (\( \beta_{U_i} \))
As noted earlier, \( \beta_{U_i} \) represents the market-based beta of an unlevered firm engaged exclusively in activity \( i \). In this study, the industry pure-play technique of Fuller and Kerr (1981) was used to obtain the \( \beta_{U_i} \) estimates. The first step in applying this technique is the assignment of an industry code to each segment of the multisegment firm. Value Line provides such assignments in conjunction with its line-of-business data. Fuller and Kerr then used security analysis to subjectively match each segment with a publicly-traded pure-play firm. A subjective matching of this nature was infeasible for the larger sample examined in this study. Instead, the Value Line codes were again used to identify the pure-play firms. That is, the pure-play firms were identified as those Value Line firms that either did not report segmental data or which reported multiple segments with the same SIC code. Using the Value Line codes for both the segments and the pure-plays achieved a consistent classification and avoided some of the judgmental issues encountered in previous research. The resulting single-segment sample consisted of 653 firms from 95 industries.

The actual calculation of the \( \beta_{U_i} \) estimates involved the following process. First, a historical OLS beta was estimated for each pure-play firm. (The procedures used to estimate the OLS betas are described in the next section.) The OLS betas for the firms classified as belonging to industry \( i \) were then averaged to obtain a levered industry beta (\( \beta_{L_i} \)). Next, two versions of \( \beta_{U_i} \) were calculated by using first the Hamada, and then the Conine, relationship to unlever the \( \beta_{L_i} \) estimates. In this unlevering, an average industry tax rate and \( D_L / S_L \) ratio were used. The industry \( D_L / S_L \) ratio was calculated as total
industry debt divided by total industry equity. Thus, the $\beta_{UI}$ measures were estimated as unlevered industry portfolio betas.

**Comparative Beta Estimates ($\beta_{OLS}$ and $\beta_{LSEG}$)**

The foregoing procedures provided the components of the Hamada and Conine models (expressions (4) and (5)) for a sample of multisegment firms. As indicated in the models, the actual $\beta_{LHAM}$ and $\beta_{LCON}$ (or $\beta_{LHAM_T}$ and $\beta_{LCON_T}$) estimates were obtained by first calculating the unlevered $\beta_U = \beta_{USEG}$ for each sample firm, and then relevering this estimate according to the tax rate and debt/equity position of the multisegment firm.

As in previous studies, the beta estimates constructed from the theoretical models were compared to a market-based OLS beta. In this study, $\beta_{OLS}$ was estimated by using monthly return data in the market model regression,

$$ R_{jt} = a_j + \beta_{OLS} R_{mt} + \epsilon_{jt}, $$

where $R_{jt}$ = return on security $j$ at time $t$, $R_{mt}$ = market index return, $\beta_{OLS}$ = OLS estimate of security $j$'s beta, $a_j$ = intercept term, and $\epsilon_{jt}$ = residual error term at time $t$.

The market index was constructed of 70 percent Ibbotson's (1984) value-weighted common stock returns and 30 percent Ibbotson's (1984) Long-Term Corporate Bond Index. These relative debt/equity weights represent the approximate proportional market values of corporate debt and equity outstanding during the sample period (as reported in the US Federal Reserve Board's *Flow of Funds Accounts*, 1979–1982). By using return data from the preceding 60 months, the OLS betas for both the multisegment and pure-play firms were recalculated for each month of the four-year sample period. As such, the various beta estimates were updated on a monthly basis for each sample firm.

Finally, Fuller and Kerr's (1981) findings with regard to the performance of the unadjusted $\beta_{LSEG}$ of expression (6) prompted the inclusion of a similar measure in this study. As indicated in expression (6), $\beta_{LSEG}$ was constructed by simply using the sales-based 'weights' ($x_i$) of the multisegment sample firms to combine the levered industry portfolio betas ($\beta_{Li}$). Again, this procedure assumes that the leverage position of the multisegment firm can be adequately represented as a weighted average of its levered industry components.

The result of the above procedures is a set of beta estimates for each multisegment firm that reflects various financial leverage adjustments and surrogation steps. This set includes an OLS beta ($\beta_{OLS}$), a segmental beta constructed with the pure-play technique but without a firm-specific adjustment for the finan-

cial leverage of the multisegment firm ($\beta_{LSEG}$), and several segmental betas formed from portfolios of unlevered pure-play firms ($\beta_{LHAM}$, $\beta_{LCON}$, $\beta_{LHAM}T$, and $\beta_{LCON}T$). The several forms of the segmental betas were estimated to examine the relative performance of the more sophisticated models and to address the measurement issues associated with the estimation of those models.

PERFORMANCE OF THE BETA ESTIMATES

Characteristics of the Beta Estimates

Summary statistics describing the characteristics of the various beta estimates are provided in Tables 2 and 3. Table 2 presents descriptive statistics for the sample of multisegment firms and for the corresponding pure-play industry portfolios. Table 3 reports the correlation coefficients between the OLS beta and the various segmental betas for the sample of multisegment firms.

The OLS betas ($\beta_{OLS}$) and the segmental betas without firm-specific financial leverage adjustments ($\beta_{LSEG}$) have almost identical mean values. Also, when $\beta_{OLS}$ is used as an unbiased benchmark, both the Hamada and Conine leverage adjustments provide upwardly biased estimates. These results are consistent with the earlier empirical work of Fuller and Kerr (1981) and Conine and Tamarkin (1985).

The OLS beta estimates are also most closely correlated with the unadjusted segmental betas ($\beta_{LSEG}$). And, notably, the unadjusted $\beta_{LSEG}$ displays less variability over time than either the OLS or the Conine and Hamada leverage-

| Table 2 |
| Descriptive Statistics of the Beta Estimates |

<table>
<thead>
<tr>
<th></th>
<th>Multisegment Firms</th>
<th>Industry Pure-Play Portfolios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation Across Firms</td>
</tr>
<tr>
<td>$\beta_{OLS}$</td>
<td>1.43*</td>
<td>0.39</td>
</tr>
<tr>
<td>$\beta_{LSEG}$</td>
<td>1.53</td>
<td>0.23</td>
</tr>
<tr>
<td>$\beta_{LHAM}$</td>
<td>2.12</td>
<td>1.03</td>
</tr>
<tr>
<td>$\beta_{LCON}$</td>
<td>2.02</td>
<td>0.87</td>
</tr>
<tr>
<td>$\beta_{LHAM}T$</td>
<td>1.98</td>
<td>0.91</td>
</tr>
<tr>
<td>$\beta_{LCON}T$</td>
<td>1.87</td>
<td>0.77</td>
</tr>
</tbody>
</table>

*The beta of the combined 30 percent corporate debt and 70 percent equity market index is 1.0. With a debt beta of 0.3, the average equity beta would be expected to be 1.30.

**The industry portfolio betas corresponding to the estimation of $\beta_{LSEG}$ are levered betas. The other industry portfolio betas are unlevered.
Table 3
Correlation of the Beta Estimates

<table>
<thead>
<tr>
<th></th>
<th>( \beta_{\text{OLS}} )</th>
<th>( \beta_{\text{LSEG}} )</th>
<th>( \beta_{\text{LHAM}} )</th>
<th>( \beta_{\text{LCON}} )</th>
<th>( \beta_{\text{LHAM}^T} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_{\text{LSEG}} )</td>
<td>0.2131</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta_{\text{LHAM}} )</td>
<td>0.1704</td>
<td>0.3187</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta_{\text{LCON}} )</td>
<td>0.1809</td>
<td>0.3680</td>
<td>0.9979</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.010)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta_{\text{LHAM}^T} )</td>
<td>0.1294</td>
<td>0.3687</td>
<td>0.3625</td>
<td>0.9687</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.068)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td></td>
</tr>
<tr>
<td>( \beta_{\text{LCON}^T} )</td>
<td>0.1420</td>
<td>0.4187</td>
<td>0.4070</td>
<td>0.9661</td>
<td>0.9978</td>
</tr>
<tr>
<td></td>
<td>(0.045)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
</tbody>
</table>

Note: The significance levels of the correlation coefficients appear in parentheses.

adjusted estimates. The difference in variability between \( \beta_{\text{OLS}} \) and \( \beta_{\text{LSEG}} \) is due to the diversification benefits of portfolio aggregation. The Hamada and Conine leverage adjustments increased the variability of the segmental betas. As would be expected, the Conine betas exhibited greater stability than the Hamada estimates, and the adjustments assuming a constant tax rate (40 percent) exhibited more stability than the adjustments that used annually changing rates.

Explanatory Power

Given the above observations, it is appropriate to investigate whether \( \beta_{\text{LSEG}} \) provides any information beyond \( \beta_{\text{OLS}} \) in explaining the returns to common stock. A test of this hypothesis was conducted by estimating a stepwise regression on the equation,

\[
R_{it} - R_{ft} = a(\beta_{\text{OLS}}(R_{mt} - R_{ft})) + b(\beta_{\text{LSEG}}(R_{mt} - R_{ft})),
\]

and examining the partial F statistics. This cross-sectional regression was estimated with contemporaneous \( R_{it} \), \( R_{mt} \) and \( R_{ft} \) (risk-free rate) returns. The beta estimates, \( \beta_{\text{OLS}} \) and \( \beta_{\text{LSEG}} \), were calculated over the immediately preceding 60-month period; i.e., from time \( t-60 \) through time \( t-1 \). The regression was performed on the pooled sample, including all 179 multisegment firms over the entire 48-month sample period.

The regression results indicated that the OLS and the unadjusted segmental betas exhibited nearly the same ability to explain the returns to common stock. In simple regressions, each of the independent variables explained about 25 percent of the variation in the dependent variable \( (R_{it} - R_{ft}) \). The change in \( r^2 \) upon adding the second variable represented less than a three percent
increase. Unadjusted segmental betas ($\beta_{LSEG}$) thus appear to reflect much of the same systematic risk information as is captured in the market-based OLS estimates.

**Predictive Ability**

In order to focus on the predictive ability of the OLS and segmental betas, actual security returns ($R_{ji}$) were compared to forecasted returns ($E[R_{ji}]$) derived from the CAPM Security Market Line,

$$E[R_{ji}] = R_{fi} + \beta_j(R_{mt} - R_{fi}),$$

where $\beta_j$ represents the firm's estimated beta, and $R_{mt}$ and $R_{fi}$ are the actual market index and risk-free returns. This framework is similar to a portfolio performance evaluation wherein performance is measured relative to *ex post* market returns on a risk-adjusted basis.

The predictions were evaluated against several benchmark forecasts. To test the null hypothesis,

$$H_0: \epsilon_{ji} = R_{ji} - E[R_{ji}] = 0,$$

the following predictions ($E[R_{ji}]$) were compared to actual returns ($R_{ji}$):

(i) a naive forecast of the risk-free rate ($\beta = 0$),

$$E[R_{ji}] = R_{fi};$$

(ii) a forecast of the average equity return (using the observed mean $\beta = 1.43$),

$$E[R_{ji}] = R_{fi} + 1.43 (R_{mt} - R_{fi});$$

(iii) a forecast using the OLS beta estimate ($\beta_{OLS}$),

$$E[R_{ji}] = R_{fi} + \beta_{OLSj} (R_{mt} - R_{fi});$$

(iv) forecasts using each of the various levered segmental betas estimates ($\beta_{LSEG}, \beta_{LHAM}, \beta_{LCON}, \beta_{LHAM^T},$ and $\beta_{LCON^T}$), e.g.,

$$E[R_{ji}] = R_{fi} + \beta_{LSEGj} (R_{mt} - R_{fi}).$$

Since $\beta_{OLS}$ and the segmental betas were updated monthly, the predictive tests were performed on a pooled sample including both cross-sectional and time series data.

In the predictive comparisons, mean error (ME) was used as a measure of prediction bias and mean square error (MSE) as a measure of forecast accuracy. A comparison of the MSE statistics at the individual security level is presented in the first column of Table 4. The average equity return predictions (based on $\beta = 1.43$) and the OLS return predictions possessed the best forecast accuracy. Among the segmental betas, only $\beta_{LSEG}$ exhibited forecast accuracy that was not significantly worse than the OLS and average return predictions.
The leverage-adjusted segmental betas did not perform as well as $\beta_{OLS}$ and $\beta_{LSEG}$. The Hamada beta ($\beta_{LHAM}$) performed even worse than the naive estimate of the risk-free rate, though not significantly so. The leverage-adjusted betas ($\beta_{LHAM,T}$ and $\beta_{LCON,T}$) using a constant tax rate performed better than the leverage-adjusted betas ($\beta_{LHAM}$ and $\beta_{LCON}$) that used actual tax rates. Also, the Conine adjustment provided better forecast accuracy than did the Hamada adjustment.

In order to examine the curious result that simply forecasting the mean market return provides predictions that are as accurate as those derived from OLS betas, the sample of multisegment firms was ranked by OLS beta and three portfolios were formed of the 20 highest beta ($\beta^{HI}$) firms, the 20 lowest beta ($\beta^{LOW}$) firms, and the 20 median beta ($\beta^{MID}$) firms. The MSE statistics associated with these three portfolios are also reported in Table 4.

The average return predictions based on $\beta = 1.43$ continued to be the most accurate for the portfolio of median systematic risk ($\beta^{MID}$). The unadjusted segmental beta ($\beta_{LSEG}$) forecasts were somewhat more accurate for the high

<table>
<thead>
<tr>
<th>Beta Estimate</th>
<th>All Firms</th>
<th>$\beta^{HI}$</th>
<th>$\beta^{MID}$</th>
<th>$\beta^{LOW}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta = 0$</td>
<td>0.0093*</td>
<td>0.0196*</td>
<td>0.0098*</td>
<td>0.0052*</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.001)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>$\beta = 1.43$</td>
<td>0.0070</td>
<td>0.0147</td>
<td>0.0071*</td>
<td>0.0049*</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta_{OLS}$</td>
<td>0.0070</td>
<td>0.0152</td>
<td>0.0073</td>
<td>0.0042</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>$\beta_{LSEG}$</td>
<td>0.0071</td>
<td>0.0145</td>
<td>0.0072</td>
<td>0.0050*</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta_{LHAM}$</td>
<td>0.0100*</td>
<td>0.0176*</td>
<td>0.0084*</td>
<td>0.0074*</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta_{LHAM,T}$</td>
<td>0.0092*</td>
<td>0.0166*</td>
<td>0.0079*</td>
<td>0.0071*</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta_{LCON}$</td>
<td>0.0091*</td>
<td>0.0162</td>
<td>0.0080*</td>
<td>0.0068*</td>
</tr>
<tr>
<td></td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta_{LCON,T}$</td>
<td>0.0085*</td>
<td>0.0157</td>
<td>0.0077*</td>
<td>0.0066*</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
</tbody>
</table>

*Different from $\beta_{OLS}$ at the 5 percent confidence level based on a t-test of significance.

Notes:
2. The sample of multisegment firms was ranked by OLS beta and three portfolios were formed of the 20 highest beta ($\beta^{HI}$) firms, the 20 lowest beta ($\beta^{LOW}$) firms, and the 20 median beta ($\beta^{MID}$) firms.
LEVERAGE ADJUSTMENTS AND SYSTEMATIC RISK

beta portfolio (\(\beta^{HI}\)). And, for the low beta firms, the OLS beta performed best. Notably, across all three portfolios, the \(\beta = 1.43\), \(\beta_{OLS}\), and \(\beta_{LSEG}\) predictions continued to significantly outperform the forecasts based on the Hamada and Conine leverage adjustments.

It is possible, however, that the Hamada or Conine estimates do capture the true linear relationship between systematic risk and return, but that this relationship is obscured in the MSE measure by bias in the estimates. Theil (1966) decomposed mean square error (MSE) into statistical bias, inefficiency, and error:

\[
MSE = E[(R - E[R])^2] = [E(R - E[R])]^2 + (1 - b)^2 \sigma_{R}^2 + (1 - r)^2 \sigma_{E[R]}^2 = \text{bias} + \text{inefficiency} + \text{error},
\]

where \(E[R]\) and \(R\) are the predicted and actual returns, \(b\) is the slope coefficient of the regression of \(R\) on \(E[R]\), \(r\) is the correlation of \(E[R]\) and \(R\), and \(\sigma_{E[R]}^2\) and \(\sigma_{R}^2\) are the variances of the predicted and actual returns.

Bias in the return predictions represents the tendency of the beta estimates to over- or underestimates the true beta. Inefficiency measures whether, after adjusting for bias, the estimated linear relationship effectively captures the true linear relationship. Attempts to adjust beta forecasts for bias and inefficiency have been reported by Blume (1971) and Vasicek (1973). In a Bayesian sense, if bias and inefficiency are foreseeable or predictable, then perhaps the segmental beta estimates can be improved by adjusting for these statistical deficiencies.

The forecast accuracy of the return predictions after adjusting for statistical bias and inefficiency are presented in Table 5. While the bias and inefficiency adjustments did not improve the accuracy of the \(\beta_{OLS}\) or \(\beta_{LSEG}\) predictions, they did, as expected, provide somewhat improved estimates for the Hamada and Conine leverage-adjusted betas. Nonetheless, the leverage-adjusted betas still did not perform as well as the betas estimated without a firm-specific leverage adjustment. Again, the Conine betas continued to demonstrate better forecast accuracy than the Hamada betas, and the levered betas using a constant tax rate outperformed the betas that used actual tax rates.

SUMMARY AND RECOMMENDATIONS

Previous empirical research had provided only limited evidence as to the practical ability of the theoretical leverage-adjusted betas to explain and predict the returns to common stock. The tests reported here provide results that are more complete and yet consistent with the previous work.

In summary, the results of this study indicate that historical OLS betas
Table 5
Monthly Prediction Errors with Theil (1966) Bias and Slope Adjustments

<table>
<thead>
<tr>
<th>Beta Estimate</th>
<th>Unadjusted</th>
<th></th>
<th>Bias and Slope Adjusted</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ME</td>
<td>MSE</td>
<td>ME</td>
<td>MSE</td>
</tr>
<tr>
<td>$\beta = 0$</td>
<td>0.0079</td>
<td>0.0093*</td>
<td>0.0000</td>
<td>0.0093*</td>
</tr>
<tr>
<td></td>
<td>(0.008)</td>
<td>(0.001)</td>
<td>(0.008)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta = 1.43$</td>
<td>0.0044</td>
<td>0.0070</td>
<td>0.0000</td>
<td>0.0069</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.000)</td>
<td>(0.004)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>$\beta_{OLS}$</td>
<td>0.0045</td>
<td>0.0070</td>
<td>0.0000</td>
<td>0.0069</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.000)</td>
<td>(0.004)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>$\beta_{LSEG}$</td>
<td>0.0042</td>
<td>0.0071</td>
<td>0.0000</td>
<td>0.0071*</td>
</tr>
<tr>
<td></td>
<td>(0.004)</td>
<td>(0.000)</td>
<td>(0.004)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>$\beta_{LHAM}$</td>
<td>0.0024</td>
<td>0.0100*</td>
<td>0.0000</td>
<td>0.0086*</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.001)</td>
<td>(0.006)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta_{LHAM}T$</td>
<td>0.0029</td>
<td>0.0092*</td>
<td>0.0000</td>
<td>0.0081*</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.001)</td>
<td>(0.006)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta_{LCON}$</td>
<td>0.0027</td>
<td>0.0091*</td>
<td>0.0000</td>
<td>0.0082*</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
<td>(0.001)</td>
<td>(0.006)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\beta_{LCON}T$</td>
<td>0.0031</td>
<td>0.0085*</td>
<td>0.0000</td>
<td>0.0079*</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.000)</td>
<td>(0.005)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

*Different from $\beta_{OLS}$ at the 5 percent confidence level based on a t-test of significance.

Note: Standard errors appear in parentheses.

(\(\beta_{OLS}\)) and segmental betas constructed without a firm-specific adjustment for financial leverage (\(\beta_{LSEG}\)) exhibit much the same ability to explain and predict security returns. The unadjusted \(\beta_{LSEG}\) is no more biased than \(\beta_{OLS}\) and has an almost identical relationship to equity returns. Additionally, \(\beta_{LSEG}\) estimates exhibit greater stability over time than \(\beta_{OLS}\) measures. The pure-play approach to beta estimation is thus especially useful when \(\beta_{OLS}\) measures are unavailable or inappropriate.

Neither the Hamada nor the Conine leverage-adjusted betas performed as well in explaining or predicting security returns. Even statistical adjustments for bias and inefficiency failed to significantly improve the forecast accuracy of these estimates relative to the \(\beta_{OLS}\) and \(\beta_{LSEG}\) estimates. The Conine adjustment consistently performed better than the Hamada adjustment. The Conine betas required smaller adjustments for inefficiency and also exhibited smaller forecast errors after adjusting for both bias and inefficiency. Finally, the leverage adjustments using a constant tax rate had consistently better predictive accuracy than the adjustments using annually changing rates. This result held even after adjusting for bias and inefficiency and was evident for both the Hamada and Conine estimates.
There are several estimation issues that may explain the practical inadequacy of the leverage-adjusted betas. As discussed in this study, the estimation of each of the theoretical beta components involves measurement problems and assumptions. In particular, financial managers, academic researchers, and others interested in employing practical estimates of the theoretical beta models should be aware that:

(i) Reported tax rates fluctuate widely across firms and over time. These fluctuations arise normally in the course of business and product life cycles, but may also be due to various nonrecurring income/expense items and/or the peculiarities of ever-changing tax and accounting systems. Smoothing reported tax rates appears to provide better leverage-adjusted estimates.

(ii) Market values of total debt may, particularly during periods of rapidly changing interest rates, vary considerably from the more readily available book value amounts. In this regard, Mulford (1985) concluded that interest rate fluctuations can impair the relationship between systematic risk and mixed book/market value measures of debt/equity position.

(iii) Uncertainty exists as to the method of calculation and firm-specific attributes of the systematic risk of corporate debt ($\beta_{DEBT}$). Some evidence exists, however, that most corporate debt of investment grade has about the same level of systematic risk.

Thus, the financial manager or researcher should be aware of these issues and might consider the impact of alternative measures of each of these beta components on derived estimates of systematic risk.

Finally, there are other theoretical leverage-related components that might contribute to improved beta estimates for the multisegment firm. In a recent article, Yagil (1987) suggested that the inclusion of personal taxes and bankruptcy costs might provide better leverage-adjusted segmental betas. Both of these components are, however, subject to numerous estimation difficulties, and a more complete practical evaluation of such estimates awaits future research.

In conclusion, then, in view of the above estimation difficulties and the explanatory and predictive results of this study, it appears that the best cross-sectional segmental beta estimate continues to be a weighted average of the industry pure-plays constructed without a specific adjustment for the debt/equity position of the multisegment firm. While the Hamada and Conine models may serve as useful pedagogical tools, they do not, in general, provide better beta estimates for the multisegment firm. These conclusions may provide further impetus for practical evaluation of the mathematical programming techniques of Boquist and Moore (1983) and Lee and Moore (1986). These techniques exploit the fact that the beta of a multisegment firm is a linear combination of the betas of other firms with involvement in the component industries. The
techniques do not adjust for differences in financial leverage. The results of this study indicate that such adjustments are probably not needed and, as such, provide added support for practical application of the programming approach.

NOTES

1. Hsia (1981) demonstrated that the CAPM beta can also be viewed as compatible with several other asset valuation theories; i.e., with the theories commonly known as 'Time State Preference Theory', the 'Modigliani and Miller Propositions', and the 'Option Pricing Model'. Hsia's demonstration of this theoretical consistency lends increased importance to an understanding of the corporate determinants of beta.

2. For a recent synthesis of the theoretical beta decomposition research, see Callahan and Mohr (1989).

3. As used herein, 'segment' refers to a firm's investment in a particular industry or line of business.

4. The Value Line amount 'Income Tax Rate' is defined as 'federal, foreign, state and local taxes, including deferred taxes and tax credits, divided by pretax income'.

5. The following corporate bond betas have been estimated in studies using a combined stock and corporate bond index similar to the market index used in this study: Weinstein (1981), 0.190; Sharpe (1973), 0.286; Friend et al. (1978), 0.362; and Alexander (1980), 0.372.

6. If there were less than three pure-play firms with a given industry code, then the firms were aggregated into the next more general SIC class.

7. Ideally, each OLS pure-play beta estimate should have been unlevered according to that firm's debt/equity ratio. Unlevering at the industry level was adopted as a computational convenience.

8. Ordinary least squares estimates of beta are generally considered to be unbiased but inefficient estimates of the firm's true beta. In this regard, see Klemkosky and Martin (1975).

9. Some perspective on the magnitude of the correlation between \( \beta_{OLS} \) and \( \beta_{SEG} \) can be gained by considering the optimistic scenario wherein \( \beta_{SEG} \) is equal to the true underlying beta while \( \beta_{OLS} \) contains an independent and normally distributed error term. Let the true beta \( \beta_{SEG} \) be represented by the independent variable \( X \). The dependent variable \( Y_i = X_i + \epsilon_i \), then represents \( \beta_{OLS} \) where \( \epsilon_i \sim N(0, \text{VAR}(\epsilon)) \) and \( E(\epsilon) = E(\epsilon X_i) = 0 \) for \( i \neq j \). The expected value of the \( i \)th observation of \( Y \) is \( \hat{Y}_i = X_i = \hat{X}_i \), and the mean of \( N \) observations is \( \bar{Y} = \bar{X} \).

The variance of the true beta \( \beta_{SEG} \) is

\[
\text{VAR}(X) = \frac{1}{N} \sum_{i=1}^{N} (X_i - \bar{X})^2.
\]

Substituting for \( \hat{Y} \) and \( \bar{Y} \), the expected regression sum of squares is then

\[
E(\text{SSR}) = \sum_{i=1}^{N} (\hat{Y}_i - \bar{Y})^2 = \sum_{i=1}^{N} (X_i - \bar{X})^2 = N \cdot \text{VAR}(X).
\]

In this study, the regression of \( \beta_{OLS} \) on \( \beta_{SEG} \) provided an error sum of squares SSE of 27.75. With \( N = 196 \) observations, the variance of \( X \) is \( \text{VAR}(X) = (0.263)^2 = 0.069 \), implying \( E(\text{SSR}) = (196)(0.069) = 13.52 \). The expected total sum of squares is then \( E(\text{SST}) = E(\text{SSR}) + \text{SSE} = 13.52 + 27.75 = 41.27 \), and the expected \( r^2 \) of the idealized regression is: \( r^2 = 1 - (\text{SSE}/\text{SST}) = 1 - (27.75/41.27) = 0.33 \), or \( r = (0.33)^{1/2} = 0.57 \). Thus, even if \( \beta_{SEG} \) is the true underlying beta, the expected correlation between \( \beta_{SEG} \) and \( \beta_{OLS} \) is still only 0.57 because of the random error in the dependent variable.

REFERENCES

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