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Working capital management has traditionally concentrated on the investment decision (current assets) while virtually ignoring the financing decision (current liabilities). While the majority of research has been directed toward developing methodologies which either maximize risk adjusted revenues or minimize costs of cash [1,21,34,35], accounts receivable [6,16,25,36], and inventory [18,41], few studies have been devoted to analyzing the appropriate source/mix of funds with which to finance the investment in working capital. Comprehensive working capital models developed to capture the dynamic relationships between working capital accounts also fail to adequately address the financing concern [17,27,38].

The two aspects of working capital financing are (1) the selection of the optimal combination of short term debt alternatives and (2) the determination of the mix of short term versus long term financing. The selection criteria for short term financing decisions commonly relies on cost minimization through a comparison of effective interest rates which consider compounding, type of interest, compensating balances, etc. [8,41]. More sophisticated approaches rely on mathematical programming to determine the optimal combination given the firm's cash budget and accompanying forecast of fund requirements [24,34,35].

Very little work has been devoted to developing a framework for determining the optimal mix of short and long term financing. Traditional guidelines suggest that alternative levels of short (long) term financing depend on management's attitude toward the differential flexibility, cost, and risk levels associated with each level. The matching principle, which states that short (long) term assets should be financed with short (long) term funds, is commonly suggested as an important guide in making this financing decision. A conservative financing strategy would be to use long term debt to finance short term needs while an aggressive strategy would be to finance long term requirements with short term funds. The conservative approach is typically more expensive and less flexible than the aggressive approach due to the higher costs of (assuming an upward sloping yield curve) and greater commitment to long term funds [41].

Alternative maturity structures of debt subject the firm to varying levels of risk exposure. Greater reliance on short term debt, for example, exposes the firm to cyclical credit markets and/or short term debt being unavailable due to firm or industry factors, such as possibility of higher interest rates (interest rate risk) when credit is required. Firms having a higher proportion of short term debt relative to long term debt are exposed to the impact of the greater volatility of interest rates in the short term credit markets than in the long term credit markets.

Beyond general rules-of-thumb (current ratio 2:1) and descriptive guidelines (risk preference of management), little research has been devoted toward the development of a valuation based framework to indicate a firm's interest rate risk exposure of alternative net working capital levels. The purpose of this paper is to present a methodology which may be used to analyze the interest rate risk exposure of alternative working capital financing structures using duration. Widely used in investments [23], and more recently used in the analysis of corporate finance problems [3,37], duration measures the sensitivity of value to changes in interest rates. Assuming a constant debt to equity ratio and asset composition, the impact of a change in interest rates on firm value may depend on the combination of short term and long term debt. By comparing the durations of assets and liabilities, differential duration [37] may be used to evaluate a firm's overall interest rate risk exposure and may provide insight into the relationship between the risk structure of alternative debt mixes and firm value.

Duration

Developed by Macauley [19], duration is typically used as a measure of a bond's average time to maturity and represents a weighted average number of periods until cash flows are received from the bond where the weights are the present value factors of each cash flow. As an alternative to time to maturity, duration, D, considers the size, timing, and risk of the cash flows.

$$D = \frac{\sum_{t=1}^{N} C_t(t)/(1+i)^t}{\sum_{t=1}^{N} C_t/(1+i)^t} \tag{1}$$

where C_t is the cash flow from the bond during period t, i is the bond's yield (or discount rate on cash flows), N is the time until maturity, and (t) is the length of time until receipt of the cash flow. An important feature of duration is the direct relationship between duration and price elasticity. Factors which increase an asset's duration, such as the number, timing, size, and risk of cashflows, subsequently increase the asset's price sensitivity to interest rate changes, thus increasing the asset's risk.

A primary application of duration allows for the elimination of interest rate risk through immunization [23]. An asset is immunized against changes in value when the investor's investment horizon (or expected holding period) is equal to the duration of the asset's cash flows since the reinvestment risk is exactly offset by the maturity risk. Hicks [14] and Samuelson [26] first suggested that the change in the relative value of assets and liabilities resulting from a change in interest rates depends on the duration of the assets/liabilities. Thus firms may (1) hedge against interest rate changes by choosing asset and liability streams of equal weighted duration, or (2) speculate on interest rate changes by adjusting the weighted duration of the assets and liabilities to match the anticipated interest rate movement. Grove [9,10] later used these relationships in developing a general model of a firm's asset/liability structure under uncertainty of income and interest rate changes. Morris [22] applied duration to a general analysis of corporate debt maturity structure and found the matching of asset and liability lives to achieve an immunized balance sheet depends on the relationship between interest costs and the firm's net operating income.

Duration also has been used as a measure of the relationship between stock values and interest rates. Shown by Hopewell and Kaufman [14], the percentage change in equity prices relative to interest rate changes is

$$\frac{dP}{P} = (-D)\left[\frac{dr}{1+r}\right] \tag{2}$$

where P is the market price of equity, D represents duration, and r is the relevant interest rate. Blocher and Stickney [3] have suggested that this relationship may be used in the selection of otherwise comparable capital budgeting projects. Projects with a shorter duration may expose the firm to a smaller risk of loss resulting from an increase in market yields. Van Auken and Dellva [38] developed the application of duration in setting working capital investment and financing strategies.

Duration and Working Capital Financing

Duration may also be used to analyze the firm's interest risk exposure from the use of alternative mixes of short term and long term debt. Such a choice reflects the working capital financing decision and determines the level of net working capital. Given the firm's investment decision, alternative short term/long term debt mixes may cause differential fluctuations in firm value with changes in market interest rates. The link between interest rate risk exposure resulting from alternative levels of short term and long term debt and firm value may be established by comparing the durations of the firm's assets (D(A)) and liabilities (D(L)). As interest rates change, the value of the firm's assets and liabilities will change in opposite directions. For example, as interest rates increase, asset values will decrease due to increased opportunity costs while the value to the firm of liabilities will increase since the firm is repaying debt with less expensive funds. The D(A) and D(L) are a weighted average of the durations of the asset and liability components.

$$D(A) = \sum_{a=1}^{N} W_a D_a \tag{3}$$

$$D(L) = \sum_{l=1}^{N} W_l D_l \tag{4}$$

where D_a and D_ℓ are the durations of specific asset and liability components, respectively, and W_a and W_ℓ represent the percent of each component's market value relative to total asset/liability market value.

The D(A) and D(L) may be combined into a differential duration, DD, measure which indicates the differential change in value of assets and liabilities resulting from a change in interest rates.

$$DD = D(A) - DL/[V(L)/V(A)] \tag{5}$$

where V(L) and V(A) are the market determined value of liabilities and assets, respectively [11]. With a given asset composition and cashflow pattern, DD can be used to measure the impact on firm value of interest rate changes and resulting risk exposure under alternative debt combinations. Net working capital provides similar information but is a static measure reflecting only the relative levels of short term and long term financing and is not formulated in a valuation framework. DD captures additional factors by incorporating the timing and risk of the cashflows from assets and liabilities to reflect changes in the relative values due to changes in interest rates.

Differential duration provides information useful to the firm's short-term versus long-term financing decision relative to current interest rate risk exposure and anticipated credit market conditions. For example, firms using an aggressive working capital financing strategy (increased reliance on short term debt) will have a lower D(L) and higher DD, ceterus paribus, than firms using a conservative financing strategy (smaller reliance on short term debt). Consequently, during periods of interest rate volatility, firms using an aggressive financing strategy will be exposed to greater changes in firm value than firms using a conservative strategy. The greater firm value volatility associated with the aggressive strategy may be positive or negative. With an increase in market interest rates (ceterus paribus), the decline in value of assets will exceed the increase in value of liabilities and result in a decline in firm value. A decrease in market interest rates will lead to an increase in firm value since the value of assets will increase more than the value of liabilities will decrease (ceterus paribus).

Value based speculative or hedging financing strategies could be developed using DD. A financing strategy leading to a large positive or negative DD could be used to leverage the effect of anticipated interest rate changes on firm value. Of course, the speculative strategy also exposes the firm to the risk of interest rates changing opposite to the anticipated direction. Firms may hedge against changing interest rates by maintaining a DD=0 since changes in the value of assets would be opposite, but equal in magnitude, to changes in the value of liabilities. The value of cashflow streams is an essential aspect of establishing value based working capital financing strategies. The traditional aggressive, matching and conservative financing strategies not only are not value based, but focus primarily on business risk in that only the pattern of cashflows is considered.

Equation 5 demonstrates that a firm's valuation based working capital financing strategies may be constrained. Since the values of the asset V(A) and liability V(L) cashflow streams are an essential aspect of the analysis, firms may be limited in their ability to achieve $DD < 0$. For all solvent firms, V(A) will be greater than V(L). At the extreme, $V(A) = V(L)$ if the firm used 100% debt financing (approaching insolvency since net worth = 0); for less than 100% financing, $V(A) > V(L)$. Thus to achieve $DD \leq 0$, $D(L) \geq D(A)$. Firms may alter the short-term/long-term financing proportions, coupon sizes, and/or maturity dates of debt to achieve the desired DD. However, for the majority of firms using a large percentage of equity financing, achieving $DD \leq 0$ may be difficult due to the large value of assets relative to liabilities.

DD can be used as a measure of the firm's overall interest rate risk resulting from alternative combinations of long term and short term debt. From equation 2

$$VE_p = (-DD) \left[\frac{dr_0}{1 + r_0}\right] \tag{6}$$

where VE_p and r_0 are the changes in equity value and the firm's overall cost of capital, respectively. Alternative debt financing structures are directly related to changes in equity values resulting from changes in market rates of interest. For example, greater use of long term debt relative to short term debt increases D(L) and decreases DD, and results in smaller changes in equity value with interest rate changes. Greater use of short term debt decreases D(L), increases DD, and results in greater changes in equity value as interest rates change.

In addition to providing a measure of the interest rate risk of an existing financing policy, DD may provide the firm with insight into the design of a financing policy which is consistent with acceptable levels of interest rate risk. DD may be used to analyze the impact of interest rate changes on firm value under an existing or alternative financing combinations and/or, given the firm's acceptable level of interest rate risk exposure, to identify an appropriate level of short/long term financing. Substituting equation 5 into equation 6 and solving for D(L)

$$D(L) = \frac{VF}{VL} \left[\frac{VE_p(1+r)}{dr}\right] + D(A) \tag{7}$$

Given the firm's existing asset composition and capital structure (VF, VL, D(A), and r constant), changes in equity value associated with changes in interest rates are directly related to the debt financing mix through D(L). By specifying acceptable levels of equity value changes associated with alternative interest rate changes (dr), the firm can determine the debt structure which achieves the required D(L). As potential interest rate volatility increases (dr increases), the firm must move toward greater use of long term debt to achieve the necessary D(L) which constrains equity value changes to acceptable levels. The required increase in D(L) with increasing interest rate changes is not directly proportional to the increasing potential interest rate changes, but increases at a decreasing rate.

While previous approaches to determining the firm's short/long term financing mix have relied on general guidelines relative to the risk preferences of the firm, the use of DD provides a value based measure of the impact of alternative financing mixes. Using equation 6 and 7, the firm may both measure the risk associated with an existing financing policy and design a financing policy which is consistent with acceptable risk levels. Analyzing the differential durations of assets and liabilities has the advantage of allowing the firm to more accurately determine a financing policy consistent with financing objectives in a valuation framework.

Working Capital Analysis: Example

Differential duration may be used to measure a firm's existing interest rate risk exposure and/or to provide guidelines into establishing a debt financing mix consistent with risk preferences. Consider, for example, the balance sheet shown in Table 1. The firm has invested approximately 36% and 64% of its funds in current and fixed assets respectively. Of the current assets ($170), $70 is assumed to be permanent (non-fluctuating) current assets. These assets are currently financed (50% debt and 50% equity) using the matching principle, with the $370 level of permanent assets being financed with $370 of long term funds and the $100 of fluctuating working capital being financed with $100 of short term debt. The firm's net operating income during the next year is expected to be $60 and to grow by 5% in each subsequent year. The proportional allocation of revenue to working capital and fixed assets (i.e. the productivity of funds invested in working capital and fixed assets) is assumed to be closely associated with the percentage of funds invested in each. The firm's cash cycle and expected life of fixed assets are 90 days and 15 years respectively. The firm also has an accounts payable turnover of 30 days, a 13% term note due in 90 days, and 15% coupon rate long term debt maturing in 15 years. The firm's average cost of capital is 15%.

From equation 3 the duration of the firm's assets is shown to be a value weighted duration of current assets (working capital) and fixed assets, with the weights determined by the component values relative to total value of assets. Ignoring taxes, the value of the firm's total assets may be determined as the value of net operating income (NOI) over the expected life of the assets using the firm's average cost of capital (12). The component weights of current assets and fixed assets depend on their relative value of total assets, or the proportion of NOI attributable to current and fixed asset invest-

TABLE I

INITIAL BALANCE SHEET

ASSETS		LIABILITIES AND EQUITY	
Cash	$ 10	Accounts Payable	50.00
Accounts Receivable	50	Notes Payable	50.00
Inventory	110		
Total Current Assets	170	Total Current Liabilities	100.00
Fixed Assets	300	Long Term Debt	135.00
		Common Equity	235.00
Total Assets	470	Total Liabilities and Equity	470.00

ments. While a precise method of attributing NOI to current assets and fixed assets is difficult, an approximation is to assume that the percent of total NOI associated with current working and fixed assets is directly to their balance sheet proportions of total assets. Using equation 3,

$$D(A) = W_c D_c + W_f D_f \tag{8}$$

where D_c = duration of current assets (years) = .25
D_f = duration of fixed assets (years) = 6.35
W_c = weight of current assets (= CA/VA) = .362
W_f = weight of fixed assets (= VF/LA) = .638
V_c = value of current assets (= VNOI*(CA/VA)) = 103.13
V_f = value of fixed assets (= VNOI*(FA/VA)) = 182.00
VNOI = value of NOI over life of assets = 285.13
VA = $V_c + V_f$
D(A) = .362(.25) + .638(6.35) = 4.14

From equation 4 the D(L) is also seen to be a value weighted duration of liability components, with the weights determined by the component values relative to total value of liabilities. For the firm shown in Table I,

$$D(L) = W_a D_a + W_n D_n + W_b D_b \tag{9}$$

where D_a	= duration of accounts payable (years)	=	.08
D_n	= duration of notes payable (years)	=	.25
D_b	= duration of long term debt (years)	=	6.72
W_a	= weight of accounts payable ($= V_a/VL$)	=	.2126
W_n	= weight of notes payable ($= V_n/VL$)	=	.2079
W_b	= weight of long term debt ($= V_b/VL$)	=	.5796
V_a	= present value of payments to suppliers	=	49.51
V_n	= present value of notes payable	=	48.42
V_b	= present value of long term debt	=	135.00
VL	$= V_a + V_n = V_b$	=	232.93

The discount rate used to determine the present value of payments to suppliers is the rate a lending institution charged if the firm borrowed funds to pay-off suppliers early. Reflecting a normally shaped yield curve, 12% was used. Using equation 9

$$D(L) = (.2126)(.08) + (.2079)(.25) + (.5796)(6.72) = 3.96$$

From equation 5, the DD resulting from the firm's debt financing structure is .905. While using the matching principle to determine levels of short term and long term debt, the firm remains exposed to value changes from interest rate changes. As interest rates increase (decrease), firm value will decrease (increase) since the weighted value of assets will decrease (increase) more than the increase (decrease) in the weighted value liabilities. Given an interest rate forecast, the firm's specific risk exposure may be determined using equation 6. For example, with a 1% forecast increase in interest rates, the change in the value of equity, VE', may be determined as

$$VE' = (-.905)(.01/1.15) = -0.0079\%$$

Since accurate forecasts of interest rates may be very difficult, a range of alternative interest rate forecast may be made to determine a distribution of possible equity value changes. Table II illustrates possible changes in equity value resulting from forecast interest rate changes of −2% to 2%. Based on a forecast directional change in interest rates, the data in Table I may also be weighted to determine an expected change in equity value.

TABLE II

Changes in Equity Values Resulting From Interest Rate Changes (K=15%)

Interest Rate Change	Change in Equity Value (%)
-.02	1.57
-.015	1.18
-.01	.79
+.01	-.79
+.015	-1.18
+.02	-1.57

Table III shows balance sheet financing mixes under possible aggressive, matching, and conservative financing strategies and relative changes in equity resulting from an increase in interest rates of 1.0%, 1.5%, and 2.0%. Each strategy is shown to be generally consistent with the strategy underlying the liability structure in that, for example, the conservative (aggressive) strategies subject the firm to less (more) equity value changes as interest rates change. However, the conservative strategy does not protect the firm from changes in equity value, but constrains the wealth changes more than the other strategies.

TABLE III

Change in Equity Values Relative to Interest Rate Changes Under Alternative Debt Structures

Financing Strategy	Current Liabilities	Long Term Debt	DD	Change in Interest Rates .02	.015	.01
Aggressive	170	65	2.47	-4.30	-3.22	-2.15
Matching	100	135	.905	-1.57	-1.18	-.79
Conservative	65	170	-0.05	0.09	0.07	0.04

Alternatively, a liability mix may be constructed which is consistent with the firm's risk preferences as measured by acceptable changes in equity values associated with potential interest rate changes. By specifying the acceptable changes in equity, the firm may identify the appropriate debt mix matching the D(L) calculated from equation 7. Table IV shows the liability weighting under alternative limits on equity value changes under a 1% change in interest rates. The distribution of weights in Table IV is consistent with the traditional financing strategies in that firms with aggressive (conservative) attitudes toward risk may move toward greater (lesser) use of short term debt. The table also reveals, however, the specific identification of component weighting consistent with the firm's specified risk tolerances. While the example assumes equal weighting between accounts payable and notes payable, firms constrained in the use of accounts payable would find a different component weighting schedule.

TABLE IV

Liability Weights Relative to Limits On Equity Value Changes

Liability Component	Percent Change in Equity Value 1.0	1.5	2.0	2.5	3.0
Accounts Payable	17.6	22.4	31.2	38.1	44.8
Notes Payable	17.6	22.4	31.2	38.1	44.8
Long Term Debt	64.8	51.2	37.6	23.8	10.3

Ultimately, firms operate in an environment where changes in interest rates are difficult to forecast. The traditionally suggested financing strategies are useful in matching the maturity structures of assets and liabilities with general management risk preferences, but provide no measure of risk or guidance on the relationship between risk levels and alternative valuation scenarios. DD provides a more comprehensive measure which incorporates risk measurements into the analysis and shows the impact on firm value of changes in interest rates under alternative long term/short term debt mixes. More appropriately, defining matching, conservative, and aggressive financing mixes using DD specifically allow for the measurement of risk rather than relying on ambiguously specified management risk preferences.

SUMMARY AND CONCLUSIONS

Traditional working capital analysis has focused on the investment decision with little regard for the financing decision. The commonly suggested approach for determining the financing decision has relied on the firm's risk preferences in selecting either a conservative, matching, or aggressive strategy. The problem associated with the use of the guidelines is that they are not valuation based and, resultingly, provide little insight into the impact of credit market changes on firm value.

An approach which provides additional insight into the working capital financing decision is to measure the differential durations of the cashflows from the firm's asset and liabilities under alternative short/long term financing combinations. Alternative combinations of short/long term financing expose the firm to different levels of interest rate risk. The use of duration allows the firm to measure the existing level of interest rate risk exposure and provides insight into the impact on firm value of interest rate changes. By specifying acceptable changes in value under alternative interest rate forecast, the financing combination which is consistent with the firm's risk preferences may be determined.

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