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Forward Markets, Stock Markets, and the Theory of the Firm

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ABSTRACT

This paper models a competitive financial market economy in which there are forward markets as well as stock and bond markets. Although there are separation theorems in the stock and forward markets literatures, this analysis shows that neither separation theorem survives in this integrated financial market economy. Next, the analysis shows that the separation results hold and are equivalent if the manager has an appropriate compensation package. Then the model is modified to allow for depreciation charges and tax credits. A positive theory of hedging is developed that shows that the corporation can preserve deductions and credits by hedging and so increase corporate value.

THE THEORY OF THE firm under uncertainty has been developed along seemingly independent lines in the literature on stock market economies and the literature on forward market economies. There are some interesting parallels, but apparently no financial market model also incorporates forward markets. Some of the models in the two literatures may be viewed as extensions of the theory of the competitive firm under uncertainty developed by both Baron [1] and Sandmo [13]. In each literature, the firm manager's optimal production decision may be characterized as the production level at which expected price equals marginal cost plus a marginal risk premium. Each literature contains a separation theorem. In the stock market literature, we have the unanimity theorem, which shows that stockholders will agree on the optimal production level despite different probability beliefs and attitudes toward risk; in a competitive stock market economy, this result is equivalent to all stockholders agreeing that the firm should maximize corporate value.[1] Since any competitive firm's manager finds it in his or her own best interests to maximize corporate value, despite his or her probability beliefs and attitude toward risk, the unanimity theorem is a separation theorem. In the forward market literature, we have a separation theorem that shows that any firm manager will select the production level at which the forward price equals marginal cost, again despite his or her probability beliefs and attitude toward risk.[2] The purpose of this paper is to investigate the theory of the competitive firm in a financial market economy characterized by stock, bond, and forward markets. Although one might expect the separation results of the two literatures to survive this generalization, we show that they do not. We go on to show that,

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[1] For example, see DeAngelo [2], Ekern and Wilson [5], Leland [9], and Merton and Subrahmanyam [11].

[2] For example, see Feder, Just, and Schmitz [6] and Holthausen [8].

although the corporate hedging decision is irrelevant in a no-tax environment, a positive theory of hedging can be developed in a financial market economy with the corporate tax.

The model constructed in the following sections maintains the basic features of those constructed by earlier authors so that direct comparison is possible.[3] The only exception is that we allow for multiproduct firms. The firm is managed by an individual with an interest in the firm, i.e., one of the shareholders. In addition to the firm's output and hedging decisions, the manager selects portfolios of stocks, bonds, and forward contracts on his or her own account. As in the previous models, the manager is assumed to make those hedging and production decisions for the firm that are consistent with maximizing his or her expected utility.

With forward markets, we show, first, that the forward position of the firm is irrelevant in an economy with no taxes because the firm's hedging position may be offset by any investor, including the manager, on personal account, thus leaving the investor's wealth distribution unaffected. It follows that the stock market value of the firm is not affected by the firm's position in the forward markets. This result is a trivial generalization of the 1958 Modigliani-Miller (MM) theorem [12]. This result is different from that of Feder, Just, and Schmitz (FJS [6]). In the FJS model, the owner-entrepreneur makes a production decision and a hedging decision and, what is more important, bears all the remaining risk in the spot market for the unhedged output. Therefore, the hedging decision of the risk-averse entrepreneur is not a matter of indifference in the FJS model. In this model, the manager makes the same decisions but is also able to diversify the risks. Of course, in this model, the corporate manager actually has two hedging portfolios, one on corporate account and the other on personal account. At least one of the two is not a matter of indifference to the manager.

Second, we show that neither the separation result in the stock market literature nor the separation result in the forward market literature survives in this financial market economy. We do show that maximizing the value of the firm is equivalent to selecting the production levels so that forward price equals marginal cost for all commodities. However, selecting the production level that maximizes corporate value is a sufficient but not necessary condition for expected utility maximization. In a financial market economy with forward markets, the manager may select a production decision that does not maximize value and then mimic the end-of-period wealth distribution associated with the optimal production decision by trading in the forward market. Since the forward markets allow the manager to break the link between the production decision and the wealth distribution, we go on to show that a nontradable stock option may be used to re-establish the link and give the manager the incentive to maximize corporate value. Alternatively, with the stock option, we show that the separation results in the two literatures hold here and are equivalent.

Third, by introducing the corporate tax, depreciation charges, and tax credits, we are able to provide a positive theory of hedging by showing that the firm has an incentive to hedge its production decision. The motivation is not to reduce

[3] This model is a generalization of Sandmo's [13], as were the models of Feder, Just, and Schmitz [6] and Holthausen [8]. This model is also similar to the Diamond [4] and Leland [9] models.

the variability of the firm's payoff as in earlier models, although it does have that effect. Rather, the hedging decision is motivated by a desire to protect either depreciation deductions or tax credits. In the case of depreciation deductions, we show that the hedge increases the cash flow to investors in the event that all depreciation deductions are lost by the unhedged firm because the taxes paid in that event are less than the value of the tax shelter, which is lost by the unhedged firm. It follows that the earlier result of Green and Talmor [7], i.e., that the firm with unusable depreciation charges in some states has an incentive to under-produce riskier commodities, is overturned.[4] In the case of tax credits, we show that hedging allows the firm to fully and costlessly protect its maximum available tax credits. In each case, we show that hedging increases the value of the firm. Beyond the point at which the firm captures all available depreciation charges and/or tax credits, the irrelevance result holds again.

In Section I, we provide the basic structure of the model and demonstrate the irrelevance of the corporation's forward market position. We also show that the value of the corporation may be expressed in a deterministic form using forward prices. In Section II, we show that the separation results in the two literatures do not hold, and then we show that a stock option can be designed for the manager that will guarantee separation. In Section III, we demonstrate conditions that are sufficient to provide the corpration with an incentive to hedge in forward markets, and, in Section IV, we provide some concluding remarks.

I. Value

Consider a competitive economy. Suppose that the economy is subject to price uncertainty in its spot markets. Let P_j be a non-negative random variable denoting the spot price of commodity $j = 1, 2, \cdots, N$. Let $P = (P_1, \cdots, P_N)$ denote the random vector of spot prices. Let y_f be a vector in $\mathbb{R}^N$ that denotes the production decision of the firm f; let c_f denote the firm's variable cost function. Then let Z_f be a random variable that specifies the firm's net revenue from the sale of all its output in the spot markets, i.e., $Z_f = Py_f - c_f(y_f)$.[5]

Next, suppose that firms may also participate in forward markets. Let $v = (v_1, \cdots, v_N)$ denote the vector of forward prices. Define a forward contract as a promise to deliver one unit of the commodity at the end of the period for the specified forward price. If we let x_f be a vector in $\mathbb{R}^N$ that denotes the forward position of firm f, then the firm delivers $y_f - x_f$ to the spot market and x_f to the forward market; this yields revenue $P(y_f - x_f)$ in the spot markets and revenue vx_f in the forward markets. Hence, the net revenue payable to bond and equity holders at the end of the period is Π_f, where

$$\Pi_f = P(y_f - x_f) + vx_f - c_f(y_f) = Py_f + (v - P)x_f - c_f(y_f) = Z_f + (v - P)x_f,$$

where $Z_f \equiv Py_f - c_f(y_f)$, i.e., Z_f is the net payoff of an unhedged firm.

Investors also trade in the forward markets. Let $x_i = (x_{i1}, x_{i2}, \cdots, x_{iN})$ denote the forward market portfolio of investor i, where x_{ij} denotes the number of

[4] See proposition I in Green and Talmor [7].

[5] Note that the only source of uncertainty, as in the earlier models, is in the spot prices.

forward contracts for commodity j purchased by investor i. The investor's payoff on this portfolio is

$$x_i(P - v) = \sum_j x_{ij}(P_j - v_j).$$

In equilibrium, demand must equal supply in the forward markets, or, equivalently,

$$\sum_f x_{fj} = \sum_i x_{ij}.$$

In addition to the forward markets, investors trade in the stock and bond markets. In the bond market, traders transfer promises to pay fixed amounts at the end of the period. Suppose that all bond commitments are met so that there is no bankruptcy.[6] Then we define one bond contract as a promise to pay $(1 + r)$ dollars at the end of the period. In the stock market, traders transfer fractional shares of the firm. If firm f has a bond issue of B_f dollars, then the return to all equity holders is $\Pi_f - (1 + r)B_f$.

The investor must select a portfolio in the bond and stock markets as well as in the forward markets. Let b_i denote the dollar amount investor i places in bonds or, equivalently, the number of bond contracts purchased/sold, and let s_{if} denote the dollar amount investor i spends on equity in firm f. In equilibrium,

$$S_f = \sum_i s_{if},$$

where S_f is the stock market value of firm f. The fraction of the firm owned by investor i is s_{if}/S_f, and the random payoff from the investment is

$$\frac{s_{if}}{S_f}[\Pi_f - (1 + r)B_f].$$

Then the investor's portfolio in the bond and stock markets is the pair (b_i, s_i), where $s_i = (s_{i1}, \cdots, s_{iF})$ is the stock portfolio.

Given the portfolio (b_i, s_i) in the bond and stock markets and the portfolio x_i in the forward markets, it is possible to define end-of-period wealth for investor i as

$$(1 + r)b_i + \sum_f \frac{s_{if}}{S_f}[\Pi_f - (1 + r)B_f] + \sum_j x_{ij}(P_j - v_j).$$

Of course, the individual investor faces the budget constraint

$$b_i + \sum_f s_{if} = k_i.$$

The budget constraint says that the value of the investor's bond and stock purchases must equal the investor's wealth k_i. Using the budget constraint to eliminate b_i, the investor's end-of-period wealth may be expressed as

$$W_i = (1 + r)k_i + \sum_f s_{if}(R_f - r) + \sum_j x_{ij}(P_j - v_j),$$

[6] Introducing costless bankruptcy would complicate the analysis, but it would not change the results in this section. Introducing costly bankruptcy would change the analysis here because then it would be possible for the firm to hedge the bankruptcy risk and so reduce the bankruptcy cost. See Smith and Stulz [14] for a discussion of this type of hedging policy.

where

$$1 + R_f = \frac{\Pi_f - (1 + r)B_f}{S_f},$$

and R_f is the firm's random rate of return on equity. Finally, let G_i denote the investor's subjective distribution function for the spot prices, and let S be the support of the distribution. Then the investor selects the pair of portfolios (s_i, x_i) to

$$\text{maximize} \int_S u_i(W_i)\, dG_i.$$

The conditions for a maximum take the following form:

$$\int_S Du_i(W_i)[R_f - r]\, dG_i = 0, \quad f = 1, 2, \cdots, F; \tag{1}$$

$$\int_S Du_i(W_i)(P_j - v_j)\, dG_i = 0, \quad j = 1, 2, \cdots, N, \tag{2}$$

where Du_i is the derivative of the utility function u_i. Letting $V_f = S_f + B_f$ denote the value of the firm and rearranging (1), we may note that the value of firm f is

$$V_f = \frac{\int_S Du_i(W_i)\Pi_f\, dG_i}{(1 + r)\int_S Du_i(W_i)\, dG_i} = \frac{1}{(1 + r)}\left[\mathrm{E}_i\Pi_f - \frac{-\mathrm{cov}_i(Du_i, \Pi_f)}{\mathrm{E}_i Du_i}\right].^7 \tag{3}$$

Hence, the value of the firm f is the present value of the firm's expected earnings minus a marginal risk premium. The right-hand side of (3) depends on the probability and risk-aversion measures of the investor; in equilibrium, all investors will adjust their portfolios (s_i, x_i) so that the equality holds.

Notice that the random firm earnings Π_f in (3) include the payoff from its operations in the spot and forward markets. Since investors may also participate in the forward markets, it should follow that any forward market position (e.g., the complete hedge $y_f = x_f$) may be duplicated or reversed by any investor. Hence, we should obtain an irrelevance result like the 1958 Modigliani-Miller capital-structure irrelevance result. Recall that Modigliani and Miller showed that the value of the levered firm equals the value of the unlevered firm. Of course, the Modigliani-Miller theorem obviously holds here due to (3). In addition, we have a simple extension of the theorem that says that the value of the hedged firm equals the value of the unhedged firm.[8]

PROPOSITION 1: *Let V_f^H denote the value of the hedged firm and V_f^U denote the value of the unhedged firm. In equilibrium, $V_f^H = V_f^U$.*

[7] To streamline the notation, the derivative of the utility function will be denoted as Du_i rather than $Du_i(W_i)$. The same convention will be adopted for other derivatives and partial derivatives; e.g., $D_j c_f(y_f)$ is the partial derivative of the cost function c_f with respect to the output y_{fj} and will be denoted by $D_j c_f$.

[8] The firm is hedged if it selects $x_f \neq 0$ and unhedged if it selects $x_f = 0$.

Proof: Note that (3) may be rewritten as

$$V_f^H = \frac{\int Du_i Z_f \, dG_i + \int Du_i[(v - P)x_f] \, dG_i}{(1 + r) \int Du_i \, dG_i}. \tag{4}$$

This expression for the value of the firm simply says that the value of the firm is equal to the present value of the firm's unhedged production portfolio plus the net present value of the firm's hedge portfolio. However, by (2),

$$\int Du_i[(v - P)x_f] \, dG_i = \textstyle\sum_j x_{fj} \displaystyle\int Du_i[v_j - P_j] \, dG_i = 0,$$

and, so,

$$V_f^H = \frac{\int Du_i Z_f \, dG_i}{(1 + r) \int Du_i \, dG_i} = V_f^U. \tag{5}$$

Q.E.D.

Propostion 1 says that the value of the hedged firm equals the value of the unhedged firm because the net present value of the hedge portfolio is zero. If the firm is viewed as a set of financial contracts, then a generalization of the 1958 MM theorem would say that the composition of the contract set is irrelevant. Proposition 1 is part of this generalization.

Another characterization of the firm value is possible. Since marginal risk premiums are already contained in forward prices, it is possible to express the value of the firm in deterministic form.

COROLLARY 1: $$V_f = \frac{v y_f - c_f(y_f)}{(1 + r)}.$$

Proof: Rewriting (5), using the first-order condition (2), we obtain

$$\begin{aligned} V_f &= \frac{\int Du_i Z_f \, dG_i}{(1 + r) \int Du_i \, dG_i} \\ &= \frac{\int Du_i P y_f \, dG_i}{(1 + r) \int Du_i \, dG_i} - \frac{c_f(y_f)}{(1 + r)} \\ &= \frac{\sum_j \int Du_i P_j y_{fj} \, dG_i}{(1 + r) \int Du_i \, dG_i} - \frac{c_f(y_f)}{(1 + r)} \\ &= \frac{\sum_j v_j y_{fj} - c_f(y_f)}{(1 + r)} \\ &= \frac{v y_f - c_f(y_f)}{(1 + r)}. \end{aligned} \tag{6}$$

Q.E.D.

Thus, the presence of forward markets in the stock market economy allows a particularly simple characterization of firm value as the present value of the quasi-rent accruing to capital.[9]

II. Separation

Now consider the decision problem of the manager of a publicly held and traded corporation. Suppose that manager i of corporation f selects the production vector y_f for the corporation and the portfolio pair (s_i, x_i) on personal account to maximize expected utility. In the literature on competitive stock markets, it is well known that the manager has the incentive to select the production decision that maximizes the value of the corporation.[10] In the literature on forward markets, it is well known that the manager has the incentive to make the production decision such that forward price equals marginal cost.[11] Neither literature incorporates both forward markets and stock markets. Both literatures provide simple separation theorems. Corollary 1 provides a link between the two literatures and the two separation theorems since it shows that maximizing value is consistent with selecting the production level such that forward price equals marginal cost. If value maximization were the unanimously supported corporate objective in a competitive financial market economy characterized by forward markets as well as stock and bond markets, then Corollary 1 would suffice to show that the forward market separation theorem also holds. In view of the separation results available in both literatures, it would be surprising if a separation result could not be established in a financial market economy that included forward markets. However, in this section, we show that the manager does not have an unambiguous incentive to maximize corporate value. Then we show that a compensation scheme can be designed for the manager that will provide an unambiguous incentive for the manager to maximize corporate value.

We extend the modeling of the financial market economy by introducing a set of forward markets. We assume that the firm is managed by an investor who holds a positive fraction of the firm. Then, by Corollary 1, it follows that the manager maximizes firm value if and only if the production levels are set such that forward price equals marginal cost for all commodities produced. However, it does not follow that these production levels provide a unique maximum for the manager's expected utility function, as one might expect. Without the forward

[9] An alternative derivation of firm value is possible. Recall that the random variable $Z_f = Py_f - c_f(y_f)$, and so, Z_f is equivalent to the random variable $Px_i^0 - vx_i^0 + (1+r)b_i^0$, where $x_i^0 = y_f$ and b_i^0 is selected so that $vy_f - (1+r)b_i^0 = c_f(y_f)$ or, equivalently, $b_i^0 = [vy_f - c_f(y_f)]/(1+r)$. The value of the portfolio $(b_i^0, x_i^0) = ([vy_f - c_f(y_f)]/(1+r), y_f)$ is

$$\frac{\int_S Du_i[P - v]y_f + [v\, y_f - c_f(y_f)]\, dG_i}{(1+r)\int_S Du_i\, dG_i},$$

and, using (2), this reduces to $[v\, y_f - c_f(y_f)]/(1+r)$. Therefore, the firm's payoff may be duplicated with a portfolio of forward contracts and bonds, and it follows that the value of the firm is equivalent to the value of this portfolio; i.e., $V_f = [v\, y_f - c_f(y_f)]/(1+r)$.

[10] See Leland's Unanimity Theorem in [9]. Also see [10] and [11].

[11] See [6] and [8].

markets, the manager's payoff, i.e., end-of-period wealth distribution, is directly linked to the production choice, and, so, the manager has the incentive to maximize the stock market value of the corporation. With the forward markets, the manager's payoff is not directly linked to the production choice of the corporation. Suppose that the manager selects a production vector that is not optimal, i.e., does not maximize stock value. Then the manager may mimic the payoff distribution that is optimal given an optimal production decision by altering his or her portfolio choice (s_i, x_i) in the stock and forward markets.

To consider the manager's choice problem, let $S_f(y_f)$ be a differentiable function of the production vector y_f and let $s_i(S_f) = (s_{i1}(S_f), s_{i2}(S_f)\cdots, s_{iF}(S_f))$ and $x_i(S_f) = (x_{i1}(S_f), x_{i2}(S_f), \cdots, x_{iN}(S_f))$ be differentiable functions of S_f. The condition that $S_f(y_f)$ is a differentiable function of the production vector y_f is necessary to ensure that the corporation can value its production plan and any change in the plan. The corporation's ability to value alternative production plans is demonstrated in equation (6) or, equivalently, in footnote 4. The conditions that s_i and x_i are differentiable functions of S_f are equivalent to the conditions that the stock and forward contract demand functions are differentiable. Now, in addition to selecting the portfolios (s_i, x_i), the manager of firm h selects the production vector y_h to maximize expected utility. The following proposition shows that the production choice is a matter of indifference to the firm manager.

PROPOSITION 2: *The production vector that satisfies the conditions $v_j = D_j c_h, j \in J_h$, does not yield a unique maximum for the manager's expected utility function.*

Proof: In addition to the first-order conditions (1) and (2), the firm manager has the first-order conditions for the outputs y_{hj}, stated in (7).

$$\sum_f Ds_{if} D_j S_h \int_S Du_i[R_f - r]\, dG_i - \frac{s_{ih}}{S_h} D_j S_h \int_S Du_i[1 + R_h]\, dG_i$$
$$+ \frac{s_{ih}}{S_h} \int_S Du_i[P_j - D_j c_h]\, dG_i + \sum_j Dx_{ij} D_j S_h \int_S Du_i[P_j - v_j]\, dG_i = 0,\text{[12]} \qquad (7)$$

for $j \in J_h$, where J_h is the set of commodities produced by firm h, $D_j S_h$ and $D_j c_h$ are partial derivatives of S_h and c_h with respect to y_{hj}, and Ds_{if} and Dx_{ij} are the derivatives of s_{if} and x_{ij} with respect to S_h. The first and fourth terms on the left-hand side of (7) are zero by conditions (1) and (2), respectively. Therefore, condition (7) may be rewritten as

$$-\frac{s_{ih}}{S_h} D_j S_h \int_S Du_i[1 + R_h]\, dG_i + \frac{s_{ih}}{S_h} \int_S Du_i[P_j - D_j c_h]\, dG_i = 0. \qquad (8)$$

Note that the second term on the left-hand side of (8) may be rewritten, using

[12] To see this, note that the partial of W_i with respect to y_{hj} is

$$D_j W_i = \sum_f Ds_{if} D_j S_h[R_f - r] + s_{ih} D_j R_h + \sum_j Dx_{ij} D_j S_h[P_j - v_j],$$

where

$$D_j R_h = \frac{S_h(P_j - D_j c_h) - (\Pi_h - (1 + r)B_h) D_j S_h}{S_h^2}.$$

(2), as

$$\frac{s_{ih}}{S_h}\int_S Du_i[P_j - D_j c_h]\, dG_i = \frac{s_{ih}}{S_h}(v_j - D_j c_h)\int_S Du_i\, dG_i.^{13} \tag{9}$$

Finally, using $D_j V_h = D_j S_h = (v_j - D_j c_h)/(1 + r)$ and (9), (8) may be equivalently expressed as

$$-\frac{s_{ih}}{S_h}\frac{1}{(1+r)}(v_j - D_j c_h)\left[\int_S Du_i[1 + R_h]\, dG_i - (1+r)\int_S Du_i\, dG_i\right]$$

$$= -\frac{s_{ih}}{S_h}\frac{1}{(1+r)}(v_j - D_j c_h)\left[\int_S Du_i[R_h - r]\, dG_i\right] = 0. \tag{10}$$

Since this equality holds for all y_{hj}, we have stated the result. Q.E.D.

Note that selecting the output vector y_h so that forward price equals marginal cost for all commodities will maximize the stock market value of firm h. Also note that it is a sufficient condition for expected utility maximization. However, $v_j = D_j c_h$ is not a necessary condition for expected utility maximization since the last term on the left-hand side of (10) is zero by (2). Since (10) is zero for all production choices, we have the result that, acting in his or her own interests, the manager of the firm will be indifferent between the output vectors available to the firm. This is obviously not the Feder, Just, and Schmitz separation result and so is somewhat surprising. However, note that the link between the manager's payoff distribution and his or her production decision is broken in a financial market economy with forward markets. To see this in its simplest setting, suppose that corporation h is an unlevered single-product firm producing commodity k and suppose that y^0_{hk} is the production level that maximizes the stock market value of the corporation. Let (s^0_i, x^0_i) be the manager's optimal portfolio pair given the production decision y^0_{hk}. Let W^0_i be the manager's payoff given the production decision y^0_{hk} and the portfolio choice (s^0_i, x^0_i). Note that the manager's payoff on the stock of corporation h is

$$s^0_{ih}[(1 + R^0_h) - (1 + r)] = \frac{s^0_{ih}}{S^0_h}[(P_k y^0_{hk} - c_h(y^0_{hk})) - S^0_h(1 + r)].$$

By Corollary 1, $S^0_h = (v_k y^0_{hk} - c_h(y^0_{hk}))/(1 + r)$, and, so, the payoff on the stock of corporation h reduces to

$$\frac{s^0_{ih}}{S^0_h} y^0_{hk}(P_k - v_k).$$

The combined payoff on the manager's stock and forward market investments in corporation h is

$$\left[\frac{s^0_{ih}}{S^0_h} y^0_{hk} + x^0_{ik}\right](P_k - v_k).$$

[13] This follows by noting that (2) may be equivalently stated as

$$v_j = \frac{\int_S Du_i P_j\, dG_i}{\int_S Du_i\, dG_i}.$$

Now suppose that the manager selects another production level $y_{hk}^1 \neq y_{hk}^0$ and a portfolio pair (s_i^1, x_i^1). Suppose that $s_i^1 = s_i^0$ and that $x_{ij}^1 = x_{ij}^0$ for $j \neq k$. Then note that, for a given stock investment s_{ih}^1, if the manager selects

$$x_{ik}^1 = x_{ik}^0 + \frac{s_{ih}^0}{S_h^0} y_{hk}^0 - \frac{s_{ih}^1}{S_h^1} y_{hk}^1,$$

then his or her combined payoff is the same. Equivalently, letting W_i^1 be the payoff distribution given the production choice y_{hk}^1 and the portfolio pair (s_i^1, x_i^1), we obtain the result $W_i^1 = W_i^0$, which simply says that the manager may maintain the same payoff distribution despite a different production choice.

With just a fractional ownership interest in the firm, the manager does not have an unambiguous incentive to maximize the value of the firm. However, it is possible to provide the manager with a compensation package that does give him or her the incentive to maximize value. The compensation scheme must irreversibly link the manager's earnings with the corporate earnings. To provide this link, suppose that the manager has a stock option as part of his or her compensation package. In particular, suppose that the manager can purchase a fixed number of shares at the end of the period if the share price of the firm is at least as great as the option's exercise price. This may not only give the manager an incentive to maximize the value of the firm but may also make the firm's hedging decision relevant to the manager; of course, the corporate hedge is still a matter of indifference to the market.

For simplicity, consider an unlevered firm h. Let N_h be the number of shares of firm-h stock. Suppose that the manager can purchase n_{ih} shares of firm h at the end of the period if the share price $p_h = \Pi_h/N_h$ exceeds price $e_h = E_h/N_h$ and zero shares otherwise. Then the option takes the following form:

$$n_{ih}\max\{0, p_h - e_h] = \frac{n_{ih}}{N_h}\max\{0, \Pi_h - E_h\}.$$

Note that the option will not alter the manager's budget constraint. Rather, it will simply result in a respecification of the manager's end-of-period wealth, denoted by W_i^c, i.e.,

$$W_i^c = (1 + r)k_i + \textstyle\sum_f s_{if}(R_f^c - r) + \sum_j x_{ij}(P_j - v_j) + \alpha_{ih}\max\{0, \Pi_h - E_h\}, \tag{11}$$

where $\alpha_{ih} \equiv n_{ih}/N_h$. It should also be noted that the stock option changes the random rate of return on equity and, so, the stock market value of firm h. The random rate of return on equity is now

$$1 + R_h^c = \frac{(\Pi_h - \alpha_{ih}\max\{0, \Pi_h - E_h\})}{S_h^c},$$

where S_h^c is the stock market value of the firm with the stock (equivalently, call) option. Similarly, let S_h^n denote the stock market value of the firm with no call option. Using a Modigliani-Miller type argument, the total value of the firm should not be affected by the composition of the contract set. Letting C_h denote the market value of the call option, we should find that the stock market value of the firm with no call option is equal to the value of the firm with a call option plus the value of the call option, i.e., $S_h^n = S_h^c + C_h$. This result is demonstrated in the following lemma.

LEMMA 1: $S_h^n = S_h^c + C_h$.

Proof: Using (1), note that

$$\int_S Du_i R_h^c \, dG_i = r \int_S Du_i \, dG_i,$$

or, equivalently,

$$\frac{1}{S_h^c} \int_S Du_i [\Pi_h - \alpha_{ih} \max\{0, \Pi_h - E_h\}] \, dG_i = (1 + r) \int_S Du_i \, dG_i.$$

Therefore,

$$S_h^c = \frac{\int_S Du_i \Pi_h \, dG_i}{(1 + r) \int_S Du_i \, dG_i} - \alpha_{ih} \frac{(\int_S Du_i \max\{0, \Pi_h - E_h\} \, dG_i)}{(1 + r) \int_S Du_i \, dG_i} = S_h^n - C_h.$$

Q.E.D.

The stock option does provide a direct link between corporate earnings and the manager's end-of-period wealth. Despite the fact that the option changes the rate of return on equity and the stock market value of the firm, the stock option unambiguously improves the welfare of the manager of the publicly held and traded corporation. The linkage between the corporate payoff and end-of-period wealth is sufficient to motivate the manager to maximize stock market value, as the following proposition shows.

PROPOSITION 3: *Suppose that the manager of firm h has a stock option with an exercise price sufficiently small so that* $\max\{0, \Pi_h - E_h\} = \Pi_h - E_h$; *then the manager's optimal production decision satisfies the conditions* $v_j = D_j c_h$ *for all* $j \in J_h$.

Proof: The manager selects the output levels y_{hj} for firm h in order to maximize expected utility. The manager's end-of-period wealth is stated in (11). Partially differentiating the manager's expected utility with respect to y_{hj} yields the following condition for a maximum:

$$\begin{aligned} &\textstyle\sum_f Ds_{if} D_j S_h^c \int_S Du_i [R_f^c - r] \, dG_i - \frac{s_{ih}}{S_h^c} D_j S_h^c \int_S Du_i [1 + R_h^c] \, dG_i \\ &\qquad + \frac{s_{ih}}{S_h^c} \int_S Du_i [P_j - D_j c_h] - \frac{s_{ih}}{S_h^c} \alpha_{ih} \int_S Du_i [P_j - D_j c_h] \, dG_i \\ &+ \textstyle\sum_j Dx_{ij} D_j S_h^c \int_S Du_i [P_j - v_j] \, dG_i + \alpha_{ih} \int_S Du_i [P_j - D_j c_h] \, dG_i = 0.^{14} \end{aligned} \tag{12}$$

[14] To see this, note that the partial of W_i^c with respect to y_{hj} is

$$D_j W_i = \textstyle\sum_f Ds_{if} D_j S_h^c [R_f^c - r] + s_{ih} D_j R_h^c + \sum_j Dx_{ij} D_j S_h^c [P_j - v_j] + \alpha_{ih} (P_j - D_j c_h),$$

By conditions (1) and (2), (12) reduces to

$$-\frac{s_{ih}}{S_h^c} D_j S_h^c \int_S Du_i[1 + R_h^c]\, dG_i + \frac{s_{ih}}{S_h^c} \int_S Du_i[P_j - D_j c_h]\, dG_i + \alpha_{ih}\left(1 - \frac{s_{ih}}{S_h^c}\right) \int_S Du_i[P_j - D_j c_h]\, dG_i = 0. \tag{13}$$

By Lemma 1 and Proposition 2, $D_j S_h^c = D_j S_h^n - D_j C_h = [(v_j - D_j c_h)/(1 + r)] - D_j C_h$. By hypothesis, $\max\{0, \Pi_h - E_h\} = \Pi_h - E_h$, and, so, $C_h = \alpha_{ih} S_h^n - \alpha_{ih} E_h/(1 + r)$. It follows that $D_j S_h^c = (1 - \alpha_{ih})(v_j - D_j c_h)/(1 + r)$. Therefore, using Lemma 1, Proposition 2, and condition (2), we may express (13) equivalently as

$$\begin{aligned}
&-\frac{s_{ih}}{S_h^c}(1 - \alpha_{ih}) \frac{V_j - D_j c_h}{1 + r} \int_S Du_i[1 + R_h^c]\, dG_i \\
&\qquad + \frac{s_{ih}}{S_h^c}(v_j - D_j c_h) \int_S Du_i\, dG_i + \alpha_{ih}\left(1 - \frac{s_{ih}}{S_h^c}\right)(v_j - D_j c_h) \int_S Du_i\, dG_i \\
&= -\frac{s_{ih}}{S_h^c} \frac{v_j - D_j c_h}{1 + r} \int_S Du_i[R_h^c - r]\, dG_i + \alpha_{ih} \frac{s_{ih}}{S_h^c} \frac{v_j - D_j c_h}{1 + r} \int_S Du_i[1 + R_h^c]\, dG_i \\
&\qquad + \alpha_{ih}(v_j - D_j c_h) \int_S Du_i\, dG_i - \alpha_{ih} \frac{s_{ih}}{S_h^c}(v_j - D_j c_h) \int_S Du_i\, dG_i \\
&= \alpha_{ih} \frac{s_{ih}}{S_h^c} \frac{v_j - D_j c_h}{1 + r} \int_S Du_i[R_h^c - r]\, dG_i + \alpha_{ih}(v_j - D_j c_h) \int_S Du_i\, dG_i \\
&= \alpha_{ih}(v_j - D_j c_h) \int_S Du_i\, dG_i = 0.
\end{aligned}$$

Therefore, the partial derivative is zero if and only if $v_j = D_j c_h$. Q.E.D.

It should be noted that the optimal production choice of the manager is also the production choice that maximizes the firm's stock market value; i.e., $v_j = D_j c_h$ if and only if $D_j S_h^c = (1 - \alpha_{ih}) D_j S_h^n = 0$. Therefore, this stock option package gives the manager the incentive to maximize the stock market value of the firm. The stock option also provides a separation result similar to the FJS result. However, the result does not follow due to risk aversion as it does in the FJS analysis. Recall that, in the FJS analysis, the risk-averse manager makes a production decision and a hedging decision; the forward market allows the manager to determine the risk that he or she will retain and so also allows him or her to separate the production decision from the retained-risk decision. Here, the manager is indifferent to any corporate hedge, and the manager selects the production levels to maximize the stock option payoff, i.e., the y_{hj} such that $D_j C_h = 0$.

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where

$$D_j R_h^c = \frac{S_h^c(P_j - D_j c_h - \alpha_{ih}(P_j - D_j c_h)) - (\Pi_h - \alpha_{ih}(\Pi_h - E_h)) D_j S_h^c}{(S_h^c)^2}.$$

Having shown that a compensation scheme can be developed that motivates the manager to maximize the stock market value of the firm, we want to consider what effect taxes have on the value of the firm and how this value may be altered by hedging on the corporate account.

III. Taxes, Depreciation, and Tax Credits

In this section, we introduce an extended treatment of corporate taxes and tax credits to see whether the irrelevance results of the previous sections remain intact. To simplify the analysis and concentrate attention on the firm's hedging decision, we first consider the case of an unlevered firm and then consider the case of a levered firm with a safe debt issue. Let the firm have Δ_f dollars in tax deductions resulting from noncash charges such as accounting depreciation and a maximum of Γ_f dollars in tax credits available. Recall that $\Pi_f = Py_f + (v - P)x_f - c_f(y_f)$ is the before-tax return to equity for the unlevered firm. Now, max $\{0, \Pi_f - \Delta_f\}$ is the firm's taxable income. Using the maximum function allows us to note that, if the depreciation charges are sufficiently large relative to the firm's earnings, then taxable income is zero. Letting t denote the corporate tax rate, we obtain $T_f = t \max\{0, \Pi_f - \Delta_f\}$ as the total random corporate tax liability. The value of the firm's utilized tax credits is $\min\{\gamma T_f, \Gamma_f\}$. This result is due to a statutory ceiling limiting usable credits to a fraction γ of the gross tax liability.[15]

In a similar tax environment, Green and Talmor [7] have recently shown that the structure of the tax liabilities has an effect on the scale of investment in the various projects selected by a value-maximizing firm. In particular, they showed that, if the firm is investing in two projects and one of the projects is riskier than the other in the Rothschild-Stiglitz sense, then the firm has the incentive to underinvest in the riskier project. They showed that strict underinvestment in the riskier project holds if the firm cannot capture its interest and depreciation deductions with certainty; in the notation here, this statement is equivalent to $P\{\Pi_f > \Delta_f\} < 1$.[16] Intuitively, this result follows because, by investing more in the safer project relative to the riskier project, the firm can increase its earnings in those states in which it pays no tax and reduce its tax liability in those states in which it does pay taxes. Of course, in the Green-Talmor analysis, there is no mechanism available to protect the firm's depreciation deductions, other than the aggregate investment level.

In this section, we show that the forward contract is a useful financial instrument in the sense that it provides the corporation with a means of protecting its depreciation deductions. We show that it is possible for the corporation to select a hedge portfolio so that $P\{\Pi_f > \Delta_f\} = 1$ and so eliminate the underinvestment incentive demonstrated by Green and Talmor. However, the feasibility of such a hedge portfolio does not guarantee its optimality. Therefore, we go on to demonstrate that such a hedge portfolio will increase the value of the firm.

Since Green and Talmor did not include tax credits in their analysis, the first

[15] See DeAngelo and Masulis [3] for a similar treatment of depreciation charges and investment tax credits.

[16] See proposition I in [7].

case that we consider here is one in which $\Delta_f > 0$ and $\Gamma_f = 0$. This will allow us to consider what impact the depreciation charges have on the hedging and production decisions of the firm. Note that $\max\{0, \Pi_f - \Delta_f\} = \max\{\Delta_f, \Pi_f\} - \Delta_f$ and that, for sufficiently small spot prices, the firm will not be taxed. However, the firm may alter its hedging position x_f. By increasing its hedge in commodity j, the firm will increase its tax liability relative to the fully hedged position for small p_j and reduce its tax liability relative to the fully hedged position for large p_j. This is shown in Figure 1, where $Z_f - \Delta_f$ is the taxable income of the unhedged firm and $\Pi_f - \Delta_f$ is the taxable income of the hedged firm. Note that, if $v\,y_f - c_f(y_f) > \Delta_f$, then it is possible for the firm to select a hedging portfolio such that $\Pi_f > \Delta_f$ for all spot prices; of course, such a hedging portfolio will yield a positive corporate tax in all states, but it will also yield full use of the depreciation charges.

Let S_f^U and S_f^H denote the stock market values of the unhedged and hedged firms, respectively. The following proposition shows that the firm may increase value by hedging to protect its depreciation deductions.

PROPOSITION 4: *Suppose that $\Delta_f > 0$, $\Gamma_f = 0$, and that $v\,y_f - c_f(y_f) > \Delta_f$. Then $S_f^H > S_f^U$.*

Proof: Let the hedged firm select a hedge portfolio such that its tax liability is $T_f = t\max\{0, \Pi_f - \Delta_f\} = t(\Pi_f - \Delta_f)$. Then the stock market value of the hedged firm is

$$\begin{aligned} S_f^H &= \frac{\int Du_i[\Pi_f - T_f]\,dG_i}{(1+r)\int Du_i\,dG_i} \\ &= \frac{\int Du_i(1-t)\Pi_f\,dG_i}{(1+r)\int Du_i\,dG_i} + \frac{t\Delta_f}{(1+r)} \\ &= \frac{\int Du_i(1-t)Z_f\,dG_i}{(1+r)\int Du_i\,dG_i} + \frac{t\Delta_f}{(1+r)}. \end{aligned}$$

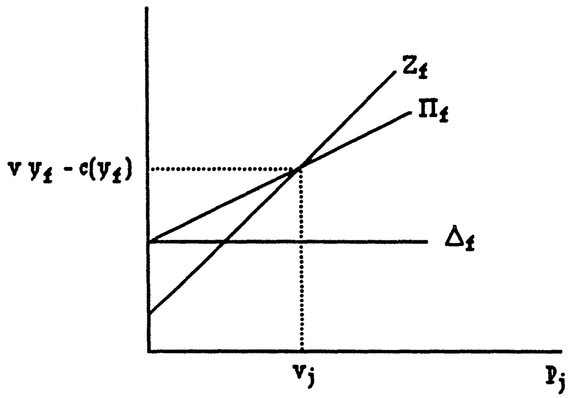

Figure 1. Hedged and Unhedged Firm Payoffs

The second equality here follows by recalling that the net present value of the hedge portfolio is zero.

Similarly, letting E denote the event $\{p \mid Z_f < \Delta_f\}$, the stock market value of the unhedged firm is

$$S_f^U = \frac{\int_S Du_i[Z_f - T_f]\, dG_i}{(1 + r) \int_S Du_i\, dG_i}$$

$$= \frac{(\int_S Du_i[Z_f - t \max\{\Delta_f, Z_f\} + t\Delta_f]\, dG_i)}{(1 + r) \int_S Du_i\, dG_i}$$

$$= \frac{\int_E Du_i[Z_f - t\Delta_f]\, dG_i}{(1 + r) \int_S Du_i\, dG_i}$$

$$+ \frac{\int_{S-E} Du_i(1 - t)Z_f\, dG_i}{(1 + r) \int_S Du_i\, dG_i} + \frac{t\Delta_f}{(1 + r)}.$$

Since $Z_f - t\Delta_f < Z_f - tZ_f$ on E, it follows that $S_f^U < S_f^H$. Q.E.D.

Without taxes, the net present value of the firm's hedge portfolio is zero, but, with them, the hedge portfolio allows the firm to fully utilize its depreciation charges and so increase value over that of the unhedged firm. Alternatively, the hedge increases the cash flow to investors in those states such that all depreciation charges are lost by an unhedged firm because the taxes paid in the event E by the hedged firm are less than the value of the tax shelter that is lost by the unhedged firm. Therefore, hedging is value increasing.

It also follows that the hedged firm will not have the incentive, found by Green and Talmor, to underproduce the riskier commodities. To see this, simply note that the stock market value of the hedged firm is

$$S_f^H = \frac{(1 - t)(vy_f - c_f(y_f))}{(1 + r)} + \frac{t\Delta_f}{(1 + r)},$$

and, so, the conditions for an optimal production decision take the following form:

$$\frac{(1 - t)(v_j - D_j c_f)}{(1 + r)} = 0, \quad j \in J_f,$$

or, equivalently,

$$\frac{v_j}{v_k} = \frac{D_j c_f}{D_k c_f} j, \quad k \in J_f.$$

Therefore, neither the relative nor the absolute scale at which the hedged firm produces is affected by the tax.

It is a simple matter to extend the results in Proposition 4 by allowing the firm to have safe debt. In this case, the taxable income of the firm is $T_f = \max\{0, \Pi_f - rB_f - \Delta_f\}$. The firm may hedge to preserve its interest deductions as well as its depreciation charges. The following corollary shows that the value of the hedged firm exceeds the value of the unhedged firm, and it follows immediately from Proposition 4.

COROLLARY 2: *Suppose that* $\Delta_f > 0$, $\Gamma_f = 0$, *and that* $v\, y_f - c_f(y_f) > rB_f + \Delta_f$. *Then* $V_f^H > V_f^U$.

The value of the firm with a hedge such that $T_f = t(\Pi_f - rB_f - \Delta_f)$ is

$$V_f^H = \frac{\int Du_i(1-t)Z_f\, dG_i}{(1+r)\int Du_i\, dG_i} + \frac{t(r\,B_f - \Delta_f)}{(1+r)}$$

$$= \frac{(1-t)(vy_f - c_f(y_f))}{(1+r)} + \frac{t(r\,B_f - \Delta_f)}{(1+r)}. \tag{13}$$

The result in (13) is analogous to the 1963 Modigliani-Miller result since it is apparent that the firm can increase value by increasing the size of the debt issue. The difference here is that the firm maximizes value at a finite level. The line of reasoning is as follows. The firm selects the fully hedged position; this makes its tax liability certain. Then the firm increases its debt issue to the point at which this tax liability is eliminated, i.e., to the point at which $r\,B_f^* + \Delta_f = v\,y_f - c_f(y_f)$. Since the fully hedged firm's tax liability T_f is zero, by (13), its value is $V_f^H = (v\,y_f - c_f(y_f))/1 + r)$. No further increase in the debt issue will increase value. The firm's value function is shown in Figure 2.

Next, consider the case $\Delta_f > 0$, $\Gamma_f > 0$. DeAngelo and Masulis [3] considered the value of a levered firm in a similar tax environment.[17] By introducing the usable tax credits as the $\min\{\gamma T_f, \Gamma_f\}$, they showed that there is an opportunity cost associated with issuing debt. Issuing debt reduces the corporation's taxable earnings, and, so, although it creates a debt tax shelter, usable tax credits are eventually reduced; i.e., $\min\{\gamma T_f, \Gamma_f\} = \gamma T_f$ for sufficiently large debt issues. Therefore, the loss in usable tax credits associated with an increase in the debt issue is the opportunity cost. It is this opportunity cost that helps generate an upward-sloping supply of corporate debt in the bond market. Limiting the size of the corporate debt issue is the only mechanism available in the DeAngelo-Masulis analysis to protect usable tax credits. Here we show that forward contracts also provide a means of protecting tax credits.

Consider an unlevered firm. Notice that, if the spot price of commodity j produced by firm f is sufficiently small, then the firm's earnings and tax liability are so small that γT_f is less than Γ_f. Then not all of the available tax credits can be utilized. However, the firm may alter its hedging position x_{fj}. By increasing its hedge in commodity j, the firm will increase its tax liability relative to the fully hedged position for small p_j and reduce its tax liability relative to the fully hedged position for large p_j; equivalently, γT_f increases for $p_j < v_j$ and decreases for $p_j > v_j$. Recall that the fully hedged position is one in which x_{fj} is equal to y_{fj} for all j, and, so, in the fully hedged position, the firm's tax liability is $t(v\,y_f - c_f(y_f) - \Delta_f)$. It follows that, if

$$\gamma t(vy_f - c_f(y_f) - \Delta_f) > \Gamma_f$$

[17] In the DeAngelo and Masulis model, investors were taxed and had restrictions on short sales.

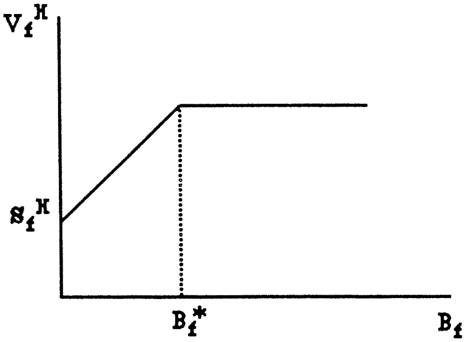

Figure 2. Debt and Hedged Firm Value

or, equivalently,

$$vy_f - c_f(y_f) > \Delta_f + \frac{\Gamma_f}{\gamma t},$$

then, by selecting an appropriate hedge, the firm can always ensure that $\min\{\gamma T_f, \Gamma_f\} = \Gamma_f$. Let x_f^0 and x_f^1 be the hedge portfolios corresponding to Π_f^0 and Π_f^1, respectively, as shown in Figure 3. The hedge portfolio x_f^0 is sufficient to protect the firm's depreciation charges, but it is not sufficient to fully protect the firm's tax credits. The hedge portfolio x_f^1 is sufficient to fully protect both. The following proposition shows that the firm can increase its stock market value by protecting its tax credits as well as its depreciation deductions; letting $S_f^{H_0}$ and $S_f^{H_1}$ denote the stock market values of the firm with hedge portfolios x_f^0 and x_f^1, respectively, this is equivalent to saying that $S_f^{H_1} > S_f^{H_0}$.

PROPOSITION 5: *Suppose that* $\Delta_f > 0$, $\Gamma_f > 0$, *and that* $v\, y_f - c_f(y_f) > \Delta_f + \dfrac{\Gamma_f}{\gamma t}$. *Then* $S_f^{H_1} > S_f^{H_0}$.

Proof: The return to equityholders given the hedge x_f^0 is $\Pi_f - T_f + \min\{\gamma T_f, \Gamma_f\}$ while the return to equityholders given the hedge x_f^1 is $\Pi_f - T_f + \Gamma_f$, where $T_f = t(\Pi_f - \Delta_f)$. Then

$$S_f^{H_0} = \frac{(\int_S Du_i[\Pi_f - T_f + \min\{\gamma T_f, \Gamma_f\}]\, dG_i)}{(1+r)\int_S Du_i\, dG_i}$$

$$= \frac{(\int_S Du_i(1+t)Z_f\, dG_i + \int_S Du_i \min\{\gamma T_f, \Gamma_f\}\, dG_i)}{(1+r)\int_S Du_i\, dG_i} + \frac{t\Delta_f}{(1+r)}$$

$$< \frac{\int_S Du_i(1-t)Z_f\, dG_i}{(1+r)\int_S Du_i\, dG_i} + \frac{\Gamma_f + t\Delta_f}{(1+r)}$$

$$= \frac{(1-t)[v\, y_f - c_f(y_f)] + t\Delta_f + \Gamma_f}{(1+r)}$$

$$= S_f^{H_1}. \quad \text{Q.E.D.}$$

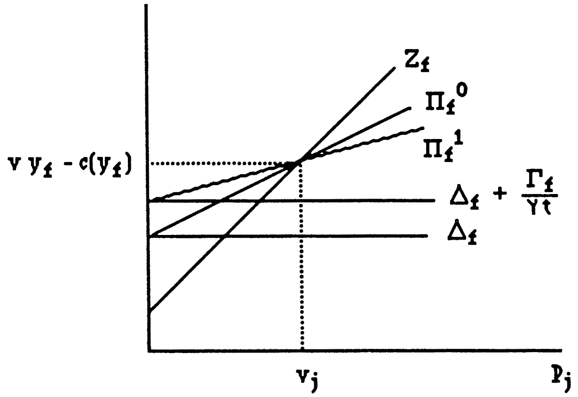

Figure 3. Hedging to Protect Tax Credits

Hence, we see that the stock market value of the firm is the present value of its after-tax earnings plus the present value of its tax shelters due to depreciation charges and tax credits.

It is clear, given the analysis in this section, that the irrelevance of the firm's forward market position does not continue to hold until the manager has provided a hedge that is sufficient to protect the firm's depreciation charges and tax credits; once a hedge is established that protects these charges and credits, any further change in the firm's position in the forward markets will have no effect on value.

IV. Concluding Remarks

In this paper, a financial market model is developed that incorporates forward markets as well as stock and bond markets. Unlike the earlier results in the forward market literature, it is shown here that, in a no-tax environment, the corporate hedge is irrelevant because individual investors can achieve the same results on personal account. Unlike the earlier results in the stock market literature, it is shown here that the corporate manager's production decision is irrelevant because the manager can alter his or her personal hedge portfolio to achieve any desired end-of-period payoff. When a stock option is constructed for the manager, it is shown that the separation results of both literatures hold and are equivalent.

In addition, it is shown that an optimal corporate hedge may exist in a tax environment. However, the motivation to hedge is not risk aversion; rather, the motivation is the protection of depreciation charges and/or tax credits. Hedging to protect depreciation charges or tax credits is not something that individual investors can duplicate on personal acocunt, and, so, the corporation is able to increase market value by hedging.

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