Should production and trading activities be separated?

by

Karan Bhanot and Antonio S. Mello[1]

This version: 08/30/06

JEL classification: G13, G33

[1] Department of Finance, College of Business Administration, The University of Texas at San Antonio, 6900 North Loop, 1604 West, San Antonio, TX-78249, and Department of Finance, School of Business, The University of Wisconsin at Madison, 975 University Avenue, Madison, WI 53706-1323. Emails: karan.bhanot@utsa.edu and amello@bus.wisc.edu. We thank John Boyd, Richard Brealey, Ian Cooper, François Ortalo-Magné, John Parsons, Reza Saidi, Sergey Tsyplakov, and seminar participants at the University of Minnesota, University of Wisconsin-Madison, University of South Carolina and the Washington Area Finance Association for many helpful comments and suggestions.

Should production and trading activities be separated?

Abstract

Firms often supplement profits from production by trading in the item that they produce; e.g., oil and electricity. We ask whether firms that engage in both production and trading should keep these two activities together under one corporate entity or separate them into different entities. What is the connection between this choice and the capital structure decision? Our results indicate that firms that engage in both production and trading benefit from diversification, from flexibility in the allocation of capital that improves risk management, and from information spillovers. Separation is preferred when trading revenues are very volatile, and when trading revenues are sensitive to losses in the production arm.

Should production and trading activities be separated?

Many commodity and energy companies and some manufacturing firms regularly engage in trading activities, beyond the firm's normal production operations. These trading activities are conducted through a separately capitalized entity, or through a unit within the same 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. This profit represented 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 had been 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 so as 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 (as opposed to other businesses) because it gives a firm great flexibility in exploiting a core competency or an information

[2] See British Petroleum's annual report for 2004.
[3] Reported by the Associated Press on January 16, 2002.

advantage. A firm can precisely monitor circumstances in its particular realm of production operations and quickly alter or enter and exit a trade. Trading also complements production activities because it provides an avenue to make forward financial exposures, and couple these forward exposures with a portfolio of physical exposures, thus providing flexibility and market completeness.

Trading at a non-financial firm typically occurs when managers in charge of raw material purchases try to take advantage of temporary swings in the prices of some inputs used in production. The treasury department of the firm may also engage in trades to hedge the firm's output. As trading activity expands, the firm may form a trading unit. Its mandate is to generate incremental profits by taking speculative positions in risk variables related to the value of the firm. In many instances, trading turns into a market-making activity. In some cases, such as at Enron and some other energy–producing companies, trading completely replaces production as the main competence of the firm, and the trading unit is often spun-off from the parent company.

The evolution just described raises two interesting questions, the first about organization, and a second about financing. First, under what conditions is it optimal to form separate entities for the production and trading activities of a firm, or integrate them under the same entity? Second, how does the choice of the organization (i.e., integration vs. separation) determine the optimal financing of the activities of the firm?

Separation means that each unit is incorporated independently. Although separate incorporation does not necessarily imply different ownership, it means that the assets and contractual commitments of one entity are not freely transferable to the other entity. 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.

The question we address is how capital should be split between production 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 risk of the cash flows from trading with the risk of the cash flows from production, gives the total risk of the firm's cash flows. Risk carries with it the possibility of incurring deadweight costs, and, therefore, it is the combined risk that determines how much leverage the firm can optimally take, given that leverage affords the firm the usual tax shields but can cause the firm to go bankrupt.

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 capital structure. However, debt in the firm's capital structure 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. Then, a higher debt-to-assets ratio (leverage) produces a lower amount of 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. Hence, it is possible to determine the optimal relative size of each activity.

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, and Refco in 2005 are three examples. By its very nature, trading requires a firm to deal with numerous counterparties. Counterparties must be confident about the sufficiency of a firm's capital, 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. Closely monitoring the positions of a firm is also very costly for counterparties. 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 despite being 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, then 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. This occurs under the following conditions:

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 reduces risk. This, however, requires that the proportion of capital tied up in trading is below some threshold level and also that the correlation between the cash flows is low. Beyond this threshold, the costs of higher risk overcome the benefits of diversification from trading. The benefits of risk reduction in cash flows are valuable and 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. [4]

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 redeployment of capital across 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 in those cases where contracts are too complex, costly to monitor and hard to enforce. Coase (1937) and Willianson (1975) have long established that transaction costs of different kind are a major determinant of organization design.

Third, the sharing of information between production and trading when the activities take place in the same firm helps to increase 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."

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

Open communication also helps prevent each unit from making mistakes (e.g, the problem faced by Ford Motor Company in 2002 mentioned earlier).[5] 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.

Another 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.

These arguments are analyzed in this article, and organized as follows: Section I describes the assumptions of the model. In particular, we outline the process characterizing the value of the firm's assets. We specify the dynamics of the forward contract that the firm can use to hedge. In Section II, the value of the firm that engages in production activities, and its financial claims, is obtained. The firm is partly financed with debt so as to avail the tax benefits of debt. We show that a firm that is engaged primarily in production always opts to hedge in order to increase its debt ratio, and to improve on its tax position, even though

[5] In this instance, the news about potential disruption in supply sources lead 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.

the available forward contract does not provide a perfect hedge. Section III determines the value of a firm that trades, and obtains the value of its claims. Capital structure affects the value of this firm in two ways: through the volume of trading, and through the likelihood of bankruptcy. In Section IV, we 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. Section V discusses the role of private information in the decision to integrate production and trading or to separate them. Section VI outlines some empirical implications and Section VII summarizes the main findings and concludes.

I. Assumptions

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. This helps to determine the optimal allocation of capital between production and trading in an organization, and the optimal choice of capital structure. In this section we specify the dynamics of the production firm, and the dynamics of forward contracts that are used for hedging and trading. These are the primary inputs for our subsequent analysis.

A. Firm value

Following other structural models of finance, we assume that the unleveraged value of a firm, $V(t)$, that produces a single commodity, follows a continuous diffusion process with constant proportional volatility under the objective probability measure[6]:

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

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 exists 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 in 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).

[6] The quantitative approach to modeling a firm's assets and liabilities was pioneered by Black and Scholes (1973), Merton (1974) and extended by Black and Cox (1976) and others.

B. Contracts for hedging and speculation

The firm can use derivative contracts to hedge and to speculate. We use forward contracts to illustrate the effects of hedging and speculative trading. Forward contracts are the most commonly used derivative contract by companies in hedging and speculation, but other contracts could also have been considered. [7]

Assume that there is a forward contract on a commodity with spot price $s(t)$, that follows a continuous diffusion process with constant proportional volatility under the risk neutral measure:

$$\frac{ds(t)}{s(t)} = (r-\delta)\,dt + \nu dz(t) + \gamma dw(t) \tag{2}$$

here r is the risk-free rate, and δ is a convenience yield. Without loss of generality, we assume that the convenience yield on the commodity equals the dividend yield on the unlevered firm, but a different amount could have been considered. In equation (2) dz and dw are the increments of standard Brownian motions; ν and γ are constants, and $\nu > \gamma$. The forward contract is for a fixed maturity $\phi = (T-t)$, and the time t price of the forward contract is given by:

$$f(t) = e^{(r-\delta)\phi} s(t). \tag{3}$$

An application of Ito's lemma yields the dynamics of the forward contract as:

$$df(t) = e^{(r-\delta)\phi} ds(t) - (r-\delta)e^{(r-\delta)\phi} s(t)dt$$

or

$$df(t) = \nu f(t)dz(t) + \gamma f(t)dw(t) \tag{4}$$

[7] See Bodnar, Hayt and Marston (1998).

Note that the process for the forward price in equation (4) is not perfectly correlated with the process for the value of the firm in equation (1). Consequently, if the firm decides to hedge, the hedge is not perfect, and there will be residual risk. An imperfect hedge is necessary to make the problem both interesting and realistic, or hedging could eliminate firm risk completely.

The overall change in value of a firm that hedges its output is given by the sum of the change in unlevered firm value in equation (1) and the cash flows from the forward contracts sold (equation (4)). For simplicity, we assume that the contract available at each instant has the same face value as the value of the firm.

We suppose that equity holders seek to maximize firm value 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.

Because equity holders manage the firm and seek to maximize its overall value, the analysis abstracts from any agency problems between managers and equity holders and between equity holders and bond holders. Agency considerations certainly impact the results, but they are not the primary driver of the choices that we are considering. Later, in section IV, we discuss the effects on the structure of conflicts between equity holders and debt holders.

C. Difference between speculation and hedging

In our analysis we differentiate between a trade for hedging and one for speculation. There are important institutional differences between trades classified for hedging and for speculation. First, in a trade for hedging, the number of forward contracts held (denoted $\Delta(t)$) is less than zero, where the quantity $\Delta(t)$ can be verified without ambiguity to be the hedge ratio that is consistent with maximizing firm value. We require that the number of forward contract sales for hedging $\Delta(t) = \Delta$ is lower than the value of the output.

Trades that are not for hedging can involve market making (matching buyers and sellers of a commodity), or outright sales and purchases (speculation). In market making, the firm finds a buyer and seller and earns a spread by selling to them at differing prices. In trades for speculation, the contract position can exceed the output, and can be either a sale or a purchase. Speculation, because it is not backed by output, requires the posting of collateral equal to a percentage of the contract value (less or equal to 100 percent) for each contract bought or sold. This means that a firm that speculates might be able to leverage its trading position by posting a small amount of collateral instead of the entire amount of the contract value. Later, we use the parameter θ to capture the extent to which a firm levers its trading positions.

Margin or capital requirements for hedging and speculation differ substantially in both exchange-traded contracts and over-the-counter contracts. A review of listed futures contracts on the Chicago Mercantile Exchange and the New York Mercantile Exchange shows that speculator margins exceed hedger margins by 30% and more in many instances. Also, over-the-counter financial products require a much lower margin if the underlying asset is either owned or produced by the hedger.

Conversations with energy and gas producers reveal that most firms maintain a separate system of accounts for their hedging and speculative activities. When they hedge the firms simply sell a number of contracts in the forward market to hedge their outputs. These are hedges against underlying goods produced generally in an amount less than or equal to the values of the outputs. Firms are not required to set aside margin capital because the sales are against goods to be delivered.

The final difference between hedging and speculative trades is that to enter into speculative trades and to perform the role of a market maker requires confidence on the part of counterparties about the financial health of the firm. Therefore, we make the additional assumption that the ability of a speculator to generate trading volume is inversely related to its debt-to-total capital ratio.

Later, in Section III when we analyze the case of the trading firm, we elaborate on this point in detail.

Using equations (1) and (4), we now analyze a firm that engages primarily in production and hedges (Section II). Then, we analyze a firm that engages in trading only (Section III). Finally, we examine the implications of combining the production and trading operations (Section IV).

II. The production firm and the impact of hedging

In this section we consider a production firm with operating assets, when the return on assets is characterized by equation (1). The firm may decide to hedge the returns on its productive assets using forward contracts, characterized by equation (4). At this stage, we depart from Leland (1994) and Leland and Toft (1996) in the formulation of the cash flows of the unlevered firm, in order to incorporate the effects of the cash flows that accrue from hedging. The resulting change in the volatility of cash flows from the decision to hedge affects the optimal proportion of debt and equity in the firm.

We show that a production firm will optimally decide to hedge its output. It does so to reduce the deadweight costs of bankruptcy, and add to the value of its tax shields in the form of additional debt capacity. Thus hedging has value because it allows the conservation of more expensive equity capital, and reduces the expected costs of bankruptcy. In this regard, hedging is an integral element of production. The implication is that all trading for hedging reasons should be integrated with, and not separated from production.

A. Model of a firm that hedges

Suppose the firm hedges by continuously rolling over forward contracts with face value equal to the proportion Δ of the value of firm's assets. The initial investment incurred by the equity holders of the unlevered firm (denoted $H(0)$) equals the value of the firm in the absence of hedging ($V(0)$), because entering into a forward contract does not require the firm to incur a cost.

The hedged firm value at any time, $H(t)$, represents the productive assets of the firm and a short position in Δ forward contracts (recall that the notional value of the forward contract is equal to the firm value). The return on this portfolio is given by the sum of the returns due to the firm's output and the returns from the cash flows from the hedge:

$$dH(t) = dV(t) + \Delta df(t) . \tag{5}$$

Using equations (1) and (4), equation (5) can be evaluated as:

$$dH(t) = rH(t)dt + (\sigma - \Delta\nu)H(t)dz(t) + \Delta\gamma H(t)dw(t) \tag{6}$$

where $0 \leq \Delta \leq \dfrac{\sigma}{\nu}$ and $\nu > \gamma$. The first term on the right-hand side of equation (6) represents the return on assets if the firm is perfectly hedged. The second and third terms represent the impact of hedging. The term $(\sigma - \Delta\nu)$ is the reduction in volatility made possible by hedging, and the last term is the residual risk incurred from entering into the imperfect hedging transaction. The firm cannot perfectly hedge its output with derivatives written on the forward contract. Thus, this setting incorporates in a simple way the residual risk associated with an imperfect hedge[8].

Given the hedged firm value process in equation (6), it is possible to formulate the pricing functions for the value of a hedged and 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 ($H(0)$), 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. Following Leland (1994), 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 H_B, and is exogenous for now. In the numerical examples later, the bankruptcy boundary is endogenously determined.

The value of debt is 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

---

[8] The hedge will trade off the reduction in volatility due to the hedge (corresponding to the

above H_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.

Proposition 1: *The debt value, $D(H_0)$, and firm value, $F(H_0)$, for a levered firm that hedges its output using forward contracts is given by:*

$$D(H_0) = \frac{C}{r}\left(1 - \left[\frac{H_0}{H_B}\right]^{-X}\right) + (1-\alpha)H_B\left[\frac{H_0}{H_B}\right]^{-X} \tag{7}$$

$$F(H_0) = H_0 + \frac{\tau C}{r}\left[1 - \left(\frac{H_0}{H_B}\right)^{-X}\right] - \alpha H_B\left[\frac{H_0}{H_B}\right]^{-X} \tag{8}$$

$$\text{where } X = a + b,\ a = \frac{r - \delta - \frac{\sigma_y^2}{2}}{\sigma_y^2},\ b = \sqrt{\frac{\left(a\sigma_y^2\right)^2 + 2r\sigma_y^2}{\sigma_y^2}}, \tag{9}$$

$$\text{and } \sigma_y^2 = (\sigma - \Delta\nu)^2 + \Delta^2\gamma^2 \tag{10}$$

Proof: See Appendix.

The term $\left[\frac{H_0}{H_B}\right]^{-X}$ is related to the risk-neutral probability that the hedged 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, $\left(1 - \left[\frac{H_0}{H_B}\right]^{-X}\right)$, plus the payoffs ($\alpha H_B$) if the firm goes bankrupt times the probability of going bankrupt. Similarly, the firm value is

term $(\sigma - \Delta\nu)$), against the increase in cross hedge risk from entering into the hedge $(\Delta\gamma)$.

the unlevered firm value, H_0, plus the tax shield, $\frac{\tau C}{r}$, times the probability of receiving this tax shield benefit, and minus the bankruptcy cost, αH_B, times the probability of going bankrupt.

B. Impact of hedging

Note that the effect of hedging is that it reduces the probability that the firm will go bankrupt by lowering the firm's asset volatility, and correspondingly increasing the function X in equation (9). For example, when $\sigma = 0.4$, $\nu = 0.3$, and $\gamma = 0.1$, a hedge ratio of $\Delta = 0.3$ changes the volatility of the firm value from 0.4 to 0.31 according to equation (10). This reduces the possibility of the firm going bankrupt through an increase in the value of *X.* All else equal, hedging also reduces the boundary H_B at which equity holders find it optimal to declare bankruptcy.

An optimally levered firm that hedges is therefore able to conserve equity or to take on more debt, and add to the tax benefits that accrue from debt financing. Alternatively, the firm's borrowing costs are lower for the same amount of debt raised. These effects motivate corporate hedging, making hedging an integral part of the production activities of the firm.

Proposition 2: *Hedging increases the value of the firm, the debt capacity of the firm, and reduces bankruptcy costs.*

Proof: See Appendix

Thus, hedging is an integral part of production activities. In our initial setting, firm value increases with hedging until a point, because residual risk becomes important. This gain in firm value to this point is attributable to an increase in the tax benefits of debt and a reduction in the bankruptcy costs. A more realistic description would include some form of cost to hedge, which would result in lower hedging. However, the main point is that hedging is preferred to no hedging.

C. Should hedging operations be separated?

The fact that a production firm should always hedge does not necessarily imply that activities related to production and hedging should always be part of one entity. Although it is correct that hedging requires knowledge of the level of production, it can be argued that as long as there is perfect communication between the production unit and the unit responsible for the hedging activities, the two could operate entirely separately. Indeed, the benefit hedging achieves in reducing volatility can be accomplished either way. So is it better to separate the two activities (production and hedging) or integrate them in the same firm?

The primary benefit of keeping both activities within the same firm is that the diminished volatility of the joint cash flows reduces the chance that the firm will go bankrupt, and this increases the overall debt capacity and value of the firm. However, only when the production unit has free disposition of the cash flows from the hedging operation it is possible that hedging reduces the likelihood of bankruptcy. Even with perfect communication this benefit would not occur if the activities were separate. And even in the case of full ownership of the combined entity, separation occurs as long as the creditors and counterparties in each unit are able to impose restrictions on the free flow of cash across different units.

Furthermore, there is no collateral requirement when hedging is undertaken against production when the activities are carried out under one common entity. If the firm's production and hedging are separate, a collateral requirement would lock up a portion of the capital for the hedging activities, because production assets in hedging would not be able to be pledged. Thus, separation of hedging and production incurs costs but at no potential benefits.

Remark : *It is optimal for a firm to keep its production and hedging operations under one corporate entity.*

Note also that hedging activities cannot be delegated to the firm's investors. In other words, if the firm does not hedge, it is not possible for investors to replicate a hedge on their own account. This is because of the friction induced by bankruptcy costs that are particular to the firm.

III. The trading firm

We now turn to the case of a purely trading operation. The trading firm earns a spread by matching buyers and sellers of financial contracts on the commodity, thus performing the role associated with market-making. Such market making activities are typical of the trading arms of commodity producing companies. At times, the trading arm may not be able to cover a purchase or sale (termed speculation). Speculation increases the volatility of earnings of the firm and may induce a correlation between the returns of the trading firm and the dynamics of the underlying commodity.

A. Model of a firm that trades

Suppose that amount of capital allocated to market making and trading is denoted $M(t)$. Assume that the returns to this trading activity (under the risk neutral measure) are given by:

$$dM(t) = (r - \delta)M(t)dt + \frac{\lambda}{\theta}M(t)dq(t)\,. \tag{11}$$

where λ is the volatility of earnings from market making activities, $dq(t)$ is the increment to a Brownian Motion, r is the risk free rate 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 when it buys (or sells) forward contracts but does not cover its purchase (or sale) by locating a party on the other side of the transaction immediately. If counterparties do not extend any credit to the trader, $\theta = 1$, the maximum position the trader can take is determined by the availability of its own capital, *M(t)*. 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 doubles the volatility of its earnings.

Trading in the forward contracts also induces correlation between trading returns and those of the forward contract: $Corr(dq(t), dw(t)) = \rho_{qw}$ and $Corr(dq(t), dz(t)) = \rho_{qz}$.

Anecdotal evidence suggests that the willingness of market participants to enter into transactions with a trading company that engages in market making activities depends on the company's credit rating. Counterparties limit exposures and eventually shy away from trading with less financially stable companies. This could be because of costly monitoring of the trader's positions by counterparties or their inability to enforce the terms of trading contracts in the event of distress. Therefore, we make the additional assumption that the trading company's ability to generate market making business is inversely related to its debt-to-total capital ratio.

To represent the dependence of the cash flow volume from market making activities on the firm's amount of debt, we assume that the operating value of a leveraged trading company is reduced by a factor κ that depends on the amount of leverage outstanding. Assume $0 < \kappa = 1 - \eta \frac{C}{M_0} \leq 1$, or that κ equals one minus the coupon flows (*C*) relative to the operating value of the assets of the trading firm, M_0, times a constant η (the trading penalty for having debt on the books). Now using equation (11), we can define the firm value process when part of the market making is funded with debt (at the outset):

$$d\left(\kappa M(t)\right) = (r - \delta)\kappa M(t)dt + \frac{\lambda}{\theta}\kappa M(t)dq(t). \tag{12}$$

If there is no debt in the trading company ($\kappa = 1$), there is no reduction in the operating value of the trading firm. The term κ represents an up-front and instantaneous loss in value. The process in equation (12) continues without limit unless the trading firm value falls to a default-triggering value.

We can now compute the value of the firm that trades -meaning 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 that occur with 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, selling debt 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 large (equivalently, a small κ), the trading company will reduce the amount of debt on its books.

Proposition 3: *The debt value $D(\kappa M_0)$ and firm value $F(\kappa M_0)$ for a firm that speculates with forward contracts and also offers market making is given by*

$$D(\kappa M_0) = \frac{C}{r}\left(1 - \left[\frac{\kappa M_0}{M_B}\right]^{-X}\right) + (1-\alpha) H_B \left[\frac{\kappa M_0}{M_B}\right]^{-X}$$

$$F(\kappa M_0) = \kappa M_0 + \frac{\tau C}{r}\left[1 - \left(\frac{\kappa M_0}{M_B}\right)^{-X}\right] - \alpha H_B \left[\frac{\kappa M_0}{M_B}\right]^{-X}$$

$$\textit{when} \quad X = a + b,\ a = \frac{r - \delta - \frac{\sigma_y^2}{2}}{\sigma_y^2},\ b = \sqrt{\frac{\left(a\sigma_y^2\right)^2 + 2r\sigma_y^2}{\sigma_y^2}},\ \sigma_y^2 = \left(\frac{\lambda}{\theta}\right)^2,$$

$$0 < \kappa = 1 - \eta \frac{C}{M_0} \leq 1.$$

Proof: See Appendix.

The default triggering value is denoted M_B. Note that the volatility of the firm value process (σ_y) is inversely proportional to the extent that the firm speculates, captured via the parameter θ. Roughly, open trading positions corresponding to $\theta = 20\%$ relative to 100% make firm value five times more volatile. More open trading positions and contracts makes 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 have 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.

B. Contamination effect of debt

If the costs of debt in the capital structure in terms of lost market making activity (equivalent to a small value of κ) exceed the benefits of debt (the tax shields net of bankruptcy costs), the trading firm will be funded essentially with equity rather than debt. For example, 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 trading for having debt, i.e., $\kappa = 1$. Assume risk-free rate $r = 0.07$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.5$, asset volatility $\lambda = 0.3$, and θ=0.2. For a firm partly funded with debt, the coupon amount that maximizes firm value gives a debt value of approximately 52.6 (and a firm value of 108.5). In this case, the benefit of debt is equal to 8.5% of the value of the operating assets of the trading firm. If there is a penalty of debt on the cash flow from trading corresponding to $\kappa = 0.9$, the firm will optimally decide to carry no debt on its books to mitigate the effect on the lost trading activity driven by a lower credit rating and a loss in the value of the firm. The results can be summarized in the proposition:

Proposition 4: *A trading firm that speculates and provides market making activities has less leverage in its capital structure than a firm that engages in production under the following conditions:*

(1) When the cash flows of the speculative part of the trading operation are more volatile than the cash flows from production.
(2) When the presence of debt in the capital structure results in a reduced volume of market making activities. This diminishes the value of the trading firm.

Proof: See Appendix

Proposition 4 states that firms that engage primarily in market making and speculative trading are capitalized predominantly with equity rather than debt. This is consistent with the findings by Shivdasani and Zenner (2005), who report that financial firms, with a median credit rating of A, operate with stronger ratings that non-financial firms, which have a median rating of BBB. We believe that due to their inherently risky nature, firms that engage in pure trading activities ought to have an even higher rating than the median financial firm.[9]

It is often the case in OTC contracts that the margin required for trading (or the ability to lever) depends on the strength of the trading firm's balance sheet. Thus, a firm with a larger capital base, because it integrates production and trading, may benefit from having to post less collateral than a firm that devotes all its capital solely to trading activities. We return to this aspect in the next section.

IV. A firm that produces and trades

Next we analyze the case of a firm that produces a commodity and hedges using forward contracts, and also allocates some of the firm's own capital to trading activities (market making and speculation). This framework allows us to illuminate the drawbacks and benefits of combining production and trading operations under one corporate entity, and to determine the optimal relative size

[9] See Shivdasani and Zenner (2005), page 27.

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

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:

$$J(t) = H(t) + M(t),$$

where the capital $H(t)$ is employed in production (with hedging), as in Section II, and $M(t)$ is employed in trading activities, as in Section III. The return on this portfolio of activities is the sum of the returns due to the production output, the returns from the cash flows due to a hedge, and the returns due to the trading operations.

Suppose first that the firm's policy is to allocate a fixed proportion (denoted x) of the firm equity capital to speculative trades and to invest the balance in its production operations. Later we solve for the optimal allocation (x) of capital between production and trading:

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

The capital $H(t) = (1-x)J(t)$ is allocated to production activities, while the capital $M(t) = xJ(t)$ is allocated to trading activities. The returns on the total portfolio are equal to the returns on the proportion of the investment in the production operations and the balance in trading. Substituting equations (6) and (12) into (13) , we get:

$$dJ(t) = (1-x)\left[(r-\delta)J(t)dt + (\sigma - \Delta\nu)J(t)dz(t) + \gamma\Delta J(t)dw(t)\right] + x\left[(r-\delta)\kappa J(t)dt + \left(\frac{\lambda\kappa}{\theta}\right)J(t)dq(t)\right] \tag{14}$$

Simplifying equation (14) gives:

$$\frac{dJ^*(t)}{J^*(t)} = (r-\delta)dt + \left[\frac{(1-x)(\sigma-\Delta\nu)}{\nu}\right]\nu dz(t) + \left[(1-x)\Delta\right]\gamma dw(t) + \frac{x\lambda}{\theta}dq(t) \tag{15}$$

where $J^*(t) = (1 - x + x\kappa)J(t)$.

The returns on the assets of the firm are made of four components. The first term on the right-hand side of equation (15) is the return on a completely hedged firm, and equals the risk-free rate minus any payouts to claimholders. The second term is the shock to firm value from the proportion of unhedged risks of the production side of the firm. The third term is the contribution to firm risk from the residual risk from hedging, $(1-x)\Delta\gamma$. The last term is the risk from the market making activities and the speculative position in the trading part of the firm. To characterize the overall resulting change in firm value, we define a new Brownian motion $y(t)$ so that it matches the instantaneous first and second moments of the returns, when the returns are given by equation (15) (see Appendix). Now the resulting change in firm value is given by:

$$dJ^*(t) = (r-\delta)J^*(t)dt + \sigma_y J^*(t)dy(t)$$

where

$$\sigma_y^2 = \left[\left((1-x)(\sigma - \Delta\nu)\right)^2 + \left((1-x)\Delta\gamma\right)^2 + \left(\frac{x\lambda}{\theta}\right)^2 \right] + \left[2\rho_{qz}(1-x)(\sigma-\Delta\nu)\left(\frac{x\lambda}{\theta}\right) + 2\rho_{qw}\left((1-x)\Delta\gamma\right)\left(\frac{x\lambda}{\theta}\right) \right] \tag{16}$$

and $J^*(t) = (1 - x + x\kappa)J(t)$.

Note that the impact of the capital allocation between production and trading affects the volatility of the firm value process (denoted σ_y^2). An optimal allocation of capital will minimize the volatility σ_y^2, if there is no penalty for debt. Before we characterize the optimal proportion of the capital allocation, we compute the debt value and firm value, following the approach in section III. 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 the residual cash flows that are 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 5: *For a firm that both produces and trades, the debt value $D(J_0^*)$ and the firm value $F(J_0^*)$ are given by:*

$$D\left(J_0^*\right) = \frac{C}{r}\left(1 - \left[\frac{J_0^*}{J_B}\right]^{-X}\right) + (1-\alpha)H_B\left[\frac{J_0^*}{J_B}\right]^{-X}$$

$$F\left(J_0^*\right) = J_0^* + \frac{\tau C}{r}\left[1 - \left(\frac{J_0^*}{J_B}\right)^{-X}\right] - \alpha H_B \left[\frac{J_0^*}{J_B}\right]^{-X}$$

$$X = a + b,\ a = \frac{r - \delta - \frac{\sigma_y^2}{2}}{\sigma_y^2},\ b = \sqrt{\frac{\left(a\sigma_y^2\right)^2 + 2r\sigma_y^2}{\sigma_y^2}}, \tag{17}$$

$J^*(t) = (1 - x + x\kappa^*)J(t)$, and σ_y^2 is given in equation (16). J_B is the default triggering value is denoted.

Proof: See Appendix.

B. The effect of changing the allocation of capital between production and trading

Note that the proportion of the firm capital allocated to trading activities, denoted by *x*, changes the bankruptcy costs, as well as the results of operating the trading function. 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 and consequently reduce the debt capacity and limit the associated tax benefits. The amount of debt-to-total capital also affects *x,* since more leverage limits the extent of market making activity and constraints the value of the trading arm. There is an optimal amount in the trading operation that is linked to the optimal capital structure that maximizes the value of the integrated firm, and solves the constrained maximization problem:

$$\operatorname*{Max}_{x,0 \le x \le 1}\left(F\left[x \mid J_0, \theta, \eta, \sigma, r, \delta, \lambda, \nu, \kappa, C\right]\right) \tag{18}$$

where F is the firm value given in Proposition 5, for an endogenously chosen level of trading, *x*, and an endogenous bankruptcy threshold, J_B.

In the absence of any trading penalty due to debt ($\kappa = 1$), the optimal allocation (denoted x^*) is the allocation that minimizes the asset volatility σ_y^2 in Proposition 5. If there is a trading penalty due to debt, the optimal allocation of capital devoted to trading, x^*, is less than this volatility-minimizing value. Then, we have that the optimal allocation in trading is such that:

$$0 \leq x^* \leq \frac{\theta\left[\Delta^2\theta\left(\nu^2+\gamma^2\right)+\sigma^2\theta+\Delta\nu\left(\lambda\rho_{qw}-2\sigma\theta\right)-\lambda\left(\Delta\gamma\rho_{qz}+\sigma\rho_{qw}\right)\right]}{\lambda^2+2\lambda\rho_{qw}\theta\left(\Delta\nu-\sigma\right)+\theta^2\left[\sigma^2+\Delta^2\left(\gamma^2+\nu^2\right)-2\Delta\sigma\nu\right]} \tag{19}$$

Equation (19) allows us to analyze the impact of the various parameters on the optimal allocation of the firm's capital to trading. Figure 1 illustrates the optimal allocation to trading as a function of the risk of the firm's production operations and the risk of the forward contract used in trading. An increase in the volatility of the forward contract increases the risk of the trading operations, which reduces the optimal allocation to trading. The optimal allocation of capital to trading increases as the firm's production assets volatility (σ) increases. To achieve the benefits of diversification through trading when the production assets of the firm are inherently risky, the equity holders will optimally decide to allocate a greater proportion of capital to trading. Also, as the extent of speculation increases (θ declines), the optimal allocation to trading declines. When counterparties to trading require less collateral, the firm needs to allocate less capital to the trading part of the business to reach the volatility level that maximizes firm value.

Proposition 6: *As the volatility of returns from productive assets increase, there is a higher amount of capital allocated to trading activities, i.e.,* $\frac{\partial x^*}{\partial \sigma} > 0$. *Also, as the extent of speculation increases (*θ *declines), there is less allocation to trading, i.e.,* $\frac{\partial x^*}{\partial \theta} > 0$

Proof: See Appendix.

C. Separation vs. Integration

To focus on the issue of combining the trading and production operations versus keeping them separate, Figure 2 plots of the increase in firm value when the firm is integrated compared to when it is separated into two entities. In each case, we compute the firm value-maximizing coupon and then compute the accretion in firm value of the combined entity compared to the non-integrated entity. We see in Figure 2 that as the firm puts more of its capital into trading (parameter *x*), initially the benefits of integration are greater than the deadweight costs. Once the weight in trading exceeds a certain amount, though, the costs of integration outweigh the benefits. The effects of the penalty on trading for having debt are also evident. A firm that loses more value in its trading operations because of having debt in the capital structure has less advantage in integrating the two activities –trading and production.

To describe the effect of speculation, Figure 3 plots the 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 $\theta = 0.8$) while the lower one gives the firm value when the firm speculates more ($\theta = 0.6$). We set the trading penalty for debt to $\eta = 0$ ($\kappa = 1$) in both cases. Also, the coupon is set to maximize firm value for each value of x. First, note that both firms experience 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 the speculative activity is large, 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 increased costs of bankruptcy and reduced debt capacity.

The point at which it is beneficial to separate production and trading depends critically on several parameters: the volatility of the operating assets and of the derivatives contract, the margin requirements in trading, the deadweight costs of bankruptcy, and the loss of trading business due to leverage. The analysis herein shows that for a trading operation that is not very volatile (the case of ancillary operations), 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 not a large amount of capital is allocated to trading, integrating even a risky trading operation with a less risky production operation may be optimal. The reason is that trading positions are in general imperfectly correlated with commitments made by the production side of the firm, and the aggregate result is a less risky firm that integrates the two businesses. The firm performing the two (imperfectly correlated) activities faces less risk than the collection of separate activities operating independently, and therefore can save on the deadweight costs of bankruptcy.

Furthermore, a combined operation lets a business allocate capital, x, in a flexible manner that maximizes firm value. Suppose the 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 but flexibility in combination with the bankruptcy barrier that induces the benefits of integration.

D. Integration and the flexibility in allocation of capital

How does flexibility in allocating capital between the two activities work? Numerical simulations show that when the values of the two activities are high, more capital can be allocated to trading as firm value is far from the bankruptcy threshold and the trading penalty due to leverage is low. The opposite occurs when the values of production and trading are both low, in which case x is reduced. 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. 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]

E. Integration and the contamination effect of debt

The willingness of market participants to trade with a levered firm also has an impact on the optimal division of capital between production and trading. The overall change in firm value because of the effect of the debt penalty, η,

[10] Ex-post inefficient bargaining over the allocation of capital also favors integration over separation.

depends on the proportion of firm capital that is devoted to speculative trading. As more capital is employed in trading activities, this trading penalty increases in the same proportion, but the diversification benefits do not increase, and may even decline. This leads to the proposition:

Proposition 7: *Integration of production and trading can reduce deal flow to the market making activities of the trading entity. This reduces the profitability of the trading operation and the allocation of capital to trading. The allocation of capital to trading will also be reduced if there is a greater trading penalty due to leverage.*

Proof: See Appendix.

Figure 4 plots the firm value for two values of this penalty, $\eta = 0.5$ and $\eta = 1$. When the penalty for debt is lower ($\eta = 0$), a higher trading amount is optimal than when the penalty is higher ($\eta = 0.1$). At some level of η, there is no advantage of keeping the two activities together, and value is maximized if they are kept separate.

We have said that one advantage of combining production and trading under the same firm is that the strength of the joint balance sheet may reduce the margin requirements, θ. At the same time, there is a risk that a negative shock to one business can reduce the value of the other business. Trading businesses are particularly sensitive to losses in the production side of the business because of an increased likelihood of bankruptcy, and a decline in the value of the firm. Because the proportion of the 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 therefore the size of the positions it can take. Moreover, the higher leverage that occurs with a decline in firm value limits the ability of the trading operation to generate counterparty business, as η (or κ) is related to the leverage ratio.[11] Therefore, a decline in the value of production operations can have a powerful feedback effect on the value of the trading part of the business. Although poor trading can also contaminate production, the trading unit is much more sensitive to bad results in production.

This contamination effect is evident in Figure 5, which plots the value of default insurance of General Motors and its subsidiary, 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 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 dropped almost to 2 percentage points a year in the days after GM said it would sell GMAC, the lowest level since January 2005. It since climbed again, more than doubling, to 4.12 percentage points a year in mid-November 2005, after the

[11] The effect is reinforced if the level of margin, θ, is a function of the firm's leverage ratio C/J_0.

markets realized that a search for the financing arm would take longer than anticipated.

In our analysis we have abstracted from any agency considerations. When equity holders maximize equity value instead of total firm value, two differences occur: first, the amount of hedging in production declines, and, second, more capital is allocated to speculative trading activities. According to equation (16), with less hedging and more capital allocated to trading (when trading is riskier than production)[12], the overall firm cash flows will become more volatile. For a trading entity that primarily speculates, the margin requirement determines the risk of the trading operation. If the firm's trading and production operations are split, agency costs decline because the overall bankruptcy costs of taking more risk in the trading entity would not spill over to the production side of the business. Similarly, the reduced incentives to hedge the production activities will not spill over to the trading side of the firm. Therefore, agency conflicts between equity holders and debt holders would suggest that the operations be split into separate entities.

---

[12] Trading is more risky when: $\left(\frac{\lambda}{\theta}\right)^2 \geq (\sigma - \Delta\nu)^2 + \Delta^2\gamma^2$.

V. 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 on 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 own 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 rewrite equation (1) as:

$$\frac{dV(t)}{V(t)} = (\mu - \delta)dt + dp(t) + dk(t) \tag{20}$$

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

$$dk(t) = \sqrt{1-\rho^2}\,\sigma_2 dz_2(t)\,. \tag{21}$$

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

Price changes in the forward contract used in trading are given by $df(t) = vf(t)dz(t) + \gamma f(t)dw(t)$. We can modify this characterization of changes in the forward contract price so that the specification is identical to that in equation (6), except that the 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:

$$df(t) = f(t)\sigma_1 dz_1(t) + f(t)\rho\sigma_2 dz_2(t) + \gamma f(t)dw(t) \tag{22}$$

Suppose the trading operation has full knowledge about the shock *dk(t)*, and the trading position reflects this private information. 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 $\sigma_1^2 + \gamma^2$. This is less 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:

$$\delta^* = E\left[\rho\sigma_2 \mid dq \mid\right] = \rho\sigma_2\sqrt{\frac{2}{\pi}}dt, \tag{23}$$

for each forward contract.

Proposition 8: *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.*[13]

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: $x \times J \times \delta^* \times 17 = .05 \times 100 \times .012 \times 17 = 1.02$ (of the same order as the incremental return). It is likely that the type of firms that benefit from such information spillovers are ones that dominate the industry, and are large in size.

Of course, increased returns from trading would imply that the proportion of firm capital employed in trading should increase beyond its optimal level (x^*), characterized earlier. 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 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

[13] 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 information flow and its effects would occur in both directions.

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 ($J^*(t) = (1 - x + x\kappa)J(t)$) in Proposition 5, 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: $J^*(t) = (1 - x + x\kappa + e^{-ax}b\rho)J(t)$, 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 ($x\kappa$) and a higher volatility of 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 its debt capacity, and increase deadweight costs related to trading. Such costs would offset the increased revenue possibilities. The decline in firm value from deviating from the optimal x^* is given by Proposition 5. 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, trading operations may be able to generate a profitable trade using this information. If the production operations are able to be adjusted their 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 offer financial products that are not offered by purely financial firms. In the words of an executive at a leading commodity producer[14]:

> "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. Consistent with this notion, Morgan Stanley bought energy producer and trader Entegy-Koch in September 2004 to better manage the risks inherent in its energy trading operations. 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.[15]

VI. Empirical Implications

Our discussion yields several interesting implications for non-financial corporations with trading operations. A first empirical implication is that the organization structure (whether a trading business is integrated or a separate

[14] See Financial Times (10/12/2005): "Top Team Helps to Offset Rising Costs".
[15] See Financial Times (11/22/2005) : "Top Team Helps to Offset Rising Costs".

entity) can be explained by the set of factors outlined in Section V. Amongst these, the relative size of the trading operation (average earnings attributable to trading), the extent of leverage used by the traders (volatility of trading revenues), the importance of information from the production side (nature of the business) are some of the primary determinants. Thus, a compilation of data on firms that have spun off their trading arm vs. those that have kept it integrated, together with these set of variables should have explanatory power.

A practical implication of our study is the manner in which the 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 occurs because the separate trading entity may be able to generate larger 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 is possible to estimate the extent to which integration or separation changes the overall firm value, 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.

VII. Summary and conclusions

Many commodity and manufacturing firms speculate in the commodities that are either inputs in or outputs 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 reallocating capital between the two businesses improves risk management. We find that the benefits of integrating a high-risk trading business with production arise when a relatively low proportion of capital is tied up in trading.

The arguments in favor of separation come from the very different cash flow profiles of the two activities, production and trading, and how this relates to the difficulty of merging under the same firm activities that require very different capital structures. The point at which it is beneficial to separate production completely from trading and incorporate them into separate entities depends critically on the volatility of the operating assets, the volatility of the derivative contract, the volatility of the speculative part of trading and 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 their ability to generate business should be spun off 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 array of businesses faced with the challenge of managing the risk of both their core business and associated trading operations. A direct implication of our paper is that both the risk profile of the cash flows and their dependence on the credit rating of the parent company determines whether the a business segment should be spun off or kept as a part of the parent. Thus, from an empirical perspective, 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 the occurrence of spin offs and the incorporation of new businesses as separate entities.

References

Alderson, D., J. C. Doyle, L. Li, and W. Willinger, 2004, More normal than normal: Scaling distributions and complex systems, Proceedings of the 2004 Winter Simulation Conference.

Black, F., and J. C. Cox, 1976, Valuing corporate securities: Some effects on bond indenture provisions, *Journal of Finance* 31, 351-367.

Black, F., and M. Scholes, 1973, The pricing of options and corporate liabilities, *Journal of Political Economy* 81, 637-659.

Bodnar, G., G. Hayt, and R. Marston, 1998, Wharton survey of derivatives usage by U.S. non-financial firms, *Financial Management* 27, 70-91.

Coase, R., 1937, The Nature of the Firm, *Economica,* 4, 386-405.

Goldstein, R., N. Ju, and H. Leland, 1997, Endogenous bankruptcy, endogenous restructuring, and capital structure choice, *Working Paper, University of California, Berkeley*.

Karlin, S., and H. M. Taylor, 1975. *A first course in stochastic processes* (Academic Press, New York).

Leland, H. E., 1994, Corporate debt value, bond covenants and optimal capital structure, *Journal of Finance* 51, 1231-1252.

Leland, H. E., and K. B. Toft, 1996, Optimal capital structure, endogenous bankruptcy, and the term structure of credit spreads, *Journal of Finance* 51, 987-1019.

Merton, R. C., 1974, On the pricing of corporate debt: The risk structure of interest rates, *Journal of Finance* 29, 449-470.

Robinson, E., 1958, The Structure of Competitive Industry, *University of Chicago Press.*

Williamson, O., 1975, Markets and Hierarchies: analysis and antitrust implications, *Free Press, New York*.

Appendix

Proof for Proposition 1:

The return process for the firm is given by (equation (5)):

$$dH(t) = (r-\delta)H(t)dt + (\sigma - \Delta\nu)H(t)dz(t) + \gamma\Delta H(t)dw(t)$$

Define a random variable y so that $dy(t) = (\sigma - \Delta\nu)dz(t) + \gamma\Delta dw(t)$ and $y(0) = 0$. Then, the instantaneous expectation of dy is 0, and the instantaneous variance is $\sigma_y^2 = (\sigma - \Delta\nu)^2 + \Delta^2\gamma^2$, and $y(t)$ is a Brownian motion (Chapter 7, Section 6 of Karlin and Taylor (1975)).

The remainder of the results are from Leland (1994) and Leland and Toft (1996). In the absence of any debt, the firm value is equal to the unlevered value H_0. The equity holders sell a stake in the firm to debt holders   Assume that debt is sold only once at time 0. Consider debt sold at time zero by equity holders, with infinite maturity and a constant coupon flow C. The cash flow requirements for the coupon payments are met by selling additional equity. Then, using risk-neutral valuation, the price of debt at time 0 is written as the sum of the expected present value of:

(a) Coupon flows if the firm value remains above , H_B.

(b) The bankruptcy payouts if the firm value crosses H_B and

When the drift rate is the risk free rate, the debt value can be written as:

$$D(H_0) = \int_0^\infty e^{-rt} C[1 - G(t, H_0, H_B)]dt + \int_0^\infty e^{-rt}(1-\alpha)H_B\, g(t, H_0, H_B)dt \qquad \text{(A1)}$$

where $g(s, H_1, H_2)$ denotes the density of the first passage time s from a level V_1 to firm value H_2 (correspondingly $G(s, H_1, H_2)$ is the cumulative distribution function of the first passage density from H_1 to H_2). An evaluation of equation (A1) gives:

$$D(H_0) = \frac{C}{r}\left(1 - \left[\frac{H_0}{H_B}\right]^{-X}\right) + (1-\alpha)H_B\left[\frac{H_0}{H_B}\right]^{-X}$$

(A2)

where $X = a + b$, $a = \dfrac{r - \delta - \dfrac{\sigma^2}{2}}{\sigma^2}$, and $b = \sqrt{\dfrac{(a\sigma^2)^2 + 2r\sigma^2}{\sigma^2}}$.

Debt issuance affects the total value of the firm in two ways. First, it reduces firm value because of possible bankruptcy. Second, it increases firm value due to the tax deductibility of the interest payments.

$$BC(H_0) = \int_0^{\infty} e^{-rs} \alpha H_B g(s, H_0, H_B) ds = \alpha V_B \left[\frac{H_0}{H_B} \right]^{-X} \tag{A3}$$

$$TB(H_0) = E\left[\int_0^{\infty} \tau e^{-rs} C[1 - G(s, H_0, H_B)] ds \right]$$

$$= \frac{\tau C}{r} - \left[\frac{\tau C}{r} \right] \left[\frac{H_0}{H_B} \right]^{-X} \tag{A4}$$

Firm value is given as the sum of the unlevered firm plus tax benefits minus bankruptcy costs:

$$F(H_0) = H_0 + \frac{\tau C}{r} \left[1 - \left(\frac{H_0}{H_B} \right)^{-X} \right] - \alpha H_B \left[\frac{H_0}{H_B} \right]^{-X} \tag{A5}$$

Again, it is important to note that firm value is altered by the presence of trading because it alters the probability of default. Equity value is the residual stake in the firm and is equal to the firm value minus the debt value (A5)-(A2).

Proof for Proposition 2

The instantaneous variance of the firm value process with hedging is given by: $\sigma_y^2 = (\sigma - \Delta \nu)^2 + \Delta^2 \gamma^2$. Thus, hedging reduces the volatility of the firm value process when $\sigma_y^2 < \sigma^2$, or when $\Delta^2 \nu^2 + \Delta^2 \gamma^2 > 2 \Delta \nu \sigma$. From (A5), $\frac{\partial F}{\partial \sigma^2} < 0$. Leland (1994, pp. 1225) shows that the debt capacity of a firm increases as the volatility declines. Also, the less volatile the firm, the lower the bankruptcy costs ($\frac{\partial BC}{\partial \sigma^2} < 0$ from equation (A3)).

Proof for Proposition 3

The firm value process is given by equation (12). Then, the framework is identical to Proposition 1 with firm volatility $\sigma_y^2 = \left(\frac{\lambda}{\theta} \right)^2$ and drift $= (r - \delta)$.

Proof for Proposition 4

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: $\left(\frac{\lambda}{\theta}\right)^2 \geq (\sigma - \Delta\nu)^2 + \Delta^2\gamma^2$ and $0 \leq \theta, \Delta \leq 1$. The relationship between debt capacity and asset volatility is discussed in the proof of Proposition 3. Also, from Proposition 3, as the deadweight cost increases (κ declines), the firm value declines or $\frac{\partial F}{\partial \kappa} > 0$. Then, the result follows from Leland (1994, pp. 1225), which shows that a firm that has less debt capacity as the firm value declines.

Proof for Equation (21) and Proposition 5

The instantaneous second moment of returns in equation (15) is given by:

$$\sigma_y^2 = \left[\left((1-x)(\sigma - \Delta\nu)\right)^2 + \left((1-x)\Delta\gamma\right)^2 + \left(\frac{x\lambda}{\theta}\right)^2 \right] +$$
$$\left[2\rho_{qz}(1-x)(\sigma - \Delta\nu)\left(\frac{x\lambda}{\theta}\right) + 2\rho_{qw}\left((1-x)\Delta\gamma\right)\left(\frac{x\lambda}{\theta}\right) \right]$$

The result then follows the Proof of Proposition 1 with a drift $= (r - \delta)$.

Proof for Proposition 6

When $0 \leq \Delta \leq \frac{\sigma}{\nu}$ and using equation (19) with $\rho_{qw} = \rho_{qz} = 0$ we get:

$$\frac{\partial x^*}{\partial \sigma} = \frac{2\lambda^2\theta^2[\sigma - \Delta\nu]}{(\lambda^2\theta^2 + \theta^2(\sigma^2 + \Delta(\Delta\gamma^2 + \Delta\nu^2 - 2\nu\sigma)))^2} > 0$$

$$\frac{\partial x^*}{\partial \theta} = \frac{2\lambda^2\theta[2\sigma^2 + 2\Delta(\Delta\gamma^2 + 2\Delta\nu^2 - 2\nu\sigma)]}{(\lambda^2\theta^2 + \theta^2(\sigma^2 + \Delta(\Delta\gamma^2 + \Delta\nu^2 - 2\nu\sigma)))^2} > 0$$

Proof for Proposition 7

The impact of debt on deal flow and firm value depends on equation (17). Then, it follows that $\frac{\partial J*(t)}{\partial \eta} < 0$, where $J^*(t)$ is the value of the integrated firm partly financed with debt .

Figure 1

Firm risk and optimal allocation in trading

This figure shows the optimal allocation in trading (x^*) when a firm integrates its trading and production operations, as a function of the firm asset volatility (σ) and the volatility of forward contracts used in trading and hedging (ν). The level of margin requirements θ=0.2. We assume a risk-free rate $r = 0.07$, payout $\delta = 0.01$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.5$, contract maturity $\phi = 1$ and deadweight costs are to $\kappa = 1$ ($\eta = 0$).

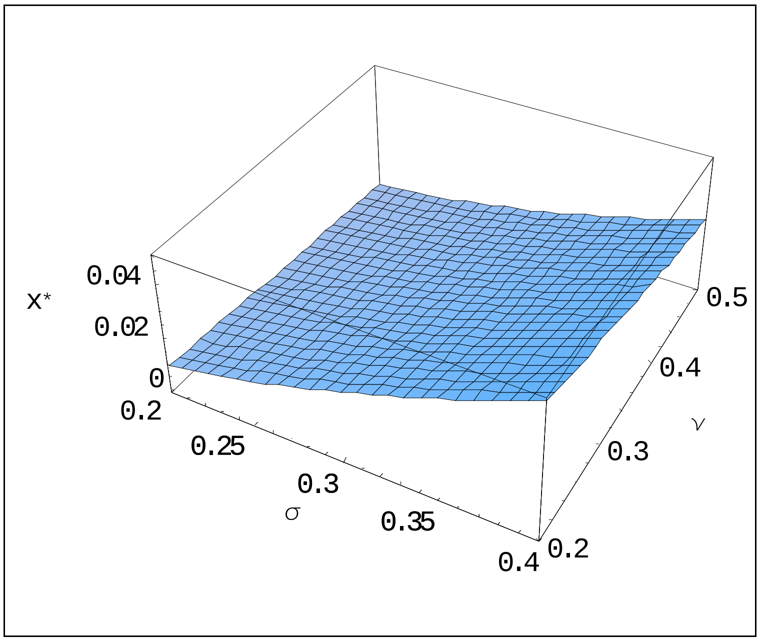

Figure 2

Incremental value from integration

This figure shows the overall increase in value (Incremental Value) when a firm integrates its trading and production operations as a function of the proportion invested in trading activities (x) when trades could involve going short or long. We assume a risk-free rate $r = 0.07$, payout $\delta = 0.01$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.4$, contract maturity $\phi = 1$, and deadweight costs corresponding to a high penalty ($\kappa = 0.99$) or low penalty ($\kappa = 0.90$). The value of unlevered assets of the firm is set at $V_0 = 100$. The coupon is set at the value that maximizes the value of the firm at each point.

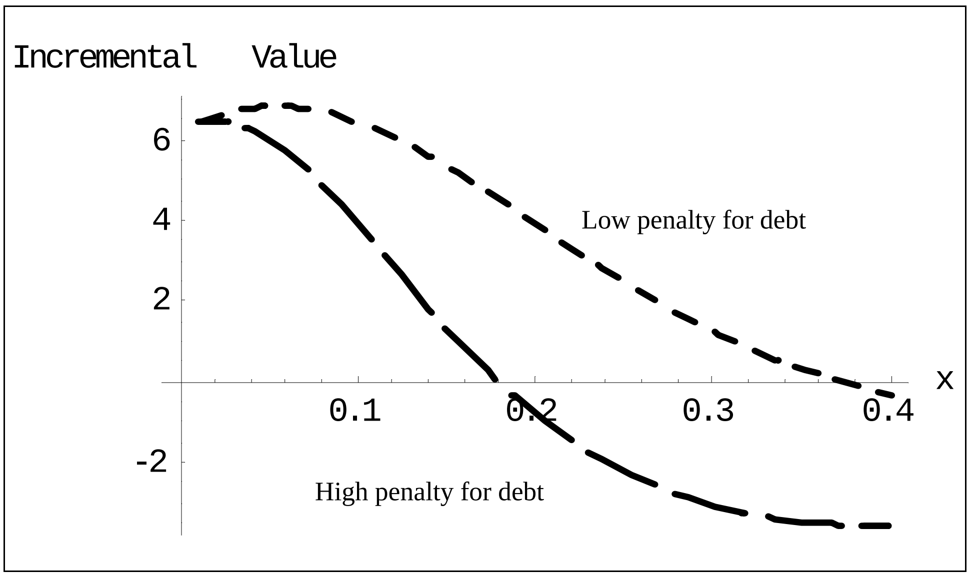

Figure 3

Effect of margin requirements on trading

This figure shows the 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=0.4 and 0.8). We assume a risk-free rate $r = 0.07$, payout $\delta = 0.01$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.4$, contract maturity $\phi = 1$ and the deadweight costs are to $\kappa = 1$ ($\eta = 0$). 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.

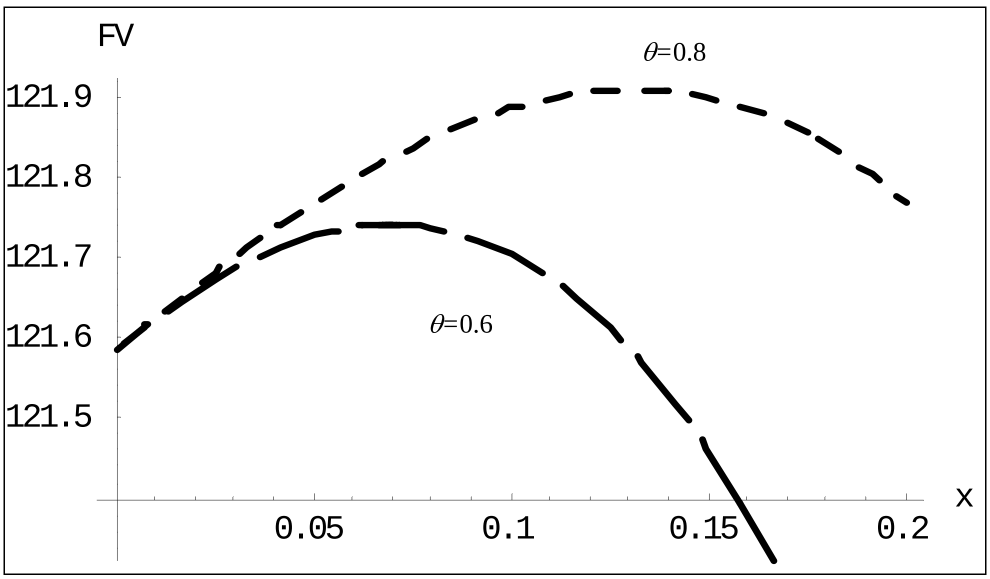

Figure 4

Effect of deadweight costs from combining production and trading

This figure shows the 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 a margin requirement θ=0.8, and two levels of deadweight costs $\eta = 0.5$ and 1. We assume a risk-free rate $r = 0.07$, payout $\delta = 0.01$, tax rate $\tau = 0.35$, recovery rate $\alpha = 0.4$, and contract maturity $\phi = 1$. The value of unlevered assets of the firm is set at $V_0 = 100$. The coupon is set at the value that maximizes the value of the firm.

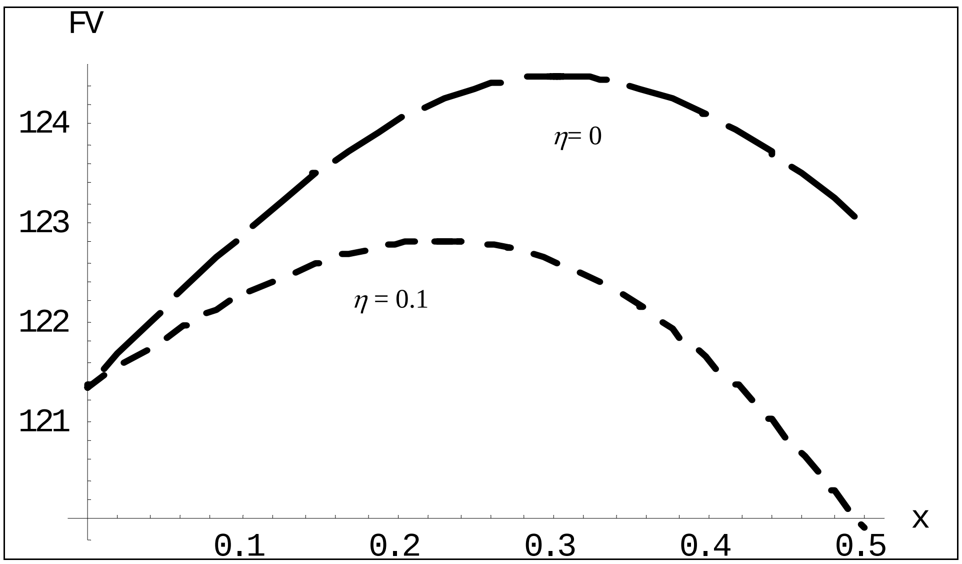

Figure 5
The contamination effect of integration

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