Should production and trading activities be separated?

by

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Abstract

Firms often supplement profits from production by trading in the item that they produce such as oil or electricity. We ask whether firms that use a commodity in production and also trade in that commodity should keep their production and trading activities together in one corporate entity, or divide them into separate entities. What is the connection between this choice and the capital structure decision? Results indicate that firms engaging in both production and trading of a commodity benefit from diversification, from flexibility in the allocation of capital that improves risk management, and from information spillovers between production and trading. Separation is preferred when trading revenues are risky, sensitive to contamination by losses in the production arm, and sensitive to the effects of leverage.

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Many commodity and energy companies and some manufacturing firms regularly engage in trading activities that go beyond the sphere of a firm's typical production operation. They trade through a separately capitalized entity, or through a unit within the firm. In the year 2004, for example, the in-house trading unit of British Petroleum reported it made $2 billion in pre-tax profits from the trading of oil, gas, and power, for 12.5% of BP's total profit in that year.[2] A few years earlier, in 2002, the treasury department at Ford Motor Company shocked Wall Street by announcing a $1 billion write-off of its stockpile of palladium that it had accumulated via the trading of financial contracts in anticipation of a supply hold up by Russia.[3] In 1996, Edison International incorporated a separate entity for its trading operations to participate in the emerging market in power-based products. Trading activities at these companies involves the matching of buyers and sellers (market making) as well as outright purchases and sales (speculation).

Trading is a unique activity under circumstances like this because the firm takes advantage of a core competence or an information advantage. A firm can monitor conditions in its particular production operations and quickly alter or enter and exit a trade. Trading also complements production activities in providing a way to make forward financial exposures and couple these with a portfolio of physical exposures, allowing flexibility and market completeness.

Trading within a firm can assume different roles. Trading can be a mere support function that helps to realize the returns of the production activity, but does not generate them. In this form, trading is a purely cash management activity and not a profit center. At the other extreme, the trading arm is essentially a financial institution, a pure-play profit center disconnected from the remainder of the firm's business. Between these two forms, trading is an activity closely tied to the firm's production activities that provides intelligence on prices, enabling the firm to optimize operations and generate the highest profit.

[2] British Petroleum's 2004 Annual Report.

[3] Reported by the Associated Press on January 16, 2002.

The taxonomy presented often obeys an intelligent design that explains why some firms adopt one form of organization of production and trading activities rather than another. We are interested in two questions. The first relates to organization, and the second to financing. First, under what conditions is it optimal to form separate entities for the production and trading activities of the firm or to integrate them under the same entity? Second, how does the choice of the organization (i.e., integration vs. separation) relate to the choice of financing of the activities of the firm?

Separation means that each unit is incorporated and run independently. A separate unit could be, for example, a fully owned subsidiary, where the parent firm has no recourse to its assets and cash flow, due to a legally enforceable agreement that protects debt holders and other stake holders of the subsidiary. Integration, on the other hand, means that trading is closely tied to the production business of the firm, and plays a multi-dimensional role that enables the firm to optimize its allocation of capital and generate the highest value condensed in a single profit function.

To answer our questions, we first address how the assets should be split between production operations and trading? Consider a firm that optimally decides to allocate a proportion x of its total capital (raised from debt plus equity) to trading activities, where $x \in [0,1]$, and the remainder $(1-x)$ to production.

Combining the trading and production operations changes the risk profile of the cash flows, and in turn determines the optimal amount of leverage in the firm. When the firm engages in trading, however, leverage has a second impact: a feedback effect on the optimal allocation of capital between trading and production. This occurs because trading activities require confidence by market participants about a firm's solvency: a higher debt-to-capital ratio results in less trading per unit of capital employed. Therefore, the optimal allocation and the optimal financing of production and trading activities of the firm must account for this feedback effect of leverage and be solved simultaneously and endogenously. The solution determines the optimal relative size of each activity. [4]

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[4] Leverage also affects production (Purnanandam (2008)), but in relative terms its effects are more severe to trading, since trading is driven by perceptions of financial strength.

The assumption in our model that a trading unit may not generate as much volume when its credit rating deteriorates means that trading requires a relatively debt-free or clean balance sheet to induce market participants to trade. The recent history of financial markets confirms that a firm that is primarily a speculator must show great prudence in the use of debt. Long-Term Capital Management in 1998, Enron in 2001, Refco in 2005, Amaranth in 2007, and Bear Stearns in 2008 are but a few examples. By its very nature, trading requires a firm to deal with numerous counterparties. Counterparties must be confident about the adequacy of a firm's capital, for they cannot closely monitor the trading positions of a firm, or they will require significant collateral for each and every trade they make with the firm. This would make trading activities very expensive, and tie up a great deal of capital. Market confidence is thus critical for a firm to be able to trade. Without confidence, counterparties will seek elsewhere to trade. Assuring market participants that trading is safe even though volatile requires a solid capital basis and limited debt. As we will show, if market participants require a strong balance sheet that is light on debt, it is preferable to separate the trading activities from production activities. This is because potential contamination of the balance sheet has a much stronger negative effect for a trading operation than for a production unit.

Our results indicate that a firm engaged in both production and trading has several advantages over firms that separate these two activities into independent corporate entities.

First, when cash flows from trading are combined with cash flows from production, there is less likelihood that a firm will go bankrupt, purely because of diversification that in turn may reduce overall volatility. This, however, is only part of the story and is limited to the proportion of capital tied up in trading at some relatively low threshold level. Beyond this threshold, the costs of higher risk overcome the benefits of diversification from trading. The benefits of risk reduction cannot be replicated by a portfolio of two stand-alone firms, a production firm and a trading firm, because of the frictions induced by bankruptcy. Here, the argument for integration results entirely from efficiency motives. [5]

A second advantage is flexibility in allocating capital between the two activities to improve risk management. Combining the cash flows from production and trading allows for an optimal state-contingent redeployment of capital between the two activities as their relative values change in a way that efficiently adjusts the risk of the overall entity, again reducing the likelihood of bankruptcy. In addition to the efficiency gains achieved from reducing the likelihood of incurring deadweight costs, there are ex-post bargaining inefficiencies that give the separated entities incentives to contract ex-ante, leading to integration when contracts are too complex, costly to monitor, hard to enforce. Coase (1937) and Williamson (1975) have long established that transaction costs of different kinds are a major determinant of organization design.

Third, that information can be shared between production and trading when the activities take place in the same firm helps to enhance firm value. In the words of an analyst commenting on the success of BP's trading activities:

> "They are able to make more money than hedge funds (pure traders) because they are exposed to the whole supply chain from well to wheel, and can take positions hedge funds cannot."

Open communication also helps prevent each unit from making mistakes (recall Ford's problem in 2002).[6] Information spillovers in our model work in a way similar to synergies arising from economies of scope, when these can be efficiently exploited only within the firm.

A fourth benefit of integration is that because the trading arm of an integrated firm has access to information and physical delivery options on the production side, it may be able to hedge or offer financial products not offered by purely financial firms. This "market completion" allows the trading part of the integrated firm to enhance firm value by gaining access to more trading and market making activity.

In related work, Leland (2007) examines the work of Robinson (1958) in a purely financial context, and concludes that mergers between diverse businesses reduce the risk of default. We have noted that such financial synergies are one positive outcome of integration.

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[5] This reason is closely related to the so-called *economies of massed reserves* argument presented first in Robinson (1958). Two units within the same firm together can sustain a proportionally less risky output, as long as they have imperfectly correlated operations.

[6] In the case of Ford and the palladium, the news about potential disruption in supply sources led the trading side of the business to increase its long positions while at the same time the production operation was devising methods to allow the company to significantly cut its use of the commodity.

In our setting, however, these synergies are arm's-length, while in Leland (2007) they result from the creation of conglomerates of diverse businesses (he focuses primarily on the financial aspects of mergers and ignores the production side). The implications that arise from the integration or separation of production and trading of a commodity are quite different from the implications for mergers of diverse businesses. In our setting, other motives for integration are equally important, such as risk management, contamination effects of leverage, and information spillovers.

We analyze these arguments in a continuous-time model of the firm. The continuous-time model permits a clear characterization of the outcomes with state and time dependent outcomes compared to a static model. It also yields a more realistic characterization of the benefits and the costs of integration versus separation, the allocation of capital between activities, the mix of debt and equity, and the impact of the model parameters on security prices.

The article is organized as follows: first we describe the assumptions of the model. In particular, we outline the process characterizing the value of the firm's assets. The firm is partly financed with debt so as to avail the tax benefits of debt. Next we determine the value of a trading firm and of its claims. Leverage affects the value of this firm in two ways: through the volume of trading, and through the likelihood of bankruptcy. We then analyze the benefits and the costs of keeping production and trading together versus separating them into two entities. We compute the optimal allocation of capital between the two activities kept within the same firm, and analyze the factors that are important in this choice. We discuss the role of private information in the decision to integrate production and trading or to separate them. At the end, we outline some empirical implications and summarize the main findings of the research.

I. The production firm

To assess whether production and trading activities should be separated, we need a model of a firm that engages in production and one that engages in trading. We specify first the dynamics of the production firm, and obtain the value of a firm that engages in production. After that we specify the dynamics of a firm that trades.

We use a continuous-time structural model because models of this type provide measures to answer the question about the extent of value creation resulting from a particular choice of organization of the firm, which is not easy to quantify in a static model.

Following other structural models of finance, we assume that the unleveraged value of the production firm, $V(t)$, that produces a single commodity follows a continuous diffusion process with constant proportional volatility under the objective probability measure:

$$\frac{dV(t)}{V(t)} = (\mu - \delta)dt + \sigma dz(t) \tag{1}$$

where μ is the total expected rate of return on $V(t)$, δ is the payout to claim-holders, σ is the volatility of firm assets, and *dz* is the increment of a standard Brownian motion. Assume there is a default-free asset that pays a constant interest rate *r*. The value process of the firm's assets is spanned by the economy and there is an equivalent risk-neutral measure under which that value process has a drift equal to the risk-free rate of interest. The process in equation (1) continues without limit unless the firm value falls to a default triggering value V_B. If there is no debt on the balance sheet, V_B is evidently zero. Let (1-α) where $0 < \alpha < 1$ is the fraction of the asset value V_B that debt holders receive in the event of bankruptcy (equity holders receive nothing).

We assume that equity holders seek to maximize the value of the equity when they make choices about: 1) the proportion of capital to allocate to trading and production activities; 2) whether to keep these activities under the same entity or separate them; and 3) the capital structure. When the firm integrates production and trading activities, there is a joint profit function and a single capital structure that funds both activities together. When the two activities are separate, each activity decides its own capital structure in view of its own value function, even if the residual owners are the same.

Given the firm value process in equation (1), it is possible to formulate the pricing functions for the value of a levered firm and its securities. If the equity owners of the firm sell debt to finance the firm, the value of the hedged and levered firm is given by the sum of the unlevered firm value $(V(0))$, plus the tax shield benefits and minus the costs of bankruptcy that accrue from carrying debt. Equity holders, who maximize firm value, now must pay debt holders a fixed coupon each year. We assume that debt is sold only once at time 0, and that it has infinite maturity and a constant coupon flow of C. It is assumed that the cash flow requirements for the coupon payments are met by selling additional equity. The firm value at which equity holders declare bankruptcy and stop paying coupons is given by V_B, and is endogenous. Leland (1998) obtains the value of debt as the present value of the promised future coupon flows, C, as long as the firm does not go bankrupt (as long as firm value remains above V_B), plus the cash flows that are paid out if the firm were to go bankrupt. Similarly, the firm value is the sum of the unlevered firm value plus the tax benefits and minus the bankruptcy costs. The equity holders are the residual claimants. The debt value, $D(V_0)$, and firm value, $F(V_0)$, for a levered firm in this setting is given by:

$$D(V_0) = \frac{C}{r}\left(1-\left[\frac{V_0}{V_B}\right]^{-X}\right) + (1-\alpha)V_B\left[\frac{V_0}{V_B}\right]^{-X} \tag{2}$$

$$F(V_0) = V_0 + \frac{\tau C}{r}\left[1-\left(\frac{V_0}{V_B}\right)^{-X}\right] - \alpha H_B\left[\frac{V_0}{V_B}\right]^{-X} \tag{3}$$

$$\text{where } X = a+b,\ a = \frac{r-\delta-\frac{\sigma^2}{2}}{\sigma^2},\ b = \sqrt{\frac{\left(a\sigma^2\right)^2 + 2r\sigma^2}{\sigma^2}},\ V_B = \frac{C(1-\tau)}{r-\delta+0.5\sigma_y^2} \tag{4}$$

The term $\left[\frac{V_0}{V_B}\right]^{-X}$ is related to the risk-neutral probability that the firm will go bankrupt. For example, the value of debt can be seen as approximately the present value of coupon flows $\frac{C}{r}$ times the probability that the firm is solvent, $\left(1-\left[\frac{V_0}{V_B}\right]^{-X}\right)$, plus the payoffs ($\alpha V_B$) if the firm goes bankrupt times the probability of going bankrupt. Similarly, the firm value is the unlevered firm value, V_0, plus the tax shield, $\frac{\tau C}{r}$, times the probability of receiving this tax shield benefit, and minus the bankruptcy cost, αV_B, times the probability of going bankrupt. Our analysis assumes that the coupon level (or the amount of debt) is optimal at the outset (i.e., it maximizes the value of the firm).

II. The trading firm

Duffie and Singleton (2003) note there is no obvious formula to determine the market value created by a firm willing to bear a given amount of risk through proprietary trading, or via intermediation. In perfect capital markets, securities are priced at fair values, and trading could therefore neither add nor subtract value. Any formula that relates financial risk-bearing in such a setting to market value depends on difficult to capture variables such as human abilities of traders and management, the information flows to the firm, and the economic environment.

We draw on the theoretical and empirical literature on market microstructure (Ho and Stoll (1983) is an example) to propose a reduced form process to capture the earnings of a trading firm. Denote the amount of capital allocated to market making and trading in forward contracts on a commodity as $M(t)$. This capital serves as collateral for trading and market making, and is retained in a cash account. The cash account earns a risk free rate of return r each period.

Market making is profitable because a market maker is able to earn a spread on matched buy and sell orders. The typical spread between the bid and the ask price is a function of the volatility of the underlying asset and the trade size (e.g., Ho and Stoll (1983) show that the spread $s = \sigma_{asset}^2 RQ$ in a competitive dealer market where R and Q are exogenous constants). Suppose the turnover of such matched transactions each period equals n percent of the capital employed ($M(t)$). Hence the spread income is snM per period. This spread is stochastic and depends in part on how the market maker's inventory changes (suppose the volatility of spreads equals σ_s percent of spread levels). Then, the return on the capital employed purely as a result of such spread income is given by:

$$dM(t) = snM(t)dt + \sigma_s snM(t)du \tag{5}$$

where *du* is an increment to a Brownian motion. Thus spread income is reduced if the turnover *n* were to decline.

In addition to the risk from variations in spread income, a market maker bears the risk arising from its own positions in the underlying asset. This risk arises because of the stochastic nature of both the return on the inventory position that is carried forward, as well as the changes in the size of the inventory. An initial proportion *b* of firm capital $M(t)$ is tied up as collateral earmarked for the inventory of forward contracts. The value of contracts (quantity times price) of the inventory at any time is therefore equal to $I(t) = \frac{bM(t)}{\theta}$ where the parameter θ ($0 \le \theta \le 1$) captures the extent to which the collateral is levered because the firm provides only a percentage as margin on its open positions. If counterparties do not extend any credit to the firm, $\theta = 1$. The maximum position the trader can take is determined by the availability of its own capital. The lower the margin required per contract, θ, the more the firm can stretch its positions beyond the contracts purchased with its own capital. Thus a value of $\theta = 0.5$ implies that the trading firm takes open positions and consequently makes earnings twice as volatile. Empirical and theoretical research shows that changes in the overall value of the inventory position are negatively related to quoted spreads because a market maker adjusts spreads in response to increases in its open positions. In the case of Kyle (1985), the inventory position of a market maker is a Brownian bridge because it must converge to zero at the end of the trading period (Manaster and Mann (1996)). We assume that the changes in the total value of the inventory denoted $I(t)$ are governed by a geometric Brownian motion, where spread changes and the value of inventory positions are negatively correlated. Thus returns on the inventory position are given by:

$$\frac{d(bM(t)/\theta)}{bM(t)/\theta} = \mu_I dt + \sigma_I dq(t) \tag{6}$$

where $dq(t)$ is the increment to a Brownian motion, and spread and inventory changes are correlated, $Corr(dq, du) = \rho_{qu}$. Now, the total return on the capital allocated to market making and trading ($M(t)$) is given by the sum of returns on the capital retained in cash that earns the risk free rate, the returns on market making from spread income, and the changes in the total value of the inventory due to quantity and price changes in the inventory accumulated:

$$dM(t) = \underbrace{rM(t)dt}_{Cash\_Account} + \underbrace{nsM(t)dt + \sigma_s nsM(t)du}_{Spread\_Income} + \underbrace{\frac{\mu_I b}{\theta}M(t)dt + \frac{b\sigma_I}{\theta}M(t)dq}_{Inventory\_Return} \tag{7}$$

Thus, returns to the trading activity net of dividend payments, under the risk neutral measure, are given by:

$$dM(t) = (r-\delta)M(t)dt + \psi M(t)du + \frac{\lambda}{\theta}M(t)dq \tag{8}$$

where $\psi = \sigma_s ns$ and $\lambda = b\sigma_I$ are the volatility of earnings from market making activities and inventory positions, and δ is the payout to claim-holders. The parameter θ $(0 \le \theta \le 1)$ captures the extent to which a firm levers its trading positions. Evidently, the capital employed $M(t)$ is the expected present value of these market making and trading activities.

Returns on the inventory are related to the commodity produced by the production firm, which in turn induces correlation between trading firm returns and the production firm value process: $Corr(dq(t), dz(t)) = \rho_{qz}$.

There is wide evidence suggesting that the willingness of market participants to enter into trading with a market making firm depends on the market maker's credit rating. It is often the case in the over-the-counter contracts that the margin required for trading (or the ability to borrow) depends on the strength of the trading firm's balance sheet. Counterparties limit exposures and restrain from trading with a less financially secure trader that might renege on deals. This could be because it costs a counterparty to monitor a trader's positions, and enforce the terms of trading contracts in the event of distress. A trading company's ability to generate business (turnover of the capital base denoted *n*) is inversely related to its leverage, that is, the demand for trading with the firm by counterparties is a downward sloping function of the firm's financial situation.[7]

[7] Recall LTCM and Mettalgeselschaft, where counterparties refused to continue trading upon learning of the financial situation of these firms.

To represent this dependence of the value of market making activities on the amount of debt, i.e. on $\frac{Capital\_Available - Debt\_Service}{Capital\_Available}$, we compute a turnover factor $\kappa(t)$. The operating value of the trading company cash flows are now given by: $\kappa(t)M(t)$ where $0 \le \kappa(t) = \frac{M(t) - \eta C}{M(t)} \le 1$, and η is a constant (the penalty for debt service). Thus, the turnover factor depends on the amount of debt service (or leverage outstanding), as well as on the current value of the state variable $M(t)$. As firm value drops, the turnover factor $\kappa(t)$ declines, and the value of the trading company's cash flows drops in a nonlinear fashion. If the state variable $M(t)$ is very high the value of the turnover factor $\kappa(t)$ approaches 1 and there is no reduction in turnover because of debt. Therefore, the feedback effect from leverage to trading is state contingent.

The idea that the turnover generated is a function of the credit rating of the firm can be captured in a simple way that allows closed-form solutions if we assume that the factor $\kappa(t)$ can take two values: It equals κ_H if $M(t) > M_S$ and κ_L if $M(t) \le M_S$ (see Figure 1). The turnover factor depends on whether the current value of the state variable $M(t)$ is higher or lower than a level M_S. Assume $0 < \kappa_i = \frac{M_i - \eta C}{M_i}$, $i = H, L$ or that κ_i depends on the debt service (*C*) relative to some operating value of the assets of the trading firm, M_i. Using equations (5)-(8), the firm value process when part of the market making is funded with debt is:

$$d\left(\kappa_i M(t)\right) = (r - \delta)\kappa_i M(t)dt + \psi \kappa_i M(t)du(t) + \frac{\lambda}{\theta}\kappa_i M(t)dq(t) \tag{9}$$

where *i*=*H* if $M(t) > M_S$ and *i*=*L* if $M(t) \le M_S$. If the trading company has no debt ($\kappa_i = 1$), there is no reduction in the operating value of the trading firm. The term κ_i represents an up-front loss in turnover. The process in equation (9) continues without limit unless the trading firm falls to a default-triggering value endogenously decided by the equity holders of the firm.

We can now compute the value of the firm that trades, to include both speculation and market making. As before, the value of a levered firm is the sum of the firm value plus the benefits and costs of debt in the capital structure. Equity holders sell a proportion of their stake in the company to debt holders and in return pay debt holders a coupon each year. Here, however, debt financing has the additional disadvantage of diminishing the firm's ability to generate future cash flows from trading and thus reduces the value of the firm. If the proportional penalty for backing trade with debt, η, is high (equivalently, a low κ_i), the trading company will reduce the amount of debt on its books.

Proposition 1: *The debt value* $D(M_0)$ *and firm value* $F(M_0)$ *for a firm that trades is given by:*

$$D(M_0) = \frac{C}{r}\left(1 - G(M_0, M_S, i)\right) + (1-\alpha)\kappa_L M_B G(M_0, M_S, i) \tag{10}$$

$$F(M_0) = \kappa_H M_0 + \frac{\tau C}{r}\left(1 - G(M_0, M_S, i)\right) - \alpha\kappa_L M_B G(M_0, M_S, i) \tag{11}$$

where i=*H* if $M(t) > M_S$ *and* i=*L* if $M(t) \le M_S$,

$$G(M_0, M_S, i = H) = \left[\frac{\kappa_H M_0}{\kappa_H M_S}\right]^{-X}\left[\frac{\kappa_L M_S}{\kappa_L M_B}\right]^{-X}, \quad G(M_0, M_S, i = L) = \left[\frac{\kappa_L M_0}{\kappa_L M_B}\right]^{-X} \tag{12}$$

$$X = a + b,\ a = \frac{r - \delta - \frac{\sigma_y^2}{2}}{\sigma_y^2},\ b = \frac{\sqrt{\left(a\sigma_y^2\right)^2 + 2r\sigma_y^2}}{\sigma_y^2},\ \sigma_y^2 = \left[\left(\frac{\lambda}{\theta}\right)^2 + \psi^2 + 2\rho_{qu}\left(\frac{\psi\lambda}{\theta}\right)\right]$$

$$0 < \kappa_i = 1 - \eta\frac{C}{M_i}, \text{ and } \quad M_B = \frac{C(1-\tau)}{\kappa_L r}\frac{X}{X+1}$$

Proof: See Appendix.

The volatility of the firm value process (σ_y) is inversely proportional to the extent that the firm speculates, which is captured via the parameter θ. Roughly, open trading positions corresponding to $\theta = 20\%$ relative to 100% make the inventory part of the firm value five times more volatile. More open trading positions and contracts make the earnings per unit of capital invested more volatile, which in turn makes the overall value of the firm more volatile. Thus, the optimal capital structure of the firm will include a lower proportion of debt. The lower the margin required by counterparties in trading (lower θ), the more reluctant the firm's original bondholders are, and consequently the less debt the firm optimally uses to fund its activities. The coupon rate (leverage) that maximizes the value of the firm is easily computed by setting the partial derivative of the firm value with respect to the coupon rate equal to zero and solving for *C*.

From Proposition 1, if the feedback effects of leverage in the capital structure in terms of lost market making activity (equivalently a low value of the turnover factor κ_i) exceed the benefits of debt (the tax shields net of bankruptcy costs), the trading firm will be funded essentially with equity rather than debt. Suppose a trading firm has a value of operating assets equal to $M_0 = 100$, and first assume there is no cash flow impact on turnover for having debt, i.e., $\kappa_H = \kappa_L = 1$. Assume the risk-free rate $r = 0.07$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.5$, asset volatility $\psi = 0$, $\lambda = 0.3$, and θ=0.2 and $M_S = 120$. For a firm funded partly with debt, the coupon amount that maximizes firm value gives a debt value of 62 (and a firm value of 112). In this case, the benefit of debt is equal to 12% of the value of the operating assets of the trading firm. If the effect of debt on the cash flow from trading represents a penalty of $\kappa_L = 0.88$, the firm will optimally decide to carry no debt on its books to mitigate the feedback effect on the lost turnover driven by a lower credit rating and a loss in the value of the firm. Recall that the feedback effect is state dependent. For example, when the firm is far from the default boundary, there is less of a reputation effect from leverage because the firm is in state *H.* On the other hand, if the firm is closer to the default boundary, there is more of a feedback effect. These features can be summarized in the proposition:

Proposition 2: *A trading firm that speculates and engages in market making activities will have less leverage in its capital structure than an equivalent sized firm that engages in production under conditions as follows (i.e., the optimal coupon that maximizes the ex-ante firm value $C_{tr} < C_{pr}$ where the subscripts tr and pr denote trading and production):*

(1) *When the cash flows of the speculative part of the trading operation are more volatile than the cash flows from production,* $\left[\left(\frac{\lambda}{\theta}\right)^2 + \psi^2 + 2\rho_{qu}\left(\frac{\psi\lambda}{\theta}\right)\right] > \sigma^2$.

(2) *When the presence of debt in the capital structure results in a reduced volume of market making activities (when* $0 \le \kappa_{H,L} < 1$*).*

Proof: See Appendix.

This proposition implies that firms that engage primarily in market making and speculative trading are capitalized predominantly with equity rather than debt. [8]

III. A firm that produces and trades – the integrated firm

Next we analyze a firm that produces a commodity and also allocates some of the firm's own capital to trading activities. This framework allows us to illuminate the drawbacks and benefits of combining production and trading operations in one corporate entity, and to determine the optimal relative size of each activity. We start by formulating the value of the integrated firm and then discuss the implications of combining production and trading within the firm.

A. Model of a firm that produces and trades

At the outset, the firm allocates its capital (denoted $J(t)$ in this case) in part to production and in part to trading activities. The unlevered value of the firm is expressed as:

$$J(t) = V(t) + M(t)$$

where the capital $V(t)$ is employed in production, as in Section I, and $M(t)$ is employed in trading activities, as in Section II. The return on this portfolio of activities is the joint return due to the output in the production arm and the results of the trading activities.

Suppose first that the firm's policy is to allocate a fixed proportion (denoted x) of the firm equity capital to trading activities and the balance to production operations. Later we solve endogenously for the optimal and state contingent allocation (x) of capital between production and trading:

$$V(t) = (1-x)J(t) \quad \text{and} \quad M(t) = xJ(t) \tag{13}$$

The capital $V(t) = (1-x)J(t)$ is allocated to production activities, while the capital $M(t) = xJ(t)$ is allocated to trading activities. Note that capital allocations in each arm cannot be negative: $0 \le x \le 1$. The returns on the total portfolio are equal to the returns on the proportion of the

[8] See Financial Times (3/28/2008), "Spotlight turns on channels of liquidity", for the feedback effect of leverage and the Bear Stearns collapse.

investment in the production operations and the balance in trading. Substituting equations (1) and (9) into (13), we get:

$$dJ(t) = (1-x)\left[(r-\delta)J(t)dt + \sigma J(t)dz(t)\right] + x\left[(r-\delta)\kappa_i J(t)dt + \kappa_i J(t)\psi du(t) + \left(\frac{\lambda\kappa_i}{\theta}\right)J(t)dq(t)\right] \tag{14}$$

where i=H if $J(t) > J_S$ and i=L if $J(t) \le J_S$.

Before we characterize the optimal proportion of the capital allocation in production and trading, we compute the debt value and firm value, following the approach in Section II. Again, the value of debt is given by the present value of the promised future coupon flows, C, as long as the firm does not go bankrupt (firm value remains above the bankruptcy barrier), and residual cash flows left if the firm were to go bankrupt. The firm value is the sum of the unlevered firm value plus the tax benefits and minus the bankruptcy costs.

Proposition 3: *For a firm that both produces and trades, the debt value* $D(J_0)$ *and the firm value* $F(J_0)$ *are given by:*

$$D(J_0) = \frac{C}{r}\left(1 - G(J_0, J_S, i)\right) + (1-\alpha)J_B^* G(J_0, J_S, i) \tag{15}$$

$$F(J_0) = J_0^*(i) + \frac{\tau C}{r}\left(1 - G(J_0, J_S, i)\right) - \alpha J_B^* G(J_0, J_S, i) \tag{16}$$

i=H if $J(t) > J_S$ and i=L if $J(t) \le J_S$,

$$G(J_0, J_S, i = H) = \left[\frac{J_0^*(H)}{J_S^*(H)}\right]^{-X}\left[\frac{J_S^*(L)}{J_B^*(L)}\right]^{-X}, \quad G(J_0, J_S, i = L) = \left[\frac{J_0^*(L)}{J_B^*(L)}\right]^{-X},$$

$$X = a + b, \; a = \frac{r - \delta - \frac{\sigma_y^2}{2}}{\sigma_y^2}, \; b = \frac{\sqrt{\left(a\sigma_y^2\right)^2 + 2r\sigma_y^2}}{\sigma_y^2},$$

$$\sigma_y^2 = \left[\left((1-x)(\sigma)\right)^2 + \left(\frac{x\lambda}{\theta}\right)^2 + (x\psi)^2\right] + \left[2\rho_{qz}(1-x)(\sigma)\left(\frac{x\lambda}{\theta}\right) + 2\rho_{qu}(x\psi)\left(\frac{x\lambda}{\theta}\right)\right] \tag{17}$$

$J_j^*(i) = (1 - x + x\kappa_i)J_j$, i=H,L and j=$S,B,0$ and $J_B = \dfrac{C(1-\tau)}{(1 - x + x\kappa_L)r}\dfrac{X}{X+1}$.

Proof: See Appendix.

Note again that the default barrier is endogenous, and is equal to the point at which equity holders do not find it optimal to finance the operation of the firm. If the penalty for debt $\kappa_i \to 0$, the value of the firm assets $J_0^*(i) = (1 - x + x\kappa_i)J_0$ would decline by x percent as the trading part of the operations stalls. If $\kappa_i \to 1$, however, there would be no penalty for debt on the trading side of the business. Equation (17) shows how the capital allocation between production and trading affects the instantaneous volatility of the firm value process (denoted σ_y^2). Also, the trading allocation impacts the endogenous bankruptcy barrier via the parameter X in the formulation for J_B.

B. Effect of changing allocation of capital between production and trading

From equation (17) the proportion of the firm capital allocated to trading activities, denoted by x, changes the volatility of the firm's earnings. If a large portion of the firm's capital is committed to trading, the increased risk from that activity will increase the probability of going bankrupt (higher value of G) and consequently reduce the associated tax benefits. A higher proportion in trading also increases the feedback effects of leverage via a reduction in the profits of the trading function in the overall firm assets, $J_0^*(i) = (1-x)J_0 + (x\kappa_i)J_0$. There is an optimal amount x^* in the trading operation that is linked to the optimal capital structure, one that maximizes the value of the integrated firm, and solves the constrained maximization problem:

$$\max_{x, 0 \le x \le 1} \left(F\left[x \mid J_0, \theta, \sigma, r, \delta, \psi, \lambda, \kappa_{i=H,L}, C \right] \right) \tag{18}$$

where F is the firm value given in Proposition 3, for an an endogenous bankruptcy threshold, J_B. Taking a partial derivative of the equation for firm value with respect to x using equation (16) in Proposition 3 gives:

$$\underbrace{-(1-\kappa_i)\left(J_0 - \alpha G \left(J_B + x\frac{\partial (J_B)}{\partial x} \right) \right)}_{contamination\_effect} + \underbrace{\left(\frac{\tau C}{r} - (1 - x + x\kappa_i) J_B \right) \frac{\partial G}{\partial x}}_{diversification\_benefit} = 0 \tag{19}$$

where i=H, L and G is related to the probability of going bankrupt (from Proposition 3).

The part of equation (19) labeled contamination effect is the net reduction in firm value because of the feedback effect of leverage via reduced profits in the trading entity. For a small increase in the allocation to trading, the feedback effect reduces the overall firm value by a factor of $(1-\kappa_i)$ times the firm value less deadweight costs. The second component is the diversification benefit. It captures the way the reduced risk of the overall entity changes the net tax benefits of debt (benefits minus bankruptcy costs) for firm value.

In the absence of any trading penalty due to debt ($\kappa_i = 1$), the optimal allocation (denoted x^U) is the allocation that minimizes the overall asset volatility σ_y^2 and corresponds to the diversification benefit in equation (19). If there is a trading penalty due to debt, the optimal allocation of capital devoted to trading, x^*, is below this volatility-minimizing value x^U. The volatility-minimizing value is given by solving

$$\frac{\partial \sigma_y^2}{\partial x} = \frac{\partial}{\partial x}\left\{\left[\left((1-x)(\sigma)\right)^2 + \left(\frac{x\lambda}{\theta}\right)^2 + \left(x\psi\right)^2\right] + \left[2\rho_{qz}(1-x)(\sigma)\left(\frac{x\lambda}{\theta}\right) + 2\rho_{qu}(x\psi)\left(\frac{x\lambda}{\theta}\right)\right]\right\} = 0 .$$

Then, we have that the optimal allocation in trading is such that:

$$0 \le x^* \le x^U = \frac{\theta\left[\sigma^2\theta - \lambda\rho_{qz}\right]}{\lambda^2 + \theta^2(\sigma^2 + \psi^2) - 2\lambda\theta(\rho_{qz} - \rho_{qu}\psi)} \tag{20}$$

C. Separation versus integration

To focus on the issue of combining the trading and production operations in a firm versus keeping them separate, the increase in firm value when the firm is integrated compared to when it is separated into two entities, using equations (3), (11) and (16) is:

$$\begin{aligned}&\underbrace{(1-x)(\kappa_{i,jo} - \kappa_{i,tr})J_0}_{\Delta feedback\_of\_leverage} + \underbrace{\frac{\tau(C_{jo} - C_{pr} - C_{tr})}{r} - \frac{\tau(C_{jo}G_{jo} - C_{pr}G_{pr} - C_{tr}G_{tr})}{r}}_{\Delta tax\_benefits} \\ &+ \underbrace{(J_{B,jo}G_{jo} - J_{B,pr}G_{pr} - J_{B,tr}G_{tr})}_{\Delta bankruptcy\_costs}\end{aligned} \tag{21}$$

where the subscripts *jo*, *pr* and *tr* denote three types of firms: joint activities, production only, and trading only. The first component of equation (21) is the feedback effect of leverage (via parameter κ_i); the second component is the tax benefits via change in the optimal coupon as well as the probability of bankruptcy (*G*); and the third is the bankruptcy costs via a change in the bankruptcy level as well as the probability of bankruptcy. To assess the total impact of these three components, Figure 2 compares the increase in firm value when the firm is integrated and when it is separated into two entities using equation (21). In each case, we compute the firm value-maximizing coupons (C_{jo}, C_{pr}, C_{tr}) and then compute the increase in firm value of the combined entity compared to the non integrated entity as given by equation (21).

We see in Figure 2 that as the firm puts more of its capital into trading (parameter x), the benefits of integration are initially greater than the costs, because the incremental deadweight costs from the feedback effect of leverage are lower than the benefits from increased coupons (debt capacity) and diversification benefits. Once the weight in trading exceeds a certain amount, the costs of integration outweigh the benefits.

The effects of the feedback of leverage on trading are also evident. A firm that loses more value in its trading operations because it has debt in its capital structure has less advantage in integrating the two activities, trading and production.

To describe the effect of speculation on the total benefit, Figure 3 plots firm value as a function of the proportion of firm capital invested in trading. The upper line gives the firm value when the firm speculates less (corresponding to $\theta = 0.5$) while the lower one gives the firm value when the firm speculates more ($\theta = 0.3$). We set the trading penalty for debt to $\eta = 0$ ($\kappa_i = 1$) in each case. The coupon is also set to maximize firm value for each value of x. First, note that in both cases the firm experiences a benefit from including trading and production. When there is less speculation, a firm benefits more by integrating production and trading, and a higher proportion of the firm capital is optimally tied up in trading. When there is considerable speculative activity, there are benefits of diversification when a lower proportion of the firm capital is tied up in trading. Now, increasing the amount tied up in trading increases firm volatility so that the diversification benefits are offset by the increased costs of bankruptcy and reduced debt capacity.

From equation (21), the point at which it is beneficial to separate production and trading depends critically on several parameters: the loss of trading business due to leverage (feedback effect), the debt capacity and tax benefits, the relative level of the volatility of the operating assets to the volatility of trading activities that impacts the function *G*, the margin requirements in trading (via its impact on G), and the deadweight costs of bankruptcy. Our analysis shows that if a trading operation is not very volatile (is an ancillary operation), it is beneficial to keep the firm integrated; the converse is true for a trading operation whose returns are highly volatile. This suggests that, in the case of ancillary operations, such as financial arms of manufacturing firms, with low deadweight costs and low asset volatility (corresponding to a high margin), it is beneficial to maintain an integrated firm.

In fact, as long as a relatively small amount of capital is allocated to trading, integrating even a risky trading operation with a less risky production operation may be optimal. The firm performing the two activities faces less risk than would the separate activities operating independently, and therefore can save on the deadweight costs of bankruptcy. Figure 4 plots firm value for three values of the feedback effects of leverage. When the feedback effect is lower, a higher trading amount is optimal than when the feedback effect is higher. At some level there is no advantage to keeping the two activities together, and value is maximized if they are kept separate.

D. *Risk management and flexibility in capital allocation*

In addition to providing the benefits of integration enumerated above, an integrated operation lets a business allocate capital, x, in a flexible manner that maximizes firm value. Suppose that trading and production operations were separate entities, and that it is possible to allocate capital back and forth between the two businesses at no cost. These separate entities would still not be as valuable as if they were integrated in a single firm, because of the frictions induced by bankruptcy. Hence, it is not simply flexibility in allocating capital between the two activities but flexibility in combination with the bankruptcy barrier that provides the benefits of integration.

How does flexibility in allocating capital between the two activities work? So far we have assumed the proportional allocation x is fixed. Suppose, however, that the firm switches between an allocation, x_H, if $J(t) > J_S$ or x_L if $J(t) \leq J_S$. In Proposition 4 we give the solution to the value of the firm and the value of debt when the equity holders switch to an allocation x_H or x_L, when the firm value changes to state *H* or *L*.

Proposition 4: *For a firm that both produces and trades, the debt value* $D(J_0)$ *and the firm value* $F(J_0)$ *with flexibility in allocating capital (* x_i *in states i=H,L) is given by:*

$$D(J_0) = \frac{C}{r}\left(1 - G(J_0, J_S, i)\right) + (1-\alpha)J_B^* G(J_0, J_S, i) \tag{22}$$

$$F(J_0) = J_0^*(i) + \frac{\tau C}{r}\left(1 - G(J_0, J_S, i)\right) - \alpha J_B^* G(J_0, J_S, i) \tag{23}$$

where i=H if $J(t) > J_S$ and *i=L* if $J(t) \le J_S$,

$$G(J_0, J_S, i = H) = \left[\frac{J_0^*(H)}{J_S^*(H)}\right]^{-y2H} \left\{\left[\frac{J_S^*(L)}{J_B^*(L)}\right]^{y2L}\left(\frac{y2H - y1L}{y1L - y2L}\right) + \left[\frac{J_S^*(L)}{J_B^*(L)}\right]^{y1L}\left(\frac{y2L - y2H}{y1L - y2L}\right)\right\}^{-1}$$

$$\begin{aligned} G(J_0, J_S, i = L) = {} & \left[\frac{J_S^*(L)}{J_S^*(L)}\right]^{-y1L} \left\{\left[\frac{J_S^*(L)}{J_B^*(L)}\right]^{y2L}\left(\frac{y2H - y1L}{y2H - y2L}\right) - \left[\frac{J_S^*(L)}{J_B^*(L)}\right]^{y1L}\right\}^{-1} \\ & + \left[\frac{J_S^*(L)}{J_S^*(L)}\right]^{-y2L} \left\{\left[\frac{J_S^*(L)}{J_B^*(L)}\right]^{y1L}\left(\frac{y2H - y2L}{y2H - y2L}\right) - \left[\frac{J_S^*(L)}{J_B^*(L)}\right]^{y2L}\right\}^{-1} \end{aligned} \tag{24}$$

$$y1i = a_i - b_i,\ y2i = a_i + b_i,\ a_i = \frac{r - \delta - \frac{\sigma_y^2(i)}{2}}{\sigma_y^2(i)},\ b_i = \frac{\sqrt{\left(a\sigma_y^2(i)\right)^2 + 2r\sigma_y^2(i)}}{\sigma_y^2(i)},$$

$$\sigma_y^2(i) = \left[\left((1-x_i)(\sigma)\right)^2 + \left(\frac{x_i\lambda}{\theta}\right)^2 + \left(x_i\psi\right)^2\right] + \left[2\rho_{qz}(1-x_i)(\sigma)\left(\frac{x_i\lambda}{\theta}\right) + 2\rho_{qu}(x_i\psi)\left(\frac{x_i\lambda}{\theta}\right)\right],$$

$J_v^*(i) = (1 - x_i + x_i\kappa_i)J_v$, *i=H,L* and *v=S,B,0* .

Proof: See Appendix.

The endogenous bankruptcy barrier J_B^* is given by the solution to $\left.\frac{\partial(F(J) - D(J))}{\partial J}\right|_{J=J_B} = 0$. While a closed form solution is not available, the endogenous barrier is readily computed numerically. Proposition 4 provides a complete assessment of the benefits of integration with flexible allocation of capital as well as changing levels in the feedback effect of leverage. The change in allocation to trading in each state impacts this feedback effect as well as the probability of bankruptcy via its impact on the function *G*, which represents the probability of bankruptcy. Note that equity holders' choice of the level in trading is driven by a number of factors: the value of the firm, its distance from the point at which it can switch allocations, and the distance from the bankruptcy level. When the value of the firm as well as the value of the two activities is high relative to the bankruptcy threshold and the switch level, more capital can be allocated to trading, and equity holders choose a higher allocation to trading at the outset.

Equity holders are also concerned about the contingent cost paid (feedback effect of leverage) paid were the firm to reach the switch point. The cost arises because market participants are no longer willing to trade with the firm as much as they did once and the turnover in trading is reduced. Hence, if firm value is higher than the switch point but not very far from it, equity holders choose a lower allocation in trading to reduce the contingent cost paid when the firm value hits the switch barrier. We can better understand some of the implications if we look at some special cases as follows:

Remark 1: Using Proposition 4:

(a) If $\kappa_i \to 1$, *there is no feedback effect of leverage:* $J_0^*(i) = J_0$ and $J_B^*(i) = J_B$.

(b)) If $\kappa_i \to 0$, *the firm value drops by x:* $J_0^*(i) = (1 - x_i)J_0$, $J_B^*(i) = (1 - x)J_B$.

(c) When $\kappa_L = \kappa_H$ *and with constant x, the feedback effect of leverage is the same in the up and the down state. Hence, changes in allocation are driven by diversification benefits only.*

(d) If $\tau \to 0$, *there are no tax benefits of debt, and the firm will optimally carry no debt. Then* $\kappa_i \to 1$ *and there is no feedback effect of leverage.*

From an overall firm value perspective, when the trading component is more valuable than the production component of the firm, the firm is better off if it transfers some additional capital from trading to production, in order to optimize its overall risk. Higher values for the trading component allow the firm to take larger positions and be less affected by the trading penalty attributable to leverage. Beyond some point, more trading does not bring additional diversification benefits to compensate for the higher inherent risks in this activity.[9] Hence, the integration of production and trading helps in the overall risk management of the combined entity so as to maximize firm value and minimize bankruptcy costs.[10] Reallocation of capital may incur some transactions costs. The overall extent to which such allocation flexibility is useful will also depend on the level of transactions costs. The cost of entering into financial trades is minimal. Expanding production, however, may be more costly if new facilities are required. While dynamic risk management is accomplished by a reallocation of capital in our case, it is accomplished via the use of derivative contracts in Fehle and Tysplakov (2003).

E. Contamination effect of integration

Recall that the capital allocated to production activities is $V(t)=(1-x_i)J(t)$, while the balance $M(t)=x_i J(t)$ is allocated to trading activities. The earnings that can be generated from the capital allocated to trading activities decline if there is leverage in the integrated entity so that the value of the trading part of the company (excluding tax benefits and bankruptcy costs) becomes $M(t)=x_i\kappa_i J(t)$. While an advantage of combining production and trading in the same firm is that the strength of the joint balance sheet may reduce the margin requirements, θ, there is also a risk that a negative shock to one business can reduce the value of the other business, we call this the *contamination effect of integration*.

Because the proportion of firm capital tied up in trading is related to the overall value of the firm, a decline in the value of the firm will reduce the capital allocated to the firm's trading operations and thereby the size of the positions it can take. Suppose the production arm experiences a negative shock of ΔJ. The corresponding reduction in the value of trading operations is $M(t)=x_i\kappa_i\Delta J$. Moreover, the higher leverage that occurs with a decline in firm value limits the ability of the trading operation to generate counterparty business, because η_i (or κ_i) is related to the leverage ratio.[11] Therefore, a decline in the value of production operations can have a multiplicative contamination effect on the value of the trading part of the business. While poor trading can also contaminate production, the trading unit is much more

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[9] If θ is made dependent on the leverage, the optimal allocation of capital in trading, when asset values increase, θ would declines and consequently the optimal fraction *x* would decline.
[10] Ex-post inefficient bargaining over the allocation of capital also favors integration over separation.
[11] The effect is reinforced if the level of margin, θ, is a function of the firm's leverage ratio C/J_0.

sensitive to bad results in production because of the feedback effect of leverage in addition to the reduced allocation to trading.

This contamination effect is evident in Figure 5, which plots the value of default insurance for General Motors (GM) and its subsidiary, General Motors Acceptance Corporation (GMAC). In October 2005, a proposed split of GM and GMAC resulted in a decoupling of the value of the insurance (or the firm value and default risk) of each entity. Before the proposed split, GM and GMAC obligations had similar patterns in changes in the costs of their insurance for default risk. The split made it more likely that pension and other obligations of GM would not impact the ability of GMAC to run its financing businesses. The annual cost of a five-year credit default swap for GMAC exceeded 5 percentage points a year in early October 2005. The cost fell to almost 2 percentage points a year in the days after GM said it would sell GMAC, the lowest level since January 2005. It has climbed since, more than doubling, to 4.12 percentage points a year in mid-November 2005, after the markets realized that a search for the financing arm would take longer than anticipated.

IV. The role of private information

So far we have assumed that information plays no special role in the analysis, although many corporations consider spillovers of information from one activity to another an important effect. As in the BP trading success story, an integrated corporation may be better positioned to capture important pieces of information related to supply and demand by virtue of its exposure to the various stages of the industry chain. The trading operation in an enterprise may have private information on demand for and supply of the commodity produced in the firm. To the extent that such private information is available only if the production and trading entities are under one corporate roof, there is a benefit to keeping the operations together. Anecdotal evidence and private conversations with oil and natural gas producers reveal that supply and demand information on the production side of the business is available to the trading operation. The same traders are responsible for hedging activities as well as speculative trades. The information flow could be in either direction. While production operations may provide information on supply and demand, the trading operation may have access to information on the overall hedging and trading activities of other firms in the industry.

Recall that changes in the value of a firm are driven by a single source of uncertainty, given by equation (1). Suppose these shocks to firm value, denoted σdz, can be decomposed into two components. The first component is seen as a price-related shock, denoted *dp(t)*. The second shock relates to the output, supply, and other variables that are known to insiders in the company, denoted *dk(t)*. We can rewrite equation (1) as:

$$\frac{dV(t)}{V(t)} = (\mu - \delta)dt + dp(t) + dk(t) \tag{25}$$

To recognize the possibility that price shocks are related to demand and supply components, we characterize these changes to firm value as:

$$dp(t) = \sigma_1 dz_1(t) + \rho\sigma_2 dz_2(t)$$

and

$$dk(t) = \sqrt{1-\rho^2}\,\sigma_2 dz_2(t) \tag{26}$$

where dz_1 and dz_2 are increments of two standard Brownian motions. The specification captures in a simple way the relation between market prices and private information on demand and supply. The variable ρ captures the extent of this relation between price changes and the private information on demand and supply. For example, if ρ =0, there is no relation between price shocks and the shocks due to supply and demand about which firm insiders have private information.

Suppose a forward contract used in the trading part of the business experiences price shocks by a factor that is common to the production firm as well as a second factor, given by $df(t) = vf(t)dz(t) + \gamma f(t)dw(t)$. We can modify this characterization of price changes in the forward contract price so that innovation in the first factor $dz(t)$ is now due to the two components that induce the price shock (*dp(t)*).

We characterize the change in the forward contract as:

$$df(t) = f(t)\sigma_1 dz_1(t) + f(t)\rho\sigma_2 dz_2(t) + \gamma f(t)dw(t) \tag{27}$$

If the trading operation has full knowledge about the shock *dk(t)*, and trading positions reflect this private information, then the trading position is positive if *dk(t) > 0*, and vice versa. The new conditional variance, conditional on knowing *dk(t)*, of payoffs for each forward contract is $\sigma_1^2 + \gamma^2$; lower than the variance without this information ($\sigma_1^2 + \rho^2\sigma_2^2 + \gamma^2$). So, private information leads to greater precision and less margin for error. Also, knowledge about *dk(t)* results in an incremental return per period equal to:

$$\delta^* = E\left[\rho\sigma_2 \mid dq \mid\right] = \rho\sigma_2\sqrt{\frac{2}{\pi}}dt\,, \tag{28}$$

for each forward contract.

Remark 2: *Integration reduces the volatility of payoffs and increases return on assets when the trading part of the business receives private information from the production side of the business.*[12]

In our setting, combining the trading operation and the production operations of the firm is valuable as long as the information variable ρ is not equal to zero. For example, when ρ=0.1 and $\sigma_2 = 0.2$, there is an incremental payoff of 1.2% each year and a corresponding reduction in volatility of returns to the operations. Thus integration enhances firm value because of increased earnings and lower risk. The capitalized value of this increased income stream (1.2% each year) adds to firm value, and can be estimated as the incremental earnings times a capitalization factor ($\frac{1}{r}$). Suppose the capitalization factor is 17, the unlevered firm value is 100, and the proportion invested in trading is *x*=0.05. This translates into a gain in the value of the company equal to: $x \times J \times \delta^* \times 17 = 0.05 \times 100 \times .012 \times 17$ =1.02 (on the same order as the incremental return). It is likely that the type of firms that benefit from such information spillovers will be large firms that dominate the industry.

Of course, increased returns from trading would imply that the proportion of firm capital employed in trading should increase beyond its optimal level (*x**), as we have characterized it. The cost of such an action is the declining marginal returns from increased allocation of capital to trading. This is because the production side can generate relevant information for trading only if it is large enough. If some considerable majority of the capital is

[12]In this setting, production operations are not flexible enough to adjust to information generated by the trading part of the business. In the more general case, the flow of information and its effects would occur in both directions.

employed in trading, there is likely to be less information generated by production. For example, it is likely that the information variable ρ depends on the proportion of capital invested in production. If the information variable ρ is a declining function of *x* (the allocation to trading), the optimal amount that a firm can invest in trading will be such that the production operations continue to provide incremental information.

To recognize this possibility, we can modify the integrated firm value ($J^*(t) = (1 - x + x\kappa_i)J(t)$) in Proposition 4, to include the information benefits of integration as well as the reduced information costs as *x* increases. Suppose we modify the integrated value of the firm as: $J^*(t) = (1 - x + x\kappa_i + e^{-ax}b\rho)J(t)$, where $a > 1$, and *b* are constants, and the percentage benefit of integration ($e^{-ax}b\rho$) is a declining function of the allocation to trading. The benefit is offset by the penalty for debt ($x\kappa_i$) and more volatile cash flows (as long as information is not perfect). For some allocation, there is no benefit of allocating more capital to trading.

Increased allocation to trading will increase the volatility of firm value, reduce the firm's debt capacity, and increase deadweight costs related to trading. Such costs would offset the increased revenue possibilities. For example, an increase in allocation to trading by 5% over the optimal x^* would increase bankruptcy costs enough to offset any potential benefits of revenue gains for the parameter values used in Figure 3. Hence, deviations from optimal x^* are likely to be low for reasonable parameter values.

The information content of production transmitted to trading is more important in some types of businesses than others. The information content of production may not be of importance in ancillary businesses like financial services and leasing activities, but an oil and natural gas producer may have relevant information on its entire stream of activities that is important for a trading operation. The benefits to firm value from other sources we have discussed can then be combined with these information benefits to arrive at a determination of the overall value added from the integration of trading and production.

The ability to obtain information and use this information to generate profits depends on the flexibility of the production operations and the costs associated with using the information. For example, even though a production operation may expect higher prices for a product, it may not be able to increase production because of capacity limitations, or because of the high costs associated with rapidly adjusting capacity. In this case, a trading operation may be able to generate a profitable trade using this information. If the production operations are able to adjust its activities in a timely and low-cost fashion, there may be no additional benefit of the trading operation.

Finally, even though we consider a complete markets setting in our analysis, there are some factors of production for which financial products are not normally available. The trading division of an integrated firm that has access to information and physical delivery options on the production side may be able to hedge and to offer financial products that are not offered by purely financial firms. In the words of an executive at a leading commodity producer[13]:

> "The ability to make a forward financial exposure and put it into a portfolio of physical exposures is something we do often, and is the key distinction between a commodity company and a financial institution".

Market completion is another argument in favor of integration of the production and trading parts of a business. The integrated firm can offer a more complete menu of financial contracts and increase its revenue more than a purely trading institution. We see that Morgan Stanley bought energy producer and trader Entegy-Koch in September 2004 to better manage the risks inherent in its energy trading operations. And, in a recent leveraged buyout of Texas Genco, Goldman Sachs underwrote the entire offering because it could take advantage of Texas Genco's access to the production side of the business with its own well-developed trading operation in commodities.[14]

V. Empirical implications

Our discussion has several interesting implications for non-financial corporations with trading operations. The first is that we can use a model to explain the organization structure (whether a trading business is integrated or a separate entity from production). Among factors determining structure are the relative size of the trading operation (average earnings attributable to trading), the extent of leverage used by traders, volatility of trading revenues,

[13] See Financial Times (10/12/2005): "Top team helps to offset rising costs".

and the importance of information from the production side (nature of the business). Thus, a compilation of data on firms that have spun off their trading arm versus those that have kept it integrated, together with this set of variables, should have explanatory power.

One practical implication of our study is the insight into the way separation of a trading operation can influence the overall credit risk of a company. Consider, for example, a company that has a large proportion of its capital allocated to trading. It is possible that a spin-off may increase firm value and enhance the credit rating of the separate entities, especially the trading part. This would occur because the separate trading entity may be able to generate more trading revenues if its balance sheet is clean, and consequently increase its value. Also, the production arm revenues of the separate entity are less volatile in the absence of a trading operation. Our results make it possible to estimate the extent to which integration or separation changes the overall firm value and the probability of default, and consequently the credit rating of the company. This analysis is of relevance to credit rating companies that constantly analyze and monitor the implications of trading on the possibility of financial distress.

VI. Summary and conclusions

Many commodities and manufacturing firms speculate in the commodity that is either an input or an output of their production process, as well as in different macroeconomic variables. Trading allows these firms to exploit a core competence or an information advantage. We have asked under what conditions it is optimal to separate or to integrate production and trading operations within the same firm, and how the choice of organization structure is related to the financing of the firm.

We find that integration provides benefits because trading profits are uncorrelated with profits from production; each activity may benefit from private information spillovers that increase return, and flexibility in the reallocation of capital between the two businesses improves risk management. We find that integrating a high-risk trading business with production is of benefit when a relatively low proportion of capital is tied up in trading.

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[14] See Financial Times (10/12/2005) : "Top team helps to offset rising costs".

The arguments in favor of separation come from the very different cash flow profiles of the two activities, production and trading, and how this affects the difficulty of merging in one firm activities that require very different capital structures. The point at which it is beneficial to separate production completely from trading to establish separate entities depends critically on several factors: the volatility of the production assets, the volatility of derivatives contracts, the volatility of the speculative part of trading, the capital requirements, and loss of trading business due to leverage. Increases in the volatility of cash flows from trading could offset the benefits that result from diversification. More important, trading operations that are particularly sensitive to changes in credit rating that affect the ability to generate trading business should be spun off in order to avoid potential contamination of the balance sheet that a negative shock to the production side of the firm would cause.

These results are applicable to a broad range of businesses that want to manage the risk of both their core business and associated trading operations. One finding in our work is that both the risk profile of the cash flows and their dependence on the credit rating of the parent company determine whether a business segment should be spun off or kept as part of the parent. Credit rating and the risk of cash flows of the business, on one hand, and the relevance of information spillovers, on the other hand, should help explain spin-offs and the incorporation of new businesses as separate entities.

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Appendix

Proof of Proposition 1

Following Leland (1998), a general solution to the value of debt is given by

$$DH(M_0) = \frac{C}{r} + \alpha_{1H}\left(\kappa_H M_0\right)^{y1} + \alpha_{2H}\left(\kappa_H M_0\right)^{y2} \text{ if } M(t) > M_S \text{ and} \qquad \text{(A1)}$$

$$DL(M_0) = \frac{C}{r} + \alpha_{1L}\left(\kappa_L M_0\right)^{y1} + \alpha_{2L}\left(\kappa_L M_0\right)^{y2} \text{ if } M(t) \le M_S\,. \qquad \text{(A2)}$$

where $y1 = -a + b$, and $y2 = -a - b$, $a = \dfrac{r - \delta - \dfrac{\sigma_y^2}{2}}{\sigma_y^2}$, $b = \dfrac{\sqrt{\left(a\sigma_y^2\right)^2 + 2r\sigma_y^2}}{\sigma_y^2}$,

$$\sigma_y^2 = \left[\left(\frac{\lambda}{\theta}\right)^2 + \psi^2 + 2\rho_{qu}\left(\frac{\psi\lambda}{\theta}\right)\right].$$

We need four boundary conditions to determine the four constants- $\alpha_{1H}, \alpha_{2H}, \alpha_{1L}, \alpha_{2L}$. These conditions relative to the state variable are:

1. As $M(t) \to \infty, DH(M) \to \dfrac{C}{r}$ or that the debt becomes risk-free.
2. As $M(t) \to M_B, DL(M) \to \alpha M_B$, the bankruptcy payoff.
3. As $M(t) \to M_S, DL(M) = DH(M)$, the value of debt is continuous with respect to the state variable *M*.
4. As $M(t) \to M_S, DL_M(M) = DH_M(M)$, the smoothness condition for the value of debt at the switch boundary.

Condition 1 gives, $\alpha_{1H} = 0$. Conditions 2, 3, and 4 respectively give:

$$\begin{bmatrix} & \alpha_{1L}\left(\kappa_L M_B\right)^{y1} + & \alpha_{2L}\left(\kappa_L M_B\right)^{y2} \\ -\alpha_{2H}\left(\kappa_H M_S\right)^{y2} + & \alpha_{1L}\left(\kappa_L M_S\right)^{y1} + & \alpha_{2L}\left(\kappa_L M_S\right)^{y2} \\ -\alpha_{2L}\kappa_H y2\left(\kappa_H M_S\right)^{y2-1} + & \alpha_{1L}\kappa_L y1\left(\kappa_L M_S\right)^{y1-1} + & \alpha_{2L}\kappa_L y2\left(\kappa_L M_B\right)^{y2-1} \end{bmatrix} = \begin{bmatrix} (1-\alpha)\kappa_L M_B - C/r \\ 0 \\ 0 \end{bmatrix}$$

Solving the equations gives $\alpha_{2H}, \alpha_{1L}, \alpha_{2L}$ and substituting in (A1) and (A2) give the desired result. The same logic follows for the firm value. The default barrier solves

$$\left.\frac{\partial\left(F(M) - D(M)\right)}{\partial M}\right|_{M=M_B} = 0\,.$$

Proof of Proposition 2

Leland (1998) shows that the debt capacity of a firm increases as its volatility lessens. The firm that trades has less debt capacity than a firm that produces when the instantaneous variance of the firm value process with trading is lower than the variance of a firm that produces. This requires: $\left[\left(\frac{\lambda}{\theta}\right)^2 + \psi^2 + 2\rho_{qu}\left(\frac{\psi\lambda}{\theta}\right)\right] > \sigma^2$. The firm value maximizing amount of debt is an increasing function of firm value (equation (21), Leland (1998)). As the deadweight cost increases (κ_i declines), the firm value declines or $\frac{\partial F}{\partial \kappa_i} = M_0 > 0$ using firm value equation in Proposition 1. As a result the optimal amount of debt is reduced.

Proof of Proposition 3

The instantaneous second moment of returns in equation (9) is given by:

$$\sigma_y^2 = \left[((1-x)(\sigma))^2 + \left(\frac{x\lambda}{\theta}\right)^2 + (x\psi)^2\right] + \left[2\rho_{qz}(1-x)(\sigma)\left(\frac{x\lambda}{\theta}\right) + 2\rho_{qu}(x\psi)\left(\frac{x\lambda}{\theta}\right)\right] \tag{A3}$$

The set up in Proposition 3 is identical to Proposition 1 for a pure trading firm.

Proof for Proposition 4

A general solution to the debt value is now given by:

$$DH(J_0) = \frac{C}{r} + \alpha_{1H}\left(J^*(0,H)\right)^{y1H} + \alpha_{2H}\left(J^*(0,H)\right)^{y2H} \text{ if } J(t) > J_S \text{ and}$$
$$DL(J_0) = \frac{C}{r} + \alpha_{1L}\left(J^*(0,L)\right)^{y1L} + \alpha_{2L}\left(J^*(0,L)\right)^{y2L} \text{ if } J(t) \le J_S. \tag{A4}$$

where

$y1i = -a_i + b_i$, and $y2i = -a_i - b_i$, $a_i = \dfrac{r - \delta - \dfrac{\sigma_y^2(i)}{2}}{\sigma_y^2(i)}$, $b_i = \sqrt{\dfrac{\left(a\sigma_y^2(i)\right)^2 + 2r\sigma_y^2(i)}{\sigma_y^2(i)}}$, where

$\sigma_y^2(i) = \left[((1-x_i)(\sigma))^2 + \left(\frac{x_i\lambda}{\theta}\right)^2 + (x_i\psi)^2\right] + \left[2\rho_{qz}(1-x_i)(\sigma)\left(\frac{x_i\lambda}{\theta}\right) + 2\rho_{qu}(x_i\psi)\left(\frac{x_i\lambda}{\theta}\right)\right]$ and

i=*H,L*. The boundary conditions in Proof of Proposition (1) remain unchanged. Also, the same applies to the firm value.

Figure 1
Two Sample Paths of Firm Values

The lower sample path illustrates a firm that is unlevered, and the upper path illustrates the sample path of a firm that has leverage and whose value jumps when the unlevered assets cross a switch level beyond which the costs of leverage are low.

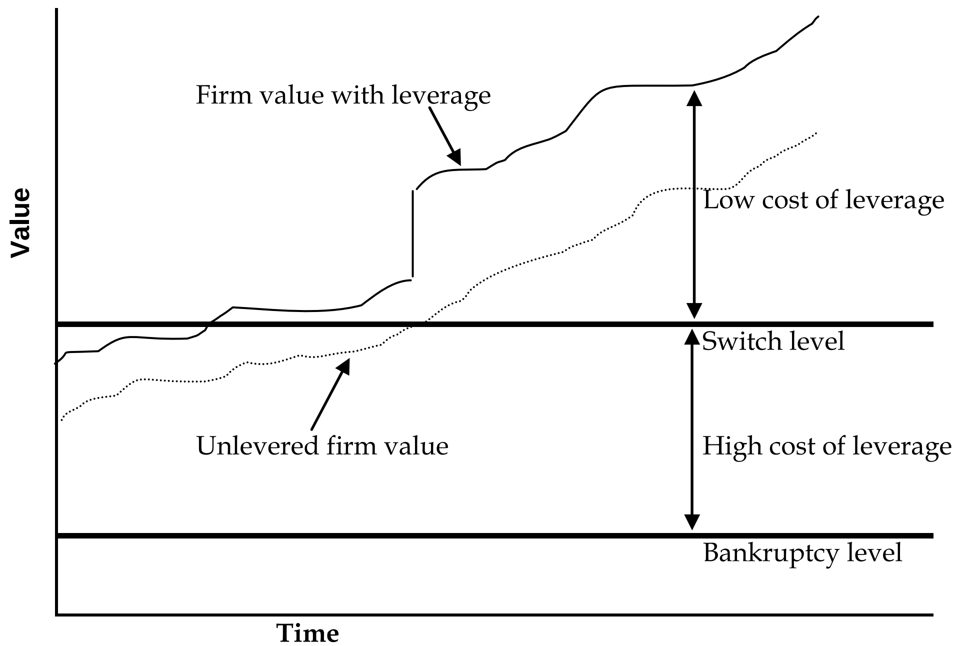

Figure 2
Incremental value from integration

Overall increase in value when a firm integrates its trading and production operations as a function of the proportion invested in trading activities (x). We assume a risk-free rate $r = 0.07$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.4$, deadweight costs in the down state corresponding to a medium feedback effect ($\kappa_L = 0.85$) or low feedback effect ($\kappa_L = 0.97$). There is no penalty in the high state. The total value of unlevered assets of the firm is set at $V_0 = 100$. The switch level is 120. The coupon is set at the value that maximizes the value of the firm at each point.

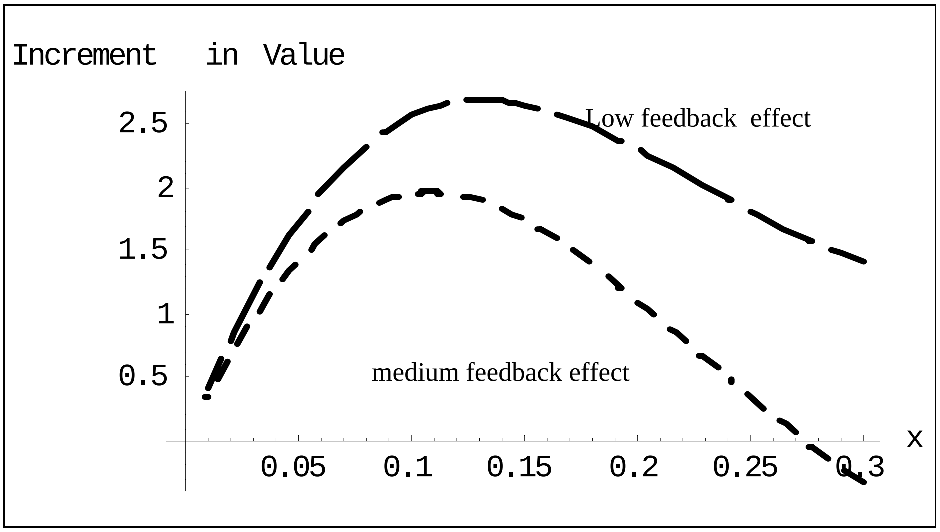

Figure 3
Effect of margin requirements on trading

Firm value when a firm integrates its trading and production operations, as a function of the proportion invested in trading activities (x) when the trades could involve going short or long and with two levels of margin requirements (θ=0.3 and 0.5). We assume a risk-free rate $r = 0.07$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.4$, and the feedback effects of leverage $\kappa_H = \kappa_L = 1$ ($\eta = 0$). The value of unlevered assets of the firm is set at $V_0 = 100$. The coupon is set at the value that maximizes firm value.

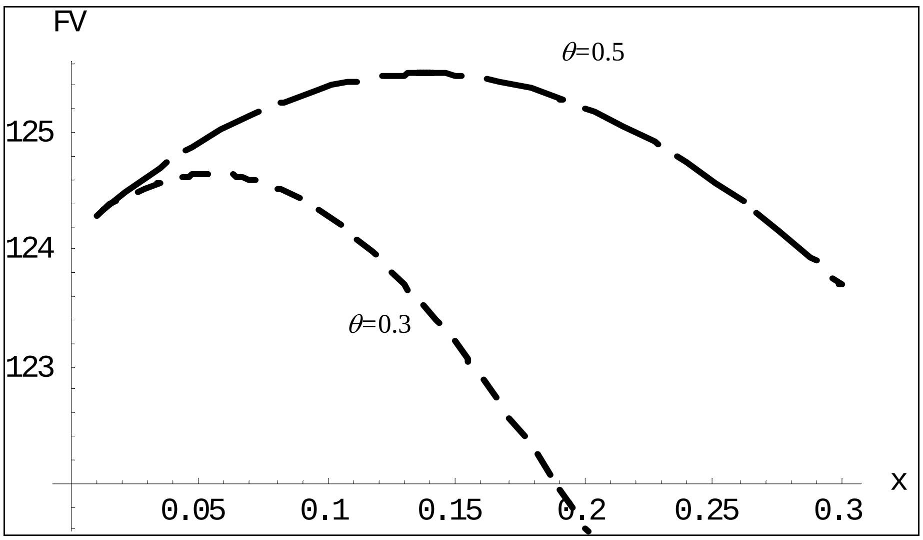

Figure 4

Effect of deadweight costs from combining production and trading

Firm value when a firm integrates its trading and production operations, as a function of the proportion invested in trading activities (x). The margin requirement θ=0.5 and deadweight costs in the down state correspond to a high feedback effect ($\kappa_L = 0.7$), medium effect ($\kappa_L = 0.85$), or low effect ($\kappa_L = 0.97$). We assume a risk-free rate $r = 0.07$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.4$ and the value of unlevered assets of the firm is set at $J_0 = 100$. The coupon is set at the value that maximizes the value of the firm.

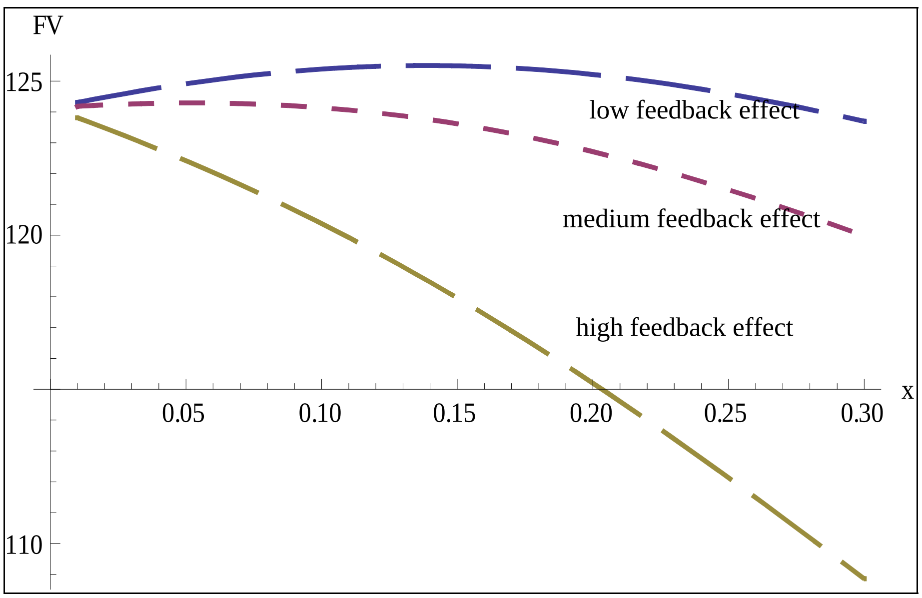

Figure 5
The feedback effect of integration

The price of default insurance for bonds sold by GM and by its subsidiary GMAC, between August and November 2005. Costs are indicated in basis points per year, for a term of 5 years. Data from the Wall Street Journal (November 25, 2005).