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ESTIMATES OF THE SENSITIVITIES OF THE VALUE OF THE FIRM TO PROFITABILITY, GROWTH, AND CAPITAL INTENSITY

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ABSTRACT

Value-based management systems concentrate on actions that generate value for the shareholders in the wealth creation process (Fisher 1995; Lieber 1996; Walbert 1994). This study focuses explicitly on profitability, growth, and capital intensity as drivers of the value of the firm by extending a free cash flow valuation model for the firm. The extended model is used to provide information about the sensitivities of the value of the firm to changes in the firm's profitability, growth, and capital intensity. These sensitivities are presented in terms of partial derivatives and dollar changes. The partial derivatives show the changes in the value of the firm resulting from a small change in the measures for profitability, growth, or capital intensity. Each dollar amount shows the dollar changes in the value of the firm resulting from a small change in the profitability, growth, or capital intensity measures. These sensitivities show the impact of changes in the profitability, growth, and capital intensity measures on the value of the firm. This information is valuable in helping managers predict the results of actions to improve the wealth generating ability of the firm by managing these value drivers more effectively (Lehn and Makhija 1996).

OVERVIEW

A detailed analytical development of the theoretical valuation model used in this research is presented. Profitability, growth,

and capital intensity are shown to be important drivers of free cash flow, the value of the firm, and the value of the firm per dollar of sales. The valuation model for the value of the firm per dollar of sales is extended to include expectations of the future values of profitability, growth, and capital intensity. These expectations are expressed as functions of the current known values of profitability, growth, and capital intensity. The resulting highly nonlinear valuation model is approximated by a third-order Taylor series expansion for the value of the firm per dollar of sales in terms of profitability, growth, and capital intensity. The approximate model using the third-order Taylor series expansion is utilized to provide analytical expressions for the sensitivities of the value of the firm per dollar of sales to profitability, growth, and capital intensity. The sensitivities presented are used to develop expressions for the sensitivities of dollar changes in the value of the firm per dollar of sales to changes in profitability, growth, and capital intensity and for the sensitivities of dollar changes in the value of the firm to changes in profitability, growth, and capital intensity. Empirical estimates for the coefficients in the third-order Taylor series approximation to the valuation model for the value of the firm per dollar of sales are used to produce empirical estimates of the value of the firm per dollar of sales and of the sensitivities of the value of the firm per dollar of sales to profitability, growth, and capital intensity. These empirical estimates are based on both the estimates of the coefficients presented

and the analytical expressions developed for the extended valuation models.

VALUE-BASED MANAGEMENT

Value-based management focuses on the application of valuation principles. The system design and implementation promote and reward decisions that add value to investor-supplied funds (Copeland, Koller, and Murrin. 1995; Stern, Stewart, and Chew 1995; Ehrbar 1998; Rappaport 1998; Stewart 1991). Value-based management systems need valuation models that are expanded to include metrics for both the income statement and balance sheet. To be useful, these valuation models need to contain variables that are related explicitly to income statement and balance sheet items. In this study, profitability, growth, and capital intensity are treated as value drivers in the extended valuation models. To make the value-based management system operate effectively, components of the employees' work should be identified and linked to profitability, growth, and capital intensity. Performance targets must be established for these value drivers. Actual performance should be measured, evaluated, and rewarded in terms of the targets for profitability, growth, and capital intensity. If the value drivers are identified and modeled properly and actual performance is reinforced effectively, value-based management systems will produce business decisions that add value to investor-supplied funds if (Stern Stewart 1992).

VALUATION MODELS

Measures of future cash flows and the cost of capital are used in generally accepted valuation frameworks to provide measures of the value of the firm. The magnitude, timing, and riskiness of future cash flows, and the cost of capital determine the value of the business and the value added by a business to investors' funds. A two-phase

valuation model for free cash flow is shown by Equation (1) in Table 1. Equations (2), and (3) in Table 1 show expressions for the continuing value when constant growth with $g < r$ occurs after time T . The first T periods in this model, phase one, represent an explicit forecast (transition) period during which varying behavior is possible and the remaining periods (phase two) are a continuing value (steady-state) period during which growth is constant and parameters have steady-state values (Copeland, Koller, and Murrin 1995; Stewart 1991; Stewart 1994). Free cash flow, FCF_t , is defined as equal to the net operating profit after taxes, $NOPAT_t$, less the required net investment, $NINV_t$. The model for free cash flow is given by Equation (4) in Table 1. Net operating profit after taxes is equal to earnings before interest and taxes, $EBIT_t$, after taxes. In this model, τ is the cash income tax rate. Equation (5) gives the expression for Net operating profit after taxes. The net investment is the required change in invested capital, $IC_t - IC_{t-1}$. The model for net investment is given by Equation (6) in Table 1. The return on invested capital, $ROIC_t$, which relates net operating profit after taxes and invested capital, IC_t , is the measure of profitability used in this study. Equation (7) in Table 1 gives the expression for return on invested capital. Capital intensity, ci_t , relates invested capital and sales revenue and is defined by Equation (8) in Table 1. These relationships provide a model for net operating profit after taxes in terms of the return on invested capital, capital intensity, and sales revenue shown in Table 1 as Equation (9). The definition for capital intensity provides the model for invested capital in terms of capital intensity and sales revenue shown in Table 1 as Equation (10). Using this model for invested capital gives the model for the required net investment in terms of capital intensity and sales revenue shown in Table 1 as Equation (11). The rate of growth from period to period for sales revenue is g_t and it relates previous and

TABLE 1
Equations for Models Used in the Study

$$V_0 = \sum_{t=1}^T \frac{FCF_t}{(1+r)^t} + \frac{V_T}{(1+r)^T} \quad (1)$$

$$V_T = \sum_{t=T+1}^H \frac{FCF_T \cdot (1+g)^{t-T}}{(1+r)^{t-T}} \quad \text{as } H \rightarrow \infty \quad (2)$$

$$V_T = \frac{FCF_T \cdot (1+g)}{r-g} = \frac{FCF_{T+1}}{r-g} \quad \text{as } H \rightarrow \infty \quad (3)$$

$$FCF_t = NOPAT_t - NINV_t \quad (4)$$

$$NOPAT_t = (1-\tau) \cdot EBIT_t \quad (5)$$

$$NINV_t = IC_t - IC_{t-1} \quad (6)$$

$$ROIC_t = \left(\frac{NOPAT_t}{IC_t} \right) \quad (7)$$

$$ci_t = \left(\frac{IC_t}{S_t} \right) \quad (8)$$

$$NOPAT_t = ROIC_t \cdot ci_t \cdot S_t \quad (9)$$

$$IC_t = ci_t \cdot S_t \quad (10)$$

$$NINV_t = ci_t \cdot S_t - ci_{t-1} \cdot S_{t-1} \quad (11)$$

$$S_t = (1+g_t) \cdot S_{t-1} \quad (12)$$

$$NINV_t = ci_t \cdot (1+g_t) \cdot S_{t-1} - ci_{t-1} \cdot S_{t-1} = [ci_t \cdot (1+g_t) - ci_{t-1}] \cdot S_{t-1} \quad (13)$$

$$FCF_t = ROIC_t \cdot ci_t \cdot S_t - [ci_t \cdot (1+g_t) - ci_{t-1}] \cdot S_{t-1} \quad (14)$$

$$FCF_t = \{ROIC_t \cdot ci_t \cdot (1+g_t) - [ci_t \cdot (1+g_t) - ci_{t-1}]\} \cdot S_{t-1} \quad (15)$$

of growth from period to period for sales revenue is g_t and it relates previous and current sales as shown by Equation (12) in Table 1. Net investment depends on sales revenue and the growth rate as shown by Equations (13) in Table 1. Free cash flow depends on the rate of return on invested capital, sales revenue, and the growth rate as shown by equations (14) and (15) in Table 1. Substituting the expressions for free cash flow into the valuation model shown in equations (1) and (3) gives a valuation model expressed in terms of the rate of return on invested capital, sales revenue, and the growth rate as shown in equations (16) and (17) of Table 2. The model for sales shown in Equation (12) can be expanded to model the sales for any year in terms of the sales at time 0 and the growth rates as shown in equations (18), (19), and (20) of Table 2. Substituting this expanded model for sales shown in equations (18) and (19) into the model for the value of the firm shown in equations (16) and (17) and dividing by S_0 gives the model for the value of the firm per dollar of sales as shown in equations (21) and (22). The time subscripts are removed from the symbols for return on invested capital, capital intensity, and sales revenue growth after time T to emphasize that steady-state values occur. This model shows how the return on invested capital, capital intensity, sales growth, and the cost of capital are drivers of the value of the firm per dollar of sales.

Profitability, Growth, and Capital Intensity

The models presented so far show that expected future values of profitability, growth, and capital intensity are important drivers of free cash flow and the value of the firm. The importance of profitability, growth, and capital intensity in the value generation process can be examined more closely by replacing the expected future values with functions for their future values expressed in terms of current known values.

The notation shown in equations (23), (24), and (25) is used to express the future values of profitability, growth, and capital intensity in terms of current known values for the explicit forecast (transition) period and the notation shown in equations (26), (27), and (28) is used to express the future values of profitability, growth, and capital intensity in terms of current known values for the continuing value (steady-state) period. Substituting these expressions for expected future value into the extended valuation model for the value of the firm per dollar of sales shown in equations (21) and (22) of Table 2 gives the valuation model shown in equations (26) and (27) of Table 2. In this model, the relationship between the value of the firm per dollar of sales and $ROIC_0$, g_0 , and ci_0 is highly nonlinear. This nonlinear relationship incorporates the expectation formation process in which known values of profitability, growth, and capital intensity are used to form expectations about future values of profitability, growth, and capital intensity. A third-order Taylor Series expansion for a cross-sectional time series version of this valuation model shown in Table 3 as Equation (28) uses a relatively low-order polynomial equation is formulated to approximate the nonlinear relationship between the value of the firm per dollar of sales and $ROIC_0$, g_0 , and ci_0 . In this model, the subscripts 0, y, j indicate that the value of the variable is measured at time 0 with respect to year y for firm j. The Greek letters are the coefficients in the cross-sectional time series version of the valuation model. These coefficients measure the respective partial derivatives in the Taylor Series expansion for $ROIC_0$, g_0 , and ci_0 . The alphas are the coefficients for the first-order terms, the betas are the coefficients for the second order terms involving $ROIC_0$, g_0 , and ci_0 , and the gammas are the coefficients for the third order terms involving $ROIC_0$, g_0 , and ci_0 . The subscripts for the coefficients identify the associated variables, $ROIC_0$, g_0 , and ci_0 . Epsilon measures the error for the approximation to the valuation

TABLE 2
Equations for Models Used in the Study

$$V_0 = \sum_{t=1}^T \frac{\{ROIC_t \cdot ci_t \cdot (1+g_t) - [ci_t \cdot (1+g_t) - ci_{t-1}]\} \cdot S_{t-1}}{(1+r)^t} + \frac{V_T}{(1+r)^T} \quad (16)$$

$$V_T = \frac{[ROIC \cdot ci \cdot (1+g) - ci_T \cdot g] \cdot S_T}{r-g} \quad (17)$$

$$S_{t-1} = \prod_{n=1}^{t-1} (1+g_n) \cdot S_0 \quad (18)$$

$$S_T = \prod_{n=1}^T (1+g_n) \cdot S_0 \quad (19)$$

$$\prod_{n=1}^0 (1+g_n) = 1 \quad (20)$$

$$\left(\frac{V_0}{S_0}\right) = \sum_{t=1}^T \frac{\{ROIC_t \cdot ci_t \cdot (1+g_t) - [ci_t \cdot (1+g_t) - ci_{t-1}]\} \cdot \prod_{n=1}^{t-1} (1+g_n)}{(1+r)^t} + \frac{\left(\frac{V_T}{S_0}\right)}{(1+r)^T} \quad (21)$$

$$\left(\frac{V_T}{S_0}\right) = \frac{[ROIC \cdot ci \cdot (1+g) - ci_T \cdot g] \cdot \prod_{n=1}^T (1+g_n)}{r-g} \quad (22)$$

$$ROIC = f_{ROIC}(ROIC_0) \quad (23)$$

$$g_t = f_{g,t}(g_0) \quad (24)$$

$$ci = f_{ci}(ci_0) \quad (25)$$

$$\left(\frac{V_0}{S_0}\right) = \sum_{t=1}^T \frac{\{f_{ROIC,t}(ROIC_0) \cdot f_{ci,t}(ci_0) \cdot (1+f_{g,t}(g_0)) - [f_{ci,t}(ci_0) \cdot (1+f_{g,t}(g_0)) - f_{ci,t-1}(ci_0)]\} \cdot \prod_{n=1}^{t-1} (1+f_{g,n}(g_0))}{(1+r)^t} + \frac{\left(\frac{V_T}{S_0}\right)}{(1+r)^T} \quad (26)$$

$$\left(\frac{V_T}{S_0}\right) = \frac{\{f_{ROIC}(ROIC_0) \cdot f_{ci}(ci_0) \cdot (1+f_g(g_0)) - [f_{ci}(ci_0) \cdot (1+f_g(g_0)) - f_{ci,T}(ci_0)]\} \cdot \prod_{n=1}^T (1+f_{g,n}(g_0))}{r-f_g(g_0)} \quad (27)$$

TABLE 3
Equations for Models Used in the Study

$$\left(\frac{V_{0,y,j}}{S_{0,y,j}}\right) = \alpha_0 + \alpha_{ROIC} \cdot ROIC_{0,y,j} + \alpha_g \cdot g_{0,y,j} + \alpha_{ci} \cdot ci_{0,y,j} +$$

$$\beta_{ROIC} \cdot ROIC_{0,y,j}^2 + \beta_g \cdot g_{0,y,j}^2 + \beta_{ci} \cdot ci_{0,y,j}^2 + \beta_{ROIC,g} \cdot ROIC_{0,y,j} \cdot g_{0,y,j} +$$

$$\beta_{ROIC,ci} \cdot ROIC_{0,y,j} \cdot ci_{0,y,j} + \beta_{g,ci} \cdot g_{0,y,j} \cdot ci_{0,y,j} + \gamma_{ROIC} \cdot ROIC_{0,y,j}^3 +$$

$$\gamma_g \cdot g_{0,y,j}^3 + \gamma_{ci} \cdot ci_{0,y,j}^3 + \gamma_{ROIC,ROIC,g} \cdot ROIC_{0,y,j}^2 \cdot g_{0,y,j} +$$
(28)

$$\gamma_{ROIC,g,g} \cdot ROIC_{0,y,j} \cdot g_{0,y,j}^2 + \gamma_{ROIC,ROIC,ci} \cdot ROIC_{0,y,j}^2 \cdot ci_{0,y,j} +$$

$$\gamma_{ROIC,ci,ci} \cdot ROIC_{0,y,j} \cdot ci_{0,y,j}^2 + \gamma_{g,ci} \cdot g_{0,y,j}^2 \cdot ci_{0,y,j} +$$

$$\gamma_{g,ci,ci} \cdot g_{0,y,j} \cdot ci_{0,y,j}^2 + \gamma_{ROIC,g,ci} \cdot ROIC_{0,y,j} \cdot g_{0,y,j} \cdot ci_{0,y,j} + \varepsilon_{0,y,j}$$

$$\frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}}\right)}{\partial ROIC_{0,y,j}} = \alpha_{ROIC} + 2 \cdot \beta_{ROIC} \cdot ROIC_{0,y,j} + \beta_{ROIC,g} \cdot g_{0,y,j} + \beta_{ROIC,ci} \cdot ci_{0,y,j} +$$

$$3 \cdot \gamma_{ROIC} \cdot ROIC_{0,y,j}^2 + 2 \cdot \gamma_{ROIC,ROIC,g} \cdot ROIC_{0,y,j} \cdot g_{0,y,j} + \gamma_{ROIC,g,g} \cdot g_{0,y,j}^2 +$$

$$2 \cdot \gamma_{ROIC,ROIC,ci} \cdot ROIC_{0,y,j} \cdot ci_{0,y,j} + \gamma_{ROIC,ci,ci} \cdot ci_{0,y,j}^2 + \gamma_{ROIC,g,ci} \cdot g_{0,y,j} \cdot ci_{0,y,j}$$
(29)

$$\frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}}\right)}{\partial g_{0,y,j}} = \alpha_g + 2 \cdot \beta_g \cdot g_{0,y,j} + \beta_{ROIC,g} \cdot ROIC_{0,y,j} + \beta_{g,ci} \cdot ci_{0,y,j} +$$

$$3 \cdot \gamma_g \cdot g_{0,y,j}^2 + \gamma_{ROIC,ROIC,g} \cdot ROIC_{0,y,j}^2 + 2 \cdot \gamma_{ROIC,g,g} \cdot ROIC_{0,y,j} \cdot g_{0,y,j} +$$

$$2 \cdot \gamma_{g,ci} \cdot g_{0,y,j} \cdot ci_{0,y,j} + \gamma_{g,ci,ci} \cdot ci_{0,y,j}^2 + \gamma_{ROIC,g,ci} \cdot ROIC_{0,y,j} \cdot ci_{0,y,j}$$
(30)

TABLE 4
Equations for Models Used in the Study

$$\frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right)}{\partial ci_{0,y,j}} = \alpha_{ci} + 2 \cdot \beta_{ci} \cdot ci_{0,y,j} + \beta_{ROIC,ci} \cdot ROIC_{0,y,j} + \beta_{g,ci} \cdot g_{0,y,j} + \quad (31)$$

$$3 \cdot \gamma_{ci} \cdot ci_{0,y,j}^2 + \gamma_{ROIC,ROIC,ci} \cdot ROIC_{0,y,j}^2 + 2 \cdot \gamma_{ROIC,ci,ci} \cdot ROIC_{0,y,j} \cdot ci_{0,y,j} +$$

$$\gamma_{g,g,ci} \cdot g_{0,y,j}^2 + 2 \cdot \gamma_{g,ci,ci} \cdot g_{0,y,j} \cdot ci_{0,y,j} + \gamma_{ROIC,g,ci} \cdot ROIC_{0,y,j} \cdot g_{0,y,j}$$

$$\Delta \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right) \cong \frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right)}{\partial ROIC_{0,y,j}} \cdot \Delta ROIC_{0,y,j} \quad (32)$$

$$\Delta V_{0,y,j} \cong \frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right)}{\partial ROIC_{0,y,j}} \cdot \Delta ROIC_{0,y,j} \cdot S_{0,y,j} \quad (33)$$

$$\Delta \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right) \cong \frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right)}{\partial g_{0,y,j}} \cdot \Delta g_{0,y,j} \quad (34)$$

$$\Delta V_{0,y,j} \cong \frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right)}{\partial g_{0,y,j}} \cdot \Delta g_{0,y,j} \cdot S_{0,y,j} \quad (35)$$

$$\Delta \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right) \cong \frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right)}{\partial ci_{0,y,j}} \cdot \Delta ci_{0,y,j} \quad (36)$$

$$\Delta V_{0,y,j} \cong \frac{\partial \left(\frac{V_{0,y,j}}{S_{0,y,j}} \right)}{\partial ci_{0,y,j}} \cdot \Delta ci_{0,y,j} \cdot S_{0,y,j} \quad (37)$$

were not significantly different from zero. All, but two, of the remaining coefficients are significantly different from zero at the 0.01 level of significance. One of the

remaining coefficients is significantly different from zero at the 0.01379 level of significance and one of the remaining coefficients is significantly different from

TABLE 5
Descriptive Information

A. For the Variables

Variable	Estimate of Mean	Estimate of Standard Deviation	Minimum	Maximum
V / S	2.01311	1.77771	0.18017	10.60864
ROIC	0.12741	0.14724	- 3.09670	3.18951
g	0.08239	0.14044	- 0.40436	0.63998
ci	1.21420	1.09480	0.14049	6.03287

B. For the Multiple Regression Model

Number of Observations	32,582
Degrees of Freedom	32,566
Adjusted R Squared	0.53097
Standard Error of Estimate	1.21748

zero at the 0.05747 level of significance. The coefficient with the 0.05747 level of significance was retained because it measures the interaction among all three of the value drivers.

ESTIMATES OF THE SENSITIVITIES

Empirical estimates of the value of the firm per dollar of sales for different fractiles of the distributions for profitability, growth, and capital intensity are presented in Table 7. These estimates are based on estimates of the coefficients retained in the model shown in Table 6. The third-degree Taylor series expansion, which approximates the theoretical relationships between the value of the firm per dollar of sales and the three value drivers, ROIC₀, g₀, and ci₀, is used to make these estimates. Empirical estimates of the sensitivities of the value of the firm per dollar of sales to profitability, growth, and capital intensity are presented in tables 5 through 7. These estimates are also based on the estimates of coefficients retained in the model shown in Table 6. The expressions for the partial derivatives of the value of the firm per dollar of sales with respect to profitability, growth, and capital intensity for the third-degree Taylor series

expansion, which approximates the theoretical relationships between the value of the firm per dollar of sales and the three value drivers, is used to estimate the sensitivities shown in tables 7 through 10. Table 8 shows estimates of sensitivities of the value of the firm per dollar of sales with respect to the rate of return on invested capital. The sensitivities of the value of the firm per dollar of sales with respect to the growth rate is shown in Table 9. Table 10 shows estimates of sensitivities of the value of the firm per dollar of sales with respect to capital intensity. All of the four tables for the value of the firm per dollar of sales and the sensitivities have a common format. A general layout is used for tables 7 through 10. In these tables, row 1 and column 1 of each section of each table are used for labels showing the numerical values of the three value drivers, ROIC₀, g₀, and ci₀, is used to produce the numerical values shown in the table. The value in the first row and first column of each section of these tables is the capital intensity for a fractile of the distribution of capital intensity for the 32,582 observations used to produce estimates for the model. Section A uses the 0.10 fractile for capital intensity to produce the numerical values shown in the cells

TABLE 6
Estimates of the Coefficients

Symbol	Variable	Estimate	Standard Error	T-Statistic	Significance
α	Constant	-0.58389	0.04321	-13.51266	0.00000
α_{ROIC}	ROIC	2.49903	0.22187	11.26336	0.00000
α_g	g	0.45113	0.14502	3.11073	0.00187
α_{ci}	ci	2.56565	0.07946	32.28947	0.00000
β_{ROIC}	ROIC ²	Excluded			
β_g	g ²	5.64643	0.37170	15.19076	0.00000
β_{ci}	ci ²	-0.59942	0.03162	-18.95640	0.00000
$\beta_{ROIC,g}$	ROIC·g	Excluded			
$\beta_{ROIC,ci}$	ROIC·ci	-1.07988	0.39194	-2.75522	0.00587
$\beta_{g,ci}$	g·ci	1.02007	0.18620	5.47852	0.00000
γ_{ROIC}	ROIC ³	-0.18758	0.07063	-2.65601	0.00791
γ_g	g ³	-8.43958	0.89700	-9.40865	0.00000
γ_{ci}	ci ³	0.06152	0.00347	17.74000	0.00000
$\gamma_{ROIC,ROIC,g}$	ROIC ² ·g	-2.62176	0.83328	-3.14633	0.00165
$\gamma_{ROIC,ROIC,ci}$	ROIC ² ·ci	3.43482	0.51830	6.62708	0.00000
$\gamma_{ROIC,g,g}$	ROIC·g ²	Excluded			
$\gamma_{ROIC,ci,ci}$	ROIC·ci ²	0.27859	0.11312	2.46275	0.01379
$\gamma_{g,g,ci}$	g ² ·ci	Excluded			
$\gamma_{g,ci,ci}$	g·ci ²	-0.18242	0.03971	-4.59386	0.00000
$\gamma_{ROIC,g,ci}$	ROIC·ci·g	0.99819	0.52544	1.89975	0.05747

located at the intersections of rows 2 through 6 and columns 2 through 6. The numerical value of capital intensity for the 0.10 fractile is shown in row 1 and column 1 of the section of the table. Section B uses the 0.25 fractile for capital intensity, Section C uses the 0.50 fractile for capital intensity, Section D uses the 0.75 fractile for capital intensity, and Section E uses the 0.90 fractile for capital intensity. Row 1 of columns 2 through 6 of each section of each table contains the numerical values of the rate of return on invested capital for the 0.10, 0.25, 0.50, 0.75, and 0.90 fractiles of the distribution for the 32,582 observations used to produce estimates for the model. Column 1 of rows 2 through 6 of each section of each table contains the numerical values of the growth rate for the 0.10, 0.25, 0.50, 0.75, and 0.90 fractiles of the

distribution for the 32,582 observations used to produce estimates for the model shown in the cells located at the intersections of rows 2 through 6 and columns 2 through 6. Table 7 shows that the numerical values of the value of the firm per dollar of sales vary from 0.00618 when profitability, growth, and capital intensity are at the lowest levels shown to 5.17020 when profitability, growth, and capital intensity are at the highest levels shown. The value of the firm per dollar of sales for other specific combinations of profitability, growth, and capital intensity can be found in Table 7. For example, if ROIC₀ equals 0.12296, g₀ equals 0.06878, and ci₀ equals 0.79771 (all three value drivers are at the 0.50 fractile level), the value of the firm per dollar of sales equals 1.48378. It should be noted that all of the numerical values for the value

TABLE 7
V / S

Section A: $ci_{0.10}$					
0.35234	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	0.23663	0.37423	0.50588	0.67925	0.89329
0.00513	0.26592	0.40422	0.53528	0.70636	0.91562
0.06878	0.34002	0.47893	0.60947	0.77852	0.98353
0.14889	0.47666	0.61635	0.74623	0.91271	1.11236
0.25367	0.68770	0.82841	0.95744	1.12056	1.31320
Section B: $ci_{0.25}$					
0.51207	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	0.55924	0.69042	0.81987	0.99512	1.21760
0.00513	0.59845	0.73103	0.86052	1.03426	1.25284
0.06878	0.68138	0.81520	0.94473	1.11712	1.33225
0.14889	0.82913	0.96452	1.09410	1.26478	1.47555
0.25367	1.05471	1.19215	1.32179	1.49025	1.69533
Section C: $ci_{0.50}$					
0.79771	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	1.07465	1.19655	1.32402	1.50504	1.74537
0.00513	1.12994	1.25450	1.38313	1.56402	1.80205
0.06878	1.22718	1.35410	1.48378	1.66455	1.90054
0.14889	1.39295	1.52284	1.65382	1.83445	2.06787
0.25367	1.64209	1.77588	1.90857	2.08900	2.31907
Section D: $ci_{0.75}$					
1.49531	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	2.05011	2.16113	2.29429	2.50239	2.80127
0.00513	2.13573	2.25247	2.38954	2.60089	2.90137
0.06878	2.25997	2.38181	2.52236	2.73661	3.03851
0.14889	2.45971	2.58796	2.73290	2.95079	3.25449
0.25367	2.75330	2.88994	3.04060	3.26327	3.56931
Section E: $ci_{0.90}$					
2.74122	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	3.12422	3.25740	3.43791	3.74022	4.19643
0.00513	3.23241	3.37680	3.56612	3.87773	4.34249
0.06878	3.37675	3.53111	3.72827	4.04816	4.52055
0.14889	3.60178	3.76870	3.97574	4.30605	4.78802
0.25367	3.92845	4.11180	4.33175	4.67569	5.17020

of the firm per dollar of sales are based on estimates obtained from 32,582 observations over 20 years. Table 8 shows that the numerical values partial derivative of the value of the firm per dollar of sales with respect to the rate of return on invested capital vary from 2.14689 when

profitability, growth, and capital intensity are at the lowest levels shown to 6.99620 when profitability, growth, and capital intensity are at the highest levels shown. If all three value drivers are at the 0.50 fractile level, $ROIC_0$ equals 0.19095, g_0 equals 0.06878, and ci_0 equals 0.79771, the partial

TABLE 8
Partial Derivative of V / S with respect to ROIC

Section A: $ci_{0.10}$					
0.35234	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	2.14689	2.31504	2.46170	2.63790	2.83418
0.00513	2.16972	2.31475	2.44075	2.59146	2.75841
0.06878	2.19004	2.31449	2.42209	2.55011	2.69097
0.14889	2.21562	2.31416	2.39862	2.49808	2.60608
0.25367	2.24907	2.31374	2.36791	2.43002	2.49504
Section B: $ci_{0.25}$					
0.51207	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	2.00907	2.24489	2.45202	2.70282	2.98492
0.00513	2.04330	2.25600	2.44247	2.66778	2.92056
0.06878	2.07377	2.26588	2.43396	2.63658	2.86326
0.14889	2.11212	2.27833	2.42326	2.59732	2.79114
0.25367	2.16228	2.29461	2.40926	2.54597	2.69681
Section C: $ci_{0.50}$					
0.79771	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	1.79806	2.15487	2.47016	2.85435	3.28993
0.00513	1.85267	2.18637	2.48099	2.83969	3.24595
0.06878	1.90129	2.21441	2.49063	2.82665	3.20680
0.14889	1.96248	2.24969	2.50277	2.81023	3.15752
0.25367	2.04252	2.29585	2.51864	2.78875	3.09307
Section D: $ci_{0.75}$					
1.49531	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	1.47379	2.12613	2.70553	3.41552	4.22592
0.00513	1.57819	2.20741	2.76615	3.45065	4.23173
0.06878	1.67113	2.27977	2.82012	3.48193	4.23690
0.14889	1.78811	2.37084	2.88804	3.52129	4.24341
0.25367	1.94111	2.48997	2.97688	3.57278	4.25193
Section E: $ci_{0.90}$					
2.74122	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	1.56924	2.74938	3.80049	5.09234	6.57217
0.00513	1.76257	2.91958	3.95003	5.21640	6.66690
0.06878	1.93467	3.07110	4.08316	5.32683	6.75123
0.14889	2.15127	3.26180	4.25071	5.46582	6.85737
0.25367	2.43459	3.51124	4.46986	5.64763	6.99620

derivative of the value of the firm per dollar of sales with respect to the rate of return on invested capital is 2.49063. This indicates that if $ROIC_0$ increases by 1 percent (0.01), the value of the firm per dollar of sales will increase by approximately 0.0249063 to approximately 1.48378 plus 0.02491.

Numerical values of the partial derivative of the value of the firm per dollar of sales with respect to the growth rate are shown in Table 9. These values vary from 0.07107 when profitability, growth, and capital intensity are at its lowest levels shown to 3.65861 when profitability, growth, and

TABLE 9
Partial Derivative of V / S with respect to g

Section A: $ci_{0.10}$					
0.35234	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	0.07107	0.06135	0.06954	0.10158	0.16842
0.00513	0.84723	0.85695	0.84876	0.81672	0.74988
0.06878	1.44691	1.45663	1.44844	1.41640	1.34956
0.14889	1.91009	1.91981	1.91162	1.87958	1.81274
0.25367	2.02540	2.03511	2.02693	1.99488	1.92804
Section B: $ci_{0.25}$					
0.51207	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	0.06767	0.08722	0.08782	0.06662	0.01225
0.00513	0.98597	1.00552	1.00612	0.98492	0.93055
0.06878	1.58565	1.60520	1.60580	1.58460	1.53023
0.14889	2.04882	2.06837	2.06897	2.04777	1.99340
0.25367	2.16413	2.18368	2.18428	2.16308	2.10871
Section C: $ci_{0.50}$					
0.79771	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	0.29256	0.32969	0.34600	0.34419	0.31212
0.00513	1.21086	1.24799	1.26430	1.26249	1.23042
0.06878	1.81054	1.84767	1.86399	1.86217	1.83010
0.14889	2.27371	2.31085	2.32716	2.32534	2.29327
0.25367	2.38902	2.42615	2.44247	2.44065	2.40858
Section D: $ci_{0.75}$					
1.49531	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	0.71667	0.79674	0.85144	0.89696	0.91935
0.00513	1.63497	1.71505	1.76974	1.81526	1.83765
0.06878	2.23465	2.31473	2.36942	2.41494	2.43733
0.14889	2.69783	2.77790	2.83259	2.87811	2.90051
0.25367	2.81313	2.89321	2.94790	2.99342	3.01582
Section E: $ci_{0.90}$					
2.74122	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	1.03241	1.18917	1.31241	1.44248	1.56214
0.00513	1.95071	2.10748	2.23071	2.36078	2.48044
0.06878	2.55039	2.70716	2.83039	2.96046	3.08013
0.14889	3.01357	3.17033	3.29356	3.42363	3.54330
0.25367	3.12887	3.28564	3.40887	3.53894	3.65861

capital intensity are at the highest levels shown. The partial derivative of the value of the firm per dollar of sales with respect to the growth rate is 1.86399 when all three value drivers are at the 0.50 fractile level, $ROIC_0$ equals 0.19095, g_0 equals 0.06878, and ci_0 equals 0.79771. If g_0 increases by 1

percent (0.01), the value of the firm per dollar of sales will increase by approximately 0.0186399 to approximately 1.48378 plus 0.01864. Table 10 shows that the numerical values partial derivative of the value of the firm per dollar of sales with respect to capital intensity vary from

TABLE 10
Partial Derivative of V / S with respect to ci

Section A: $ci_{0.10}$					
0.35234	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	2.10125	2.05836	2.04214	2.05087	2.10019
0.00513	2.16544	2.12695	2.11466	2.12824	2.18314
0.06878	2.22258	2.18801	2.17922	2.19712	2.25699
0.14889	2.29449	2.26485	2.26047	2.28381	2.34993
0.25367	2.38856	2.36537	2.36675	2.39720	2.47151
Section B: $ci_{0.25}$					
0.51207	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	1.93966	1.90226	1.89094	1.90572	1.96200
0.00513	1.99968	1.96668	1.95930	1.97893	2.04079
0.06878	2.05311	2.02403	2.02014	2.04410	2.11093
0.14889	2.12036	2.09621	2.09673	2.12612	2.19920
0.25367	2.20832	2.19062	2.19690	2.23340	2.31467
Section C: $ci_{0.50}$					
0.79771	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	1.67418	1.64659	1.64404	1.66964	1.73837
0.00513	1.72674	1.70356	1.70494	1.73539	1.80971
0.06878	1.77354	1.75427	1.75916	1.79393	1.87321
0.14889	1.83244	1.81810	1.82739	1.86760	1.95314
0.25367	1.90948	1.90159	1.91665	1.96397	2.05768
Section D: $ci_{0.75}$					
1.49531	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	1.15237	1.14876	1.16763	1.21965	1.31878
0.00513	1.18674	1.18753	1.21033	1.26721	1.37192
0.06878	1.21734	1.22204	1.24835	1.30955	1.41923
0.14889	1.25585	1.26548	1.29620	1.36283	1.47877
0.25367	1.30622	1.32230	1.35878	1.43253	1.55664
Section E: $ci_{0.90}$					
2.74122	0.00618	0.06785	0.12296	0.19095	0.26916
-0.06637	0.66734	0.70653	0.76366	0.86288	1.01630
0.00513	0.66921	0.71280	0.77386	0.87793	1.03694
0.06878	0.67087	0.71838	0.78295	0.89134	1.05532
0.14889	0.67297	0.72541	0.79438	0.90821	1.07844
0.25367	0.67571	0.73460	0.80934	0.93027	1.10868

2.10125 when profitability, growth, and capital intensity are at the lowest levels shown to 1.10868 when profitability, growth, and capital intensity are at the highest levels shown. When all three value drivers are at the 0.50 fractile level with $ROIC_0$ equals 0.19095, g_0 equals 0.06878,

and ci_0 equals 0.79771, the partial derivative of the value of the firm per dollar of sales with respect to capital intensity is 1.75916. If all three value drivers are at the 0.50 fractile level and ci_0 increases by 1 percent (0.01), the value of the firm per dollar of sales will increase by approximately 0.01759.

SUMMARY AND CONCLUSIONS

This research extends valuation models to be used in value-based management so that they include explicit treatment of profitability, growth, and capital intensity. The extended valuation models are developed so that they explicitly show the relationships between these value drivers and the value of the firm. Partial derivatives for the extended valuation models are used to provide expressions for the sensitivities of the value of the firm per dollar of sales to profitability, growth, and capital intensity. The sensitivities are used to provide expressions for dollar changes in the value of the firm per dollar of sales and the value of the firm associated with changes in profitability, growth, and capital intensity. The partial derivatives and dollar changes can be used as measures of the sensitivities of value of the firm with respect to changes in these value drivers. The empirical estimates for the coefficients of the valuation model and the sensitivities provide information about the relative importance of changes in profitability, growth, and capital intensity in terms of changes in the value of the firm. The models developed in this paper and empirical estimates are used to generate information about the value of the firm per dollar of sales and the sensitivities of the value of the firm per dollar of sales for different numerical values of profitability, growth, and capital intensity. The information presented in the tables in this paper is based on 32,582 observations for actual firms over a time period of 20 years. This information provides insights about the actual impacts on the value of the firm and the value of the firm per dollar of sales of changes in these value drivers.

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