VERTICAL RELATIONS UNDER CREDIT CONSTRAINTS

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Abstract
We model the impact that credit constraints and market risk have on the vertical relationships between firms in the supply chain. Firms which might face credit constraints in future investments become endogenously risk averse when accumulating pledgable assets. In the short run, the optimal supply contract involves risk sharing, so inducing double marginalization. Credit constraints thus result in higher retail prices, and this is true whether the firm is debt or equity funded. Further, we offer a new theory of supplier finance arms as we show an intrinsic complementarity between supply and lending which reduces financing inefficiencies created by informational asymmetries. The model offers: a theory of countervailing power based on credit constraints; a transmission mechanism linking the cost of borrowing with retail prices; and a motive for outsourcing supply (or distribution) in the face of market risk. (JEL: L14, L16)

1. Introduction

Credit constraints have been known to be a part of corporate reality for decades (Hubbard 1998, and references therein). Massively reduced access to credit has been a feature of the major financial crisis of recent years. It is also well known that firms are subject to substantial market risk—whether on the demand side or supply side. Incorporating corporate finance aspects into an industrial organization model of the vertical supply chain, we study the interaction between credit constraints and market

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risk, and their effects on short-run retail pricing, long-run investment, and welfare. We show that credit constraints and market risk impact optimal vertical contracting, resulting in higher prices through double marginalization and slotting fees. We show that combining supply with lending can reduce financing frictions and so provide a new theory of finance arms. Further, the model gives rise to a novel theory of countervailing power based on credit constraints, and provides a rationale for outsourcing.

Consider a vertical supply chain consisting of a single upstream firm ('he') supplying a single downstream firm ('she'), and exposed to demand-side risk. The joint-profit maximizing supply contract would involve per unit input prices at the upstream firm's marginal cost, irrespective of any demand-side risk. Now suppose the downstream firm has some future investment opportunities but is credit constrained. The size of the loan she is able to raise to fund the investment, and therefore the actual investment level, depend on the size of the pledgable assets she owns. Under the standard assumption that investment is subject to diminishing marginal returns, when pledgable assets are low, the induced investment level is low as well. This implies that the return on a marginal dollar of investment would be high, and so an extra marginal dollar of pledgable assets can be greatly levered through the banking sector. Hence we show that the profit-maximizing firm becomes endogenously risk averse when accumulating pledgable assets.

As a result, the optimal contract between the downstream firm and its upstream supplier involves risk sharing and double marginalization. The endogenously risk-averse downstream firm wants to insure her level of pledgable assets. So she demands a risk-sharing contract in which the supplier bears some loss for poor demand realizations. For the supplier to recoup these potential losses, he requires payments in high demand states to grow at a rate faster than cost. Hence, double marginalization is introduced, causing the retail price of the downstream firm to rise. The cost of the insurance made necessary by the credit constraints is in this sense partly paid for by final consumers.

The optimal supply contract can be thought of as involving a fixed payment from the upstream to the downstream firm and demand-dependent repayments. This may help explain the increasingly common use of slotting fees in the grocery market as well as in other industries such as software and publishing. These fees are fixed payments many retailers require of manufacturers in return for stocking their products. Empirical evidence suggests that an important part of their rationale is the sharing of risk (Sudhir and Rao 2006; White, Troy, and Gerlich 2000), which accords with our model.[1]

These results apply whether or not the firm carries debt. The presence of debt can make equity more tolerant of risk as losses fall disproportionately on debt holders (see Jensen and Meckling 1976, and a long literature which follows). However, conditional on the firm surviving the short-term risk and being able to make investments for the future, the endogenous risk aversion remains. The marginal value of extra pledgable assets is greatest in the worst states—conditional on the firm surviving. The optimal supply contract involves risk sharing in which the downstream firm seeks to increase her profits conditional on survival: thus high retail prices remain.

1. Theoretical explanations for this practice have portrayed the slotting fee as a signalling device (Klein and Wright 2007, and references therein).

It is standard to see the input suppliers and the banking sector as two completely separate industries. However, if the input supplier also provides profit insurance, as in our model, it is no longer clear whether such a separation is indeed optimal. In fact we demonstrate that there exists an intrinsic complementarity between the provision of insurance and lending. An input supplier with access to funds at the same rate as the banking sector could actually lend on rates that the independent banking sector would find unprofitable. This result offers an original insight into the existence and profitability of finance arms of major companies such as GE and Cisco. As financial companies lend almost \$1 for every \$2 lent by a mainstream bank, gaining an insight into what makes financial companies effective competitors to banks seems a first-order issue.

The complementarity we find between supply insurance and lending arises because of the countervailing incentives the downstream firm faces when dealing with the insurer and the lender. By pooling insurance and lending, the downstream firm can effectively reduce her temptation to misreport the demand state. This reduces the informational inefficiencies which hinder financing and so allows for larger investments, for less double marginalization, and therefore for higher profits.

As the pre-investment degree of risk aversion of the downstream firm is endogenous, it is a function of market-level and firm-level parameters such as the interest rate, the quality of corporate governance, the firm's asset endowment, and her bargaining power in the vertical chain. We demonstrate that if parameters change so as to increase the coefficient of absolute risk aversion with respect to pledgable assets, then retail prices will rise in the short run (and vice versa). We use this result to demonstrate that firms with greater exogenous assets ('asset-rich firms') are less risk averse, generating the prediction that there should be less double-marginalization amongst asset-rich downstream firms.

Relaxing our assumption that the downstream firm has all of the bargaining power, we show that an increase in the downstream firm's bargaining power vis-à-vis her supplier makes the firm less risk averse when accumulating pledgable assets. Hence, a more powerful downstream firm charges lower retail prices in the short run. The model therefore gives rise to a new theory of *countervailing power* (Galbraith 1952) that is based on credit constraints. We also show that an increase in the interest rate that the downstream firm has to pay to finance her investment makes the firm more risk averse when accumulating pledgable assets. Hence, a higher interest rate leads to higher retail prices in the short run.

We finally demonstrate a link between market risk and outsourcing. A credit-constrained downstream firm cannot insure herself. By outsourcing input supply, however, the downstream firm can purchase insurance as the upstream supplier is in a unique position to monitor the volumes supplied to the downstream firm. Our result is supported by empirical evidence (Harrigan 1985; Sutcliffe and Zaheer 1988) which points in this direction.[2]

2. The main theoretical arguments in the extant literature have had difficulty with this empirical evidence as they work in the opposite direction. These theories commonly cite problems of incomplete contracting, which mandate integration in the face of risk to save on contracting costs (Mahoney 1992).

Related Literature. Our paper builds on some existing insights from the industrial organization and corporate finance literatures. On the corporate finance side, we build on Holmstrom and Tirole (1997) in modelling credit constraints as an endogenous outcome caused by a moral hazard problem associated with the firm's investment project. In contrast to Holmstrom and Tirole, however, we assume that the firm's investment project has decreasing returns. It is this (standard) decreasing-returns assumption that implies that the rate at which the marginal dollar can be leveraged is decreasing. A related issue is studied by Froot, Scharfstein, and Stein (1993). Froot et al.'s core model supposes that external finance is more costly than internally generated funds. If so then a firm would seek to avoid needing to access external funds in the face of market risk and so would hedge financial variables correlated with this risk. Thus capital market imperfections can generate risk-averse behavior. Our contribution here is to demonstrate that firm risk aversion arises from standard assumptions of diminishing returns to investment. Further, we explore the implications credit constraints have on final prices, vertical contracting and so on consumers—Froot et al. do not consider these real economy issues.

Firms might borrow from their suppliers either for investment purposes (usually through finance arms) or by implication of making late repayments for inputs received (known as 'trade credit'). We demonstrate that a supplier has complementarities in providing insurance and also credit for future investment projects. As trade credit is usually very short term (measured in tens of days) our work offers insight to the understanding of finance arms. While finance arms are arguably not well understood, there is a literature studying trade credit. Burkart and Ellingsen (2004) note that goods are less divertable to private benefits than money and so they argue that trade credit and bank lending are complementary. Cuñat (2007) suggests that a supplier can enforce repayment as he has a long-term relationship with a downstream buyer over inputs which cannot be supplied by another. Cuñat therefore argues that this essential relationship can make a supplier able to provide liquidity insurance to a firm which a bank would not. We show that even without any exogenous advantage over banks in terms of the longevity of the relationship, or the divertability of the loan, there is a complementarity between supplier insurance and lending for investment purposes.

On the industrial organization side, it is probably fair to say that the literature has been skeptical about the assumption that firms are risk averse. It is perhaps more accepted that small owner-managed firms might inherit the risk aversion of the owner; but, in general, it has proved harder to justify why risk aversion should significantly alter the behavior of firms with dispersed ownership. Such explanations would typically require that managers' interests cannot be fully aligned with those of the owners. Here we demonstrate that risk aversion can result even without such a separation of goals between owners and managers, and that it has real impacts on prices and investments.

Assuming exogenously risk-averse downstream firms, Rey and Tirole (1986) show that the best two-part tariff contract involves double marginalization. Our work demonstrates that risk aversion would be expected if the firms are credit constrained and that double marginalization results not only from two-part tariff contracts, but even from the fully optimal contract. More importantly, however, we demonstrate that credit constraints lead to an intrinsic complementarity between supplier insurance and lending (which may explain the existence of finance arms); provide a theory of countervailing power which predicts that more powerful retailers will charge lower prices; and create a new transmission mechanism linking interest rates with short-run pricing.

2. The Model

We consider a model of a vertically related industry with two firms, a downstream firm D and an upstream firm U. There are two periods: period 0 and period 1.

Period 0. In period 0, U can produce an intermediate input at marginal cost $c \geq 0$. U supplies the input to D which D transforms into a final good on a one-to-one basis at zero cost, and then sells on. When choosing output Q and facing market size z, D faces inverse demand $p(Q/z)$.[3] We assume that D is exposed to market risk in that market size z is a random variable with finite support $\{z_1, \ldots, z_n\}$ and state z_i occurs with probability g_i. A larger value of z implies that the volume supplied is a smaller proportion of the total market, and so a higher unit price results. We label states in increasing order so that $0 < z_1 < z_2 < \cdots < z_n$.

ASSUMPTION 1. We make the following standard assumptions on downstream demand.

(i) Marginal revenue $d[Qp(Q/z)]/dQ$ is declining in quantity Q for all Q such that $p(Q/z) > 0$.
(ii) The reservation price exceeds marginal cost at $Q = 0$, $p(0) > c$, and falls below marginal cost, $P(Q/z) < c$, for Q sufficiently large.

Assumption 1 implies that, in any demand state z, industry profit $Q[p(Q/z) - c]$ is strictly concave in quantity Q. Moreover, it implies that in demand state z, industry profit is maximized at quantity $Q = zq(c)$, where $q(c)$ is the unique solution in q to $p(q) + qp'(q) = c$. The downstream price that maximizes industry profit is $p(q(c))$ in every demand state z.

Before the demand state is realized, D offers U a menu of contracts of the form $\{Q_i, W_i\}_{i=1}^n$, where $Q_i = Q(z_i)$ is the input (and output) volume in state z_i, and $W(z_i)$ the associated transfer payment from D to U. If U rejects D's offer, both firms make zero profit. (That is, we assume for now that D has all of the bargaining power.) If U accepts D's offer, then D privately learns the realization of the demand state z and reports state $\hat{z}$ to U. As U and D cannot contract on the state of demand z (nor on the retail price), D can equivalently be thought of as picking $\{\hat{Q} = Q(\hat{z}), \hat{W} = W(\hat{z})\}$

3. D can equivalently be thought of as setting price p and facing demand $zQ(p)$.

from the menu.[4] D then receives $\hat{Q} = Q(\hat{z})$ units of input from U, transforms the input into a final good, and fetches a retail price of $p(\hat{Q}/z)$ per unit. Finally, D pays $W(\hat{z})$ to U. For notational simplicity, we assume in the baseline model that D has no initial assets. We relax this assumption to explore the comparative statics with respect to firm wealth in Section 6. D's asset level by the end of period 0, a, is therefore given by D's net profit in that period: $a = \hat{Q}p(\hat{Q}/z) - W(\hat{z})$.

Period 1. Overnight between periods 0 and 1, D has to decide how much to invest in a project. Based on the moral hazard formulation offered by Holmstrom and Tirole (1997), we assume that D is endogenously credit constrained. Specifically, after choosing the investment level I, D can choose whether or not to shirk at the investment stage. If she does not shirk and invests amount I then in period 1, D makes a gross profit of $\pi(I)$. If instead she does shirk on the investment, then the investment project fails and yields a payoff of zero in period 1, while D receives a benefit proportional to the size of the investment, $B \cdot I$, where $B \leq 1$.[5]

If D wishes to invest more than her pledgable assets, $I > a$, she can choose to verifiably show her asset level a to an external banking sector so as to attempt to secure a loan of $I - a$. For now, we set the market interest rate to zero so that D has to pay back only the amount of the loan, $I - a$. Any loan has to satisfy the no-shirking condition

$$BI \leq \pi(I) - (I - a) \tag{1}$$

as, otherwise, D would decide to shirk and so would be unable to pay back her loan.

ASSUMPTION 2. We make the following assumptions.

(i) The gross return function $\pi(I)$ is strictly increasing and strictly concave in I. Further, $\pi(0) > 0$, $\pi'(0) > 1 + B$, and $\pi'(I) < 1$ for I sufficiently large. This implies that the first-best level of investment, $\hat{I} \equiv \arg\max_I \pi(I) - I$, is strictly positive.

(ii) In equilibrium, any realized value of D's asset level a is smaller than the level necessary to finance the first-best investment level, $a < (B + 1)\hat{I} - \pi(\hat{I})$. That is, the no-shirking constraint (1) is always binding in equilibrium.

Assumption 2(i) contains the standard assumption that investment opportunities exhibit diminishing marginal returns. Assumption 2(ii), which states that the no-shirking constraint is always binding, is for convenience. What is needed for our results is that D would find herself constrained in the level of her investment if she should experience the worst demand state(s) in period 0.

4. Note that contractibility of the quantity of input that U ships to D does not imply contractibility of the state of demand z as D can choose to alter quantities requested from U given z.

5. This reduced-form approach to period 1 allows us to simplify the working of the model while demonstrating our results and intuition cleanly. Section 4 discusses numerous extensions to the model.

3. Equilibrium Analysis

We solve the model by backward induction.

3.1. The Investment Decision and Period-1 Profits

Suppose D's asset level at the end of period 0 is given by a. By Assumption 2(ii), D chooses an investment level $I(a)$ and an associated loan $I(a) - a$ so that the no-shirking constraint is just binding. While D would like to invest more, the banking sector would be unwilling to provide a larger loan. Thus, $I(a)$ is given by a solution in I to

$$BI = \pi(I) - (I - a). \tag{2}$$

Given pledgable assets $a \geq 0$, equation (2) has a unique positive solution $I(a)$ with $0 < I(a) < \hat{I}$, where $\hat{I}$ is the first-best investment level. To see this, consider the function $\Psi(I) \equiv \pi(I) - (1 + B)I$. Positive roots to $\Psi(I) + a = 0$ satisfy (2). By Assumption 2(i), $\Psi(0) + a = \pi(0) + a > 0$ for $a > 0$; and $\Psi'(0) = \pi'(0) - (1 + B) > 0$. By assumption 2(ii), $\Psi(\hat{I}) + a < 0$. As $\Psi(\cdot)$ is concave, there is a unique positive investment level $I(a) \in (0, \hat{I})$ at which $\Psi(I(a)) + a = 0$, as stated.

Note that Assumption 2 also ensures that at $I(a)$ the marginal gross return satisfies

$$1 < \pi'(I(a)) < 1 + B. \tag{3}$$

The first inequality follows as the investment level is below the first-best level. The second inequality is an implication of credit being constrained at $I(a)$. Since the no-shirking constraint is binding, D's net payoff at the end of the second period is $\pi(I(a)) - [I(a) - a] \equiv BI(a)$. The following lemma holds.

LEMMA 1. *D's net payoff, $BI(a) \equiv \pi(I(a)) - [I(a) - a]$, is (i) increasing at a rate greater than B and (ii) strictly concave in the pledgable asset level a.*

Proof. Implicitly differentiating $I(a)$ in equation (2) yields

$$\frac{dI}{da} = \frac{1}{1 + B - \pi'(I)} > 1 \quad \text{and} \quad \frac{d^2I(a)}{da^2} = \frac{\pi''(I)\left[\dfrac{dI}{da}\right]^2}{1 + B - \pi'(I)} < 0,$$

where the inequalities follow from equation (3) and Assumption 2(i). □

The fact that firm D's objective function in the asset accumulation stage becomes concave is a key preliminary result. It shows that the interaction of credit constraints and diminishing marginal returns to investment make firm D endogenously risk averse with respect to changes in her pledgable asset level a. To get some intuition, suppose that D were not credit constrained. After period 0, firm D would borrow $\hat{I} - a$ to invest at the first-best level $\hat{I}$, resulting in end-of-period-1 wealth of $\pi(\hat{I}) - \hat{I} + a$, for every realization of a. D would therefore be risk-neutral with respect to end-of-period-0 asset level a. Thus diminishing returns to investment alone do not yield the endogenous risk aversion result.

Now consider the fact that D is assumed to be credit constrained, and the extent of the constraint is endogenous as it depends on D's pledgable assets. As D has an investment opportunity she can secure a loan of some size from the banking sector. But as D is credit constrained the size of this loan grows with her pledgable assets. Because marginal returns to investment are diminishing, the rate at which the marginal dollar of pledgable assets can be leveraged is itself diminishing. This says that the returns to extra pledgable assets decline in the level of assets—and so D becomes endogenously risk averse.

3.2. Period-0 Vertical Contracting

The risk aversion identified in Lemma 1 will affect the agreement D requires from her supplier U. This will in turn affect the retail prices in period 0 (the 'short run') and the expected level of investment reached in period 1 (the 'long run'). Thus credit constraints will—via the supply-chain relationship—affect consumer welfare both in the short and long run.

Let us now analyze period-0 contracting. If the state is z_i and D truthfully reports it, then she would receive a payoff of $BI(Q_i p(Q_i/z_i) - W_i)$. Suppose instead D were to lie and claim that the state is z_j, thereby requesting volume Q_j in exchange for payment W_j. This would mean that the retail price received by D would be $p(Q_j/z_i)$. This yields D pledgable assets of $a = Q_j p(Q_j/z_i) - W_j$ at the end-of-period-0. Invoking the Revelation Principle, we restrict attention to contracts that maximize the value of D's pledgable assets when the truth is being told.

Program Bank. The optimization program when D uses an independent banking sector is given by

$$\max_{\{Q_i, W_i\}} \quad \sum_{i=1}^{n} g_i B \cdot I\left(Q_i\, p\left(\frac{Q_i}{z_i}\right) - W_i\right)$$

subject to the individual rationality constraint for U,

$$\sum_{i=1}^{n} g_i \left\{W_i - Q_i c\right\} \geq 0, \tag{4}$$

and the incentive constraint at the quantity setting stage for D,

$$Q_i\, p\left(\frac{Q_i}{z_i}\right) - W_i \geq Q_j\, p\left(\frac{Q_j}{z_i}\right) - W_j \quad \text{for all } j \neq i. \tag{5}$$

This problem is isomorphic to one explored by Hart (1983) in the context of optimal labor contracts. U here maps to workers (the marginal cost c corresponding to workers' reservation wage) in Hart's analysis and D maps to a firm demanding labor specifically. The following proposition then follows.

PROPOSITION 1. *(Hart, 1983, Proposition 2) The solution to Program Bank, $\{Q_i^*, W_i^*\}_{i=1}^n$, has the following properties:*

Property 1. *There is no distortion at the top:* $\frac{\partial}{\partial Q}[Q_n^* p(\frac{Q_n^*}{z_n})] = c$.

Property 2. *There is inefficiently low quantity demanded in all other states:*

$$\frac{\partial}{\partial Q}\left[Q_i^* p\left(\frac{Q_i^*}{z_i}\right)\right] > c \quad \text{for all } i < n. \tag{6}$$

Property 3. *D's pledgable assets increase in the state:*

$$Q_i^* p\left(\frac{Q_i^*}{z_i}\right) - W_i \geq Q_{i-1}^* p\left(\frac{Q_{i-1}^*}{z_{i-1}}\right) - W_{i-1} \quad \text{for all } i > 1.$$

Property 4. *U's payoff increases in the state:*

$$W_i - Q_i^* c \geq W_{i-1} - Q_{i-1}^* c \quad \text{for all } i > 1. \tag{7}$$

Proof. Hart (1983) yields all four conditions.[6] We have a strict inequality in his second condition as U is risk neutral here. □

Note that the optimal contract involves risk sharing: both U and D are better off in better demand states (Properties 3 and 4).[7] By exploring a general input into a downstream firm D, we obtain important corollaries of the previous proposition.

COROLLARY 1. *[Risk Sharing and Prices] The optimal contract with a supplier U when D is subject to credit constraints and market risk results in:*

1. *Retail prices are too high relative to the level that would maximize joint period-0 profit in all except the best demand state. That is, the optimal contract induces double marginalization.*

6. For D, explicitly, in Hart's notation, we have the revenue function $f(z, Q) = Qp(Q/z)$, which satisfies Hart's Assumptions 2 (as marginal revenue is positive and declining) and 6 (as profit grows in high demand states). As to his Assumption 5, we require the marginal revenue to grow in high demand states. This is true as

$$\frac{\partial^2 f}{\partial Q \partial z} = \left\{\frac{\partial\left(\frac{\partial f}{\partial Q}\right)}{\partial\left(\frac{Q}{z}\right)}\right\} \frac{\partial\left(\frac{Q}{z}\right)}{\partial z} =_{\text{sign}} -\left[-\frac{Q}{z^2}\right] > 0,$$

where we have used the fact that the term in curly brackets is negative (as marginal revenue is declining). The other assumptions follow as U is assumed to be risk neutral and $I(\cdot)$ has been shown to be concave.

7. As U's income increases in the state the optimal contract is robust to Innes' (1990) critique. Had the monotonicity not held then D would have an incentive to misreport the state as being better than it was and so save on repayments to U. Such a contract is sub-optimal here as it increases the variance of D's pledgable assets rather than reducing it.

2. *The optimal contract has the supplier making a net loss in low demand states. Hence, if marginal cost c is sufficiently small, the transfer from D to U, $W(z_i)$, is negative for small realized demand states z_i and positive for large z_i.*

Proof. For Part 1, note that equation (6) guarantees that the marginal revenue is above marginal cost at all demand states except for the highest. Hence, as marginal revenue is declining, we must have quantities being below (and, thus, retail prices being above) the industry-profit maximizing levels.

For Part 2, note that U's individual rationality constraint is binding,

$$\sum_{i=1}^{n} g_i \left\{W_i^* - Q_i^* c\right\} = 0,$$

while $\{W_i^* - Q_i^* c\}$ is, by equation (7), increasing in i. Hence we must have some state j such that

$$\begin{cases} W_i^* - Q_i^* c \leq 0 & \text{for } i \leq j; \\ W_i^* - Q_i^* c \geq 0 & \text{for } i > j. \end{cases}$$

Since U optimally shares in some of the risk, $W_1^* - Q_1^* c < 0$ and $W_n^* - Q_n^* c > 0$.□

In the absence of either credit constraints or market risk, or both, the optimal supply contract would stipulate the myopic first-best quantity $z_i q(c)$ in state z_i, resulting in the retail price $p(q(c))$ that maximizes joint period-0 profit. Proposition 1 and Corollary 1 show that the interaction of credit constraints and market risk imply that this (joint period-0 profit maximizing) contract is not an optimal one for the endogenously risk-averse firm D to demand of her supplier. It can be improved by requiring U to share in the risk faced by the downstream firm D. Intuitively, such risk sharing implies that U is made to provide D with profit insurance. Since U earns zero profit on average,[8] he must make a loss in the worst state(s) and profits in the best yielding Part 2 of Corollary 1.[9] We will provide empirical evidence that such risk-sharing contracts in which U can suffer losses are widespread in Section 3.3.

The optimal supply contract has D using U to lower the variance of the value of her end-of-period-0 assets. This is done, in effect, by having U make a fixed payment to D which D repays according to the state of realized demand. However, for U to be able to make back this ex-ante committed payment in expectation, the variable payments made to U must increase in volumes by more than the marginal cost of supply. Hence, double marginalization is created. This double marginalization is optimally spread across (almost) all demand states to reduce the temptation D has to misreport the state of demand. As a result, the optimal risk-sharing contract induces retail prices

8. More formally, U is held to his participation constraint. That his payoff from the contract equals zero is a normalization.

9. Note that this implies that $a \geq 0$ as in state 1, $Q_1^* < z_1 q(c)$ and so $Q_1^* p(Q_1^*/z_1) > c Q_1^* \geq W_1^*$, and D's pledgable income increases in the state.

that are (in almost all demand states) strictly higher than the myopic industry profit-maximizing level, $p(q(c))$. Hence, some of the burden of credit constraints and market risk is borne by consumers.

REMARK 1. In our analysis, we have allowed for general contracts between the upstream supplier U and the downstream firm D. Suppose instead that firms were restricted to two-part tariff contracts of the form $W(Q) = f + wQ$, where f is a fixed fee and w the per-unit input price. In this case, the equilibrium contract in period 0, (f^*, w^*), involves double marginalization in all demand states, $w^* > c$, and payment of a slotting fee from the upstream firm to the downstream firm, $f^* = -E[z] \cdot q(w^*)(w^* - c) < 0$.

3.3. Evidence on Retail Pricing and Contract Form

We have presented a model in which credit constrained firms have high retail prices as their supply contracts are altered to share risk, thereby increasing marginal costs. Empirical evidence of this effect is provided by Chevalier and Scharfstein (1996). These authors study retail prices in the US supermarket industry. In each city studied they compare the prices charged by local supermarkets against those of national chains over a period when some cities faced a bad demand shock (recession) while others did not. Arguing that local stores are more likely to be credit constrained, they offer the empirical finding that firms facing credit constraints post higher retail prices than non-constrained firms in response to bad demand shocks.

Chevalier and Scharfstein offer an alternative explanation of this evidence through a model of constant and fixed input prices with the presence of consumer switching costs giving supermarkets a rationale for altering the price level. The mechanism we offer also fits the empirical findings without recourse to switching costs.

There is evidence that the form of contract we have explored is in widespread use. We have noted that the optimal contract can be thought of as involving a fixed payment from U to D (and demand-dependent repayments). In the marketing literature, this fixed payment is known as a slotting fee. Slotting fees are commonly used in the grocery industry as well as in software and publishing industries. While it has been noted that slotting fees can be rationalized by, for example, suppliers signalling the quality of their products to retailers (Klein and Wright 2007), recent survey evidence suggests that risk sharing is a part of the rationale for slotting fees (Sudhir and Rao 2006; Bloom, Gundlach, and Cannon 2000). Further note that the very largest retailers, such as Wal-Mart and Costco in the United States, do not use slotting fees.[10] These very large retailers are unlikely to be credit constrained and so this observation is in line with the predictions of our model.

10. See Federal Trade Commission (2001), "Report on the Federal Trade Commission Workshop on Slotting Allowances and Other Marketing Practices in the Grocery Industry", available at: http://www.ftc.gov/os/2001/02/slottingallowancesreportfinal.pdf.

There is also evidence of firms signing risk-sharing contracts with their vertical partners. One celebrated example is the Risk and Revenue Sharing Partnerships used by Rolls Royce.[11] Case studies exist exploring such arrangements in multiple industries.[12]

4. Firm Debt, Risk Aversion, and Model Robustness

A debate exists within the corporate finance literature as to whether external financial frictions cause firms to be effectively risk averse, or instead risk loving. We have studied an asset accumulation stage in which the downstream firm is trying to secure funds to allow borrowing to take place. As the amount which can be borrowed increases in the level of pledgable assets, and the return to investment has diminishing marginal returns (both standard assumptions), the firm is endogenously risk averse. Other theoretical mechanisms exist which would also result in a firm acting as if she is effectively risk averse.[13] Empirical evidence for risk aversion in firms exists. Panousi and Papanikolaou (2012) present evidence of risk aversion playing an active role in firms' investment strategies. That firms' objective function is concave (implying risk aversion) is similarly the empirical conclusion of Leahy and Whited (1996).[14] Chevalier and Scharfstein (1996) has already been cited as evidence supporting our link between credit constraints and retail price rises.

However, theory is not unambiguous in pointing to financial constraints leading to risk aversion. Jensen and Meckling's (1976) seminal work explained that the presence of debt can make equity more tolerant of risk as losses fall disproportionately on debt holders. Brander and Lewis (1986) argue that this risk-shifting rationale will make firms act in a risk-loving way in their production decisions. Our risk-sharing and double marginalization results are robust to the presence of debt contracts. To demonstrate this, let us extend our core model slightly and suppose that D has a debt contract at the beginning of period 0 which we model as D commencing with negative assets of $-d$. After period-0 trade, firm D will generate a net asset position of a. If profits in period 0 are less than d, then a will be negative. In that case, D is not necessarily bankrupt, however, as D has future ($t = 1$) investment opportunities. Thus D may be able to borrow funds to both pay off her end-of-period-0 debt and invest the remainder between periods 0 and 1.

11. See the 2008 Annual Report for example, available at http://www.rolls-royce.com/reports/2008/finance-directors-review.html.

12. See for example Figueiredo, Silveira, and Sbragia (2008) for aircraft in Brazil and Camuffo, Furlan, and Rettore (2007) for air-conditioning in Italy.

13. Managers who are risk averse and hold their firm's stock will take decisions under risk aversion (Stulz 1984). Managers may be risk averse to avoid disadvantageous comparisons with their peers (Breeden and Viswanathan 1990; DeMarzo and Duffie 1995).

14. Not all empirical studies have generated clear evidence of risk aversion. See, for example, Brainard et al. (1980).

LEMMA 2. *There is a minimum end-of-period-*0 *asset level* $\hat{\kappa} < 0$ *below which* D *is unable to borrow funds. If the end-of-period-*0 *asset level* a *satisfies* $a \geq \hat{\kappa}$*, then* D *can borrow to make some investment and pay off her existing debt.*

Proof. All missing proofs are contained in the Appendix. □

If $a < \hat{\kappa}$, then D is unable to access any loans as her moral hazard problem is too severe. Thus she carries her existing debt into period $t = 1$, can make no extra investment, and would finish with a negative payoff of $a + \pi(0)$. As any firm always has the option of shutting down, we must extend our model to allow for this possibility. We suppose that after learning the demand state, and before receiving inputs from U, D may shut down and default on any outstanding debt and secure a private payoff of b. We allow for any payoff b such that $\hat{\kappa} + \pi(0) \leq b < BI(\hat{\kappa})$. If the payoff parameter is equal to zero, $b = 0$, then we have a literal model of limited liability. If $b < 0$, then the model captures some shut-down costs; whereas if $b > 0$, then the model captures some management perks. With this limited liability condition, D's net payoff is given by

$$V^{\text{debt}}(a) = \begin{cases} BI(a) > 0 & \text{if } a \geq \hat{\kappa}, \\ b & \text{otherwise.} \end{cases} \tag{8}$$

There are at least three motivations for this modelling choice. The first is that in many markets it is illegal to trade when the firm knows it is insolvent. Here we are exactly assuming that as soon as D realizes that she has a negative NPV, she shuts down. A second motivation is that D has some (arbitrarily small) time discounting. In this interpretation, if D can secure b either at the end or at the start of $t = 0$, because of time discounting D prefers to secure b sooner rather than later. The final interpretation is that D's existing debt is senior to any supply contract with U. Thus U appreciates that if a bad demand state is reported then he will not receive full payment from D. In such a situation U would not be willing to supply D as per the terms of the contract.

The jump in the payoff function creates the potential for risk-loving behavior: D can gain disproportionately if she pushes her end-of-period-0 assets above $\hat{\kappa}$.

PROPOSITION 2. *Suppose that* D *has a debt contract so that she begins period* $t = 0$ *with negative assets* $-d$*. As long as the grid of probabilities* $\{g_i\}$ *is sufficiently fine:*

1. *D will shut down if the demand state is bad enough; that is, there exists some state $k \geq 1$ such that D shuts down in state $i < k$.*
2. *There will be double marginalization at all demand states at which D remains in business, except the highest.*
3. *U provides insurance in all states at which D remains in business.*

The downstream firm D wishes to manage her supply contract to allow her to remain in business, and subject to this, to invest to maximize her payoff. D therefore wishes to grow her returns in poor states sufficiently to get over the point at which she can borrow, repay her existing debt and potentially invest for the future. This requirement is entirely compatible with the desire to insure her period-0 income conditional on being in business. Both requirements cause D to wish to grow her assets in low states (conditional on remaining in business) and she is willing to sacrifice assets in high states to do this. This follows as, conditional on remaining in business, the marginal payoff to greater pledgable assets is much larger if the level of assets is low (yet above $\hat{\kappa}$) than if the level of assets is high. If demand is so bad that D will have an asset value which is too negative to permit any further borrowing then D will shut down. Thus U is asked to provide the revenue boost in low demand states which permits D to continue as a going concern. U is willing to participate due to expected profits in higher demand states. It follows that identical reasoning to Corollary 1 guarantees that double marginalization remains.

Our result is compatible with the risk-shifting insight of Jensen and Meckling (1976) as the downstream firm is unable to opportunistically exploit the upstream supplier. In the standard risk-shifting set-up, the debt is present before commercial and risk decisions are taken. The firm therefore has an incentive to exploit the debt holders through the commercial decisions taken. In contrast, the interaction with the supplier is, in our model, part of the commercial decision-making process. U therefore agrees to a supply contract in the knowledge of the prior debt level. The supplier is therefore used for profit insurance, the optimal contract protecting the supplier from being exploited as a repository for extra risks. The effect of this income insurance is retail double marginalization.

We conclude that debt does not affect our retail price results.

4.1. Discussion of Model Assumptions and Extensions

4.1.1. Future Investment Correlated with Period-0 Demand. In our core model, the expected returns from a given investment in period 1 do not vary with the realized period-0 demand. It is possible to imagine positive or negative correlation between current demand and future investment returns arising from information revelation as to the product's appeal, or due to the macro-economic cycle.

Suppose that the level of future investment returns is positively correlated with period-0 demand. Formally period-0 state i implies expected period-1 returns of $\pi(I) + \theta\varphi(z_i)$, with $\theta > 0$ and φ increasing.[15] This alteration implies that D's objective function in state i is $B \cdot I(a + \theta\varphi(z_i))$. The extra additive term in period-1 returns acts as a state-dependent change in pledgable assets. As before, D's objective function is concave in the end-of-period-0 asset level a for any given realization of the demand state. An increase in θ (the parameter measuring the strength of correlation between period-0 demand and the level of the returns to period-1 investment) induces a mean-preserving spread of revenues. This increases D's endogenous risk aversion and reinforces the results.

15. Suppose also that $\pi(0) + \theta\varphi(z_1) > 0$ and that $\sum_i g_i \theta\varphi(z_i) = 0$, implying that the ex-ante expected returns are the same as before.

Now consider the impact of positive correlation between period-0 demand and the gradient of the returns to investment, modelled for example by $\pi(I) \cdot \varphi(z_i)$. First, after low period-0 demand, the expected returns in period 1 are shifted down. This effect, analyzed previously, acts to reinforce our results. Second, the marginal return to extra investment is reduced after low period-0 demand. This latter effect acts to lower the marginal returns to extra assets in low period-0 states and raises them in high period-0 states – hence this is a force towards making D risk loving and reversing our results. Which of these opposing effects dominates will depend upon the specifics of any given situation.

4.1.2. Functional Form of Investment Returns and Shirking Returns. In the core model, D faces a moral hazard problem as she can misuse the funds meant for investment and shirk instead. If she shirks, then D secures a payoff which is linear and proportional to the investment funds I. The linearity assumption is not key to the results. One might instead consider any shirking reward function $\mathcal{B}(I)$ which is convex and increasing—that is, $\mathcal{B}'(I) > 0$ and $\mathcal{B}''(I) \geq 0$. If D has only a small amount of money to invest then it is difficult to discretely redirect it to unproductive perks; however if the funds D has are large then detailed oversight is more difficult and potentially large sums can be redirected to unproductive perks. The convexity of the shirking function delivers a concave payoff function $\mathcal{B}(I(a))$. It follows that our results on short-term retail prices continue to apply.

Now turn to the shape of the returns to investment. The standard assumption concerning future technology is that there are decreasing returns to scale ($\pi''(I) \leq 0$). However over some ranges it is possible for the technology to exhibit increasing marginal returns to investment (for example, if some critical scale were required). Under a generalized private benefit function all that would matter is the curvature of $\pi(I) - \mathcal{B}(I)$. If the private benefit function is sufficiently convex to render this sum concave, then our results and approach are unchanged. Otherwise, our results would reverse. D would be risk loving and so would like the opposite of insurance from U. In that case, D would like extra pledgable assets from U in good states of the world, paid for by accepting reduced profits in bad states of the world. To ensure truth telling, and not falsely claiming the state is better than the truth, U would increase the quantity that D must sell faster than optimal. Consumers would see prices below (not above) the short-run profit-maximizing level.

4.1.3. Modelling of Period-1 Contracting. Suppose that after investment, in period 1, D must select a supplier and contract upon the same informational basis as in period 0, and consider the borrowing phase which takes place between periods 0 and 1. If in all period-1 states of demand D can repay her loan when not shirking, then the model proceeds unaffected as the loan is determined by the expected period-1 profit, not the profit in each state. Suppose instead that D can only repay her loan if period-1 demand is not in the worst state(s). As D would have a default risk in period 1, the bank would require a positive interest rate so as to break even in expectation. It remains the case that the amount that can be borrowed grows in the level of the pledgable assets.

As there are diminishing returns to investment, the rate at which extra assets can be leveraged declines in the assets. Hence, D remains endogenously risk averse in the period-0 asset accumulation phase, and so the results remain.

4.1.4. Credit Constraints Upstream and Downstream. We now consider the impact if U also had investment opportunities to fund between periods 0 and 1, and U were credit constrained. The analysis of Lemma 1 would deliver that U would also be endogenously risk averse in the asset accumulation phase (period 0). His preferred supply contract would then be the standard myopically optimal one in which the wholesale price per unit equals the marginal cost as this generates perfect insurance for U. As U is endogenously risk averse, he would value the optimal contract from our baseline model less and so would be unwilling to accept it. Combining the effects implies that the optimal contract will be a weighted average of these two contracts, thus preserving the features summarized in Corollary 1.[16]

5. Complementarities between Supplier Insurance and Banking

In the model, the supplier U optimally provides firm D with profit insurance, and D then borrows from the banking sector to fund investment. If U could borrow and lend at the same interest rate as banks can, then U could take the place of the bank, providing the loan for investment as well as period-0 income insurance. This section shows that borrowing from U and committing not to use a separate banking sector strictly dominates using a banking sector.

Lending from finance companies as opposed to from banks is an important source of corporate debt. Yet the extent to which bank loans and non-bank loans are substitutable is, arguably, poorly understood. Here we propose that by combining supply with lending the inefficiencies in financing created by informational asymmetries can be reduced. Concretely, by having to return to U for a loan, D can commit to charge a retail price which is less double marginalized and more profitable for the supply chain. This is because if she misreports the state in period 0 and so makes extra profits by exploiting the supply contract with U, then U can commit not to allow them to be leveraged. This permits D to credibly discipline herself. As a result, this section will offer a novel explanation for the existence of supplier finance arms.

To derive this result, suppose that D committed not to use a banking sector and only deal with U. D would now be proposing the contract $\{Q_i, T_0^i, T_1^i\}$, where Q_i is quantity of input delivered in period 0 if the state is z_i, T_0^i is a payment from D to U at the end-of-period-0 (so that D's investment in period 1 is her revenue minus T_0^i), and T_1^i is a payment from D to U at the end of period 1, after the investment returns are realized.

The program to solve with no bank is as follows.

16. This is of relevance to slotting fees as one might suspect that suppliers to supermarkets are at least as likely to be credit constrained as the supermarkets themselves.

Program No Bank. The optimal program when U provides the loan is given by

$$\max_{\{Q_i, T_0^i, T_1^i\}} \quad \sum_{i=1}^{n} g_i \left\{ \pi \left(Q_i \, p\left(\frac{Q_i}{z_i}\right) - T_0^i \right) - T_1^i \right\},$$

subject to:

$$\sum_{i=1}^{n} g_i \left\{ T_0^i + T_1^i - Q_i c \right\} \geq 0, \tag{9}$$

$$\left[Q_i \, p\left(\frac{Q_i}{z_i}\right) - T_0^i \right] \cdot B \leq \pi \left(Q_i \, p\left(\frac{Q_i}{z_i}\right) - T_0^i \right) - T_1^i, \tag{10}$$

$$\pi \left(Q_i \, p\left(\frac{Q_i}{z_i}\right) - T_0^i \right) - T_1^i \geq \pi \left(Q_j \, p\left(\frac{Q_j}{z_i}\right) - T_0^j \right) - T_1^j \quad \text{for all } j < i. \tag{11}$$

Here, (9) is the individual rationality constraint for U, (10) is D's no-shirking constraint at the investment stage in period 1, and (11) is D's incentive constraint when reporting the state of demand in period 0. The optimal contract can involve a large penalty if D were unable to show all of the assets that she should have earned in period 0 according to her demand report. This parallels the baseline model in that D cannot claim to have pledgable assets which she does not have as collateral for a loan. This implies that D can only under-report but not over-report the demand state in period 0.

Note that if D should lie about the state and claim it is j when in fact it is $i > j$, then her assets will in truth be higher than she would have had under state j. However, the size of her loan (T_0^j) is not altered. These extra assets cannot, therefore, be leveraged.[17]

Proposition 3. *[Finance Arms] Using U as a bank strictly dominates using a separate banking sector.*

The complementarity between supplier insurance and lending results from countervailing incentives being pooled. When applying for a loan, D would like to over-report the size of her assets so as to secure a larger loan. In contrast, in her supply insurance relationship, D would like to under-report the demand state so as to exploit the supply contract and secure a larger insurance payout. By committing to leverage only those assets that are consistent with D's demand report, U can effectively reduce D's temptation to under-report the demand state and thus remove some double

17. We assume here that any such extra assets could still be invested, although not leveraged. Assuming otherwise would only strengthen our result.

marginalization from the supply contract.[18] Note that a third party, such as the bank, would be in a worse position than U to provide both the insurance and the lending unless the third party could verifiably observe the input supply of U to D.

Our mechanism does not require that the upstream firm U provides all of the lending to D. Instead, U may cooperate with banks in a consortium of lenders—with the banks providing 'inframarginal' lending (the part of the loan that would be provided even in the worst demand state) and U only providing the 'marginal' lending that is sensitive to the reported demand state. To enforce this, the borrowing firm must be limited in its access to further lenders for top-up loans. Covenants could be written to this effect.[19]

5.1. Empirical Evidence: Lending via Financial Companies Versus Banks

Proposition 3 provides a rationale for suppliers maintaining finance arms, as indeed many major firms do (e.g., GE, Cisco). The finance arm will be able to offer terms which improve on those from a bank by linking the size of the loan to the quantity of input supplied. That a supplier with the same access to capital markets as an external bank can lend on rates that the independent banking sector would find unprofitable, is a new result. Understanding when such non-bank lenders have a comparative advantage over banks is important. In 2008, US financial companies lent just over 608 billion dollars to business borrowers. This figure does not include financial companies lending to private consumers or for real-estate assets.[20] This compares with bank lending to businesses of 1.5 trillion dollars (commercial and industrial assets on US bank balance sheets at end 2008). Thus financial companies lend almost \$1 for every \$2 lent by a mainstream bank. Therefore gaining an insight into what makes financial companies effective competitors for banks is arguably a first-order issue.

Carey, Post, and Sharpe (1998) and Denis and Mihov (2003) present evidence that finance companies are over-represented in loans to higher risk firms. Such a distribution of loans could be explained if there is a complementarity between supplying input and lending, implying that such lenders can make a profit even with risky borrowers, whereas banks cannot. Our mechanism is new: Carey et al. report that there is as yet little literature on why finance companies may have a competitive advantage over banks in lending to riskier firms. They speculate that financial regulation might have encouraged banks to avoid these loans to limit risks; or that banks might wish to preserve a reputation for being lenient which they could not be with the riskiest borrowers. However these arguments are not explicitly modelled or tested.

In our model, the lending provided by U is identical to that which a bank can provide. The extent to which finance companies provide loans which are a substitute

18. The mechanism offered here is related to the literature on countervailing incentives; see, for example, Lewis and Sappington (1989). These authors show that, with countervailing incentives, the optimal contract may involve pooling in some states. Instead, our focus is to show that by pooling principals (supplier, bank), the agent (buyer) derives a benefit.

19. Indeed, there is evidence that, if lending is undertaken by a consortium, then covenants are more likely to be required (Bradley and Roberts 2004).

20. This is drawn from the Federal Reserve G20 statistical release. Available at http://www.federalreserve.gov/econresdata/releases/statisticsdata.htm.

for bank loans has been explored by Billett, Flannery, and Garfinkel (1995) and by Preece and Mullineaux (1994). Both papers find that there is no statistically significant difference in the market's reaction to new loans, whether they originate from a bank or a non-bank. Thus finance company loans carry the same good news which a bank loan would. This finding sits comfortably with the mechanism we have proposed.

6. Cross-sectional Predictions

We have shown that the interaction between credit constraints and market risk causes a risk-neutral (downstream) firm to become endogenously risk averse with respect to her pledgable assets. The endogenous risk aversion causes the firm to seek to push risk on to her vertical partner, and this results in double marginalization so that retail prices rise. How risk averse the firm is, and so how large the effect on retail prices, will depend upon market-level and firm-level parameters. Let $I(a;\theta)$ denote the (endogenous) investment level as a function of the realized asset level a and some parameter θ. The following lemma demonstrates that if a change in θ increases the Arrow–Pratt measure of absolute risk aversion of the investment function with respect to pledgable assets, then the period-0 retail price will rise in all demand states except the highest and those at which the optimal contract involves pooling.

LEMMA 3. *Suppose a change in model parameter θ causes the coefficient of absolute risk aversion, $-(\partial^2 I/\partial a^2)/(\partial I/\partial a)$, to increase (decrease) at all pledgable asset levels. Then, at all states $i < n$ at which the optimal contract does not involve pooling, $Q^*_{i-1} < Q^*_i < Q^*_{i+1}$, the optimal quantity sold in period 0 decreases (increases). Hence, the short-run retail price in such states increases (decreases). The result holds weakly at state $i < n$ if the optimal contract in that state involves pooling, $Q^*_i \in \{Q^*_{i-1}, Q^*_{i+1}\}$.*

Proof. See the Online Appendix. □

6.1. Asset-Rich Firms and Double Marginalization

Suppose that the downstream firm has some exogenous assets equal to $A \geq 0$. We assume these are not so large that Assumption 2 is contravened. Credit constraints would then ensure that the investment level $I(a, A)$ would be given implicitly by

$$B \cdot I = \pi(I) - (I - [a + A]). \tag{12}$$

Thus if the downstream firm has extra assets A then her investment returns as a function of pledgable assets match those in the core model: $I(a, A) \equiv I(a + A)$. It follows that the coefficient of absolute risk aversion is given by

$$-\frac{\partial^2 I}{\partial a^2} \Big/ \frac{\partial I}{\partial a} = -\pi''(I) \left[\frac{\partial I}{\partial a}\right]^2. \tag{13}$$

PROPOSITION 4. *[Asset Rich] Suppose that the curvature of the technology function is regular in the sense that it declines in magnitude at higher investment levels—that is,* $\pi'''(I) \geq 0$. *Then, an increase in D's initial asset endowment (i.e., an increase in A) results in lower retail prices in the short run (period 0).*

To understand this result suppose that an asset-rich downstream firm signed the same period-0 supply contract as an asset-poor firm. If D is asset rich, then she will have more pledgable assets at the end of period 0 for any given realization of demand. These extra assets allow the amount borrowed, and thus the investment level, to grow. But at higher investment levels, the marginal return to extra investment is lower, and thus the marginal incentive to shirk larger. The size of the marginal incentive to shirk captures the size of the moral hazard problem. Hence, if assets were to increase a little further then the amount of extra borrowing would be modest. Therefore $\partial I/\partial a$ shrinks as the initial asset endowment grows. Further, if the initial asset endowment grows then the level of investment rises, and, as we have assumed that the investment returns function π has regular curvature, the link between future profits and investment becomes less sensitive. Overall, therefore, both of the elements of risk aversion given in (13) decline. Hence, Lemma 3 guarantees that the degree of risk aversion felt in period 0 declines. Therefore asset-rich firms seek to transfer less risk to their vertical partners, so less double marginalization is induced and so retail prices are lower.

6.2. *Countervailing Power and Credit Constraints*

Now we relax the assumption that D has all of the bargaining power and suppose that U receives an expected payoff of β from the relationship. Hence, β is a measure of U's bargaining strength and the bargaining analogue of Program Bank is modified by replacing the individual rationality constraint of U (equation (4)) by $\sum_{i=1}^{n} g_i\{W_i - Q_i c\} \geq \beta$. From inspection of D's objective it follows that efficient bargaining does not alter the generic structure of the optimal contract as the new problem is isomorphic to Program Bank.

COROLLARY 2. *[Countervailing Power] Suppose that the curvature of the technology function is regular in the sense that it declines in magnitude at higher investment levels—that is,* $\pi'''(I) \geq 0$. *An increase in D's bargaining power (a smaller value of* β*) induces lower retail prices in the short run (period 0).*

Corollary 2 follows from Proposition 4. If D's bargaining power rises, then U secures a lower return. This is equivalent to D gaining extra assets in addition to the income she makes through her normal business dealings in period 0. The extra assets for D act in the same way as exogenous assets did in Proposition 4.

Corollary 2 provides a novel theory of countervailing power based on credit constraints. The term ‘countervailing power’ was coined by Galbraith (1952) but Snyder (2008) notes that formalizing the concept has proved difficult. Katz (1987) models bargaining as a supplier matching the price of some outside option, whereas

Chipty and Snyder (1999) and Inderst and Wey (2007) model bilateral bargaining so that the transfer depends upon the expected incremental cost of supply. Here we offer, to our knowledge, the first model of countervailing power based on credit constraints, and the first countervailing power model to capture retail price effects within an efficient bargaining paradigm.

6.3. The Cost of Borrowing and Retail Prices

Now we study the effect of changes in the cost of capital on the optimal supply contract. We show that an increase in the interest rate can be expected to increase D's endogenous risk aversion and thus lead to higher retail prices in the short run.

Suppose that money borrowed from the external banking sector between periods 0 and 1 needs to be repaid at an interest rate of r. As D has to pay back $(I-a)(1+r)$ to the bank, the no-shirking constraint in period 1 is now given by

$$BI + (I-a)(1+r) - \pi(I) = 0. \tag{14}$$

This relationship between investment and assets implies

$$\frac{\partial I}{\partial a} = \frac{1+r}{B+1+r-\pi'(I)} \quad \text{and} \quad \frac{\partial^2 I}{\partial a^2} = \pi''(I)\left[\frac{\partial I}{\partial a}\right]^3 \frac{1}{1+r}. \tag{15}$$

Hence, analogously to (13) we have

$$-\frac{\partial^2 I}{\partial a^2}\Big/\frac{\partial I}{\partial a} = -\pi''(I)\left[\frac{\partial I}{\partial a}\right]^2 \cdot \frac{1}{1+r}. \tag{16}$$

PROPOSITION 5. *Suppose the curvature of the technology function, $-\pi''(I)$, is sufficiently large in magnitude and declining at higher investment levels (i.e., $\pi'''(I) \geq 0$). Then, an increase in the interest rate causes retail prices to rise in the short run (period 0).*

Invoking Lemma 3 the result follows from the effect of interest rates on risk aversion as given by (16). The dominant effect comes from how a higher interest rate affects the sensitivity of the investment level to pledgable assets $[\partial I/\partial a]$. As interest rates rise the level of investment declines and the returns to investment at the margin are greater at lower investment levels due to the diminishing returns to investment. This acts to lower the incentive to shirk at the margin, so lowering the moral hazard problem and making investment more responsive to extra assets. However, as interest rates increase more needs to be repaid to the banks. This acts to raise the marginal incentive to shirk. Whether the investment level becomes more or less sensitive to extra assets depends on which effect dominates. A sufficient, but not necessary, condition for the first effect to dominate is that the investment returns function, $\pi(I)$, is sufficiently curved. In this case, increasing r raises the sensitivity of investment to assets, and ensures that increasing the interest rate r raises the coefficient of risk aversion of investment with respect to pledgable assets.

We have established a mechanism by which increasing interest rates which a firm must pay on future investments raises its aversion to risk in the asset accumulation phase and so results in price rises in the short term. Evidence in the macro literature exists for this effect at an aggregate level: the 'price puzzle' (Christiano, Eichenbaum, and Evans 1999).[21] Evidence also exists that retail prices rise with debt interest rates at more disaggregated industry levels (Gaiotti and Secchi 2006).[22]

7. Outsourcing

If a third party can verifiably observe the input supply, then D may decide to source the input from U at marginal cost c and separately secure insurance from the third party. However, the retail price implications are unchanged as the insurance would induce double marginalization for the same reason as before. If a third party cannot verifiably observe the input supply, then we have the following proposition.

PROPOSITION 6. *[Outsourcing] The credit-constrained downstream firm D strictly prefers to outsource input production to U rather than produce in-house at the same cost.*

Proof. Suppose D were to produce the input in-house at marginal cost c. The supply contract would satisfy $W_i = cQ_i$ for all states i. Hence, for any demand state realization, the integrated firm would set marginal revenue equal to marginal cost and implement the non-double-marginalized retail price. However, by Proposition 1, Property 2, though implementable, this is not the optimal tariff when D is outsourcing input production to U. Hence, D strictly prefers outsourcing to U. □

Our model thus provides a new rationale for credit-constrained firms exposed to market risk to outsource supply: the suppliers can provide revenue insurance that a third party cannot to the same extent.

There are many reasons why outsourcing might be a good idea. But the relationship between market risk and outsourcing is still a topic of debate. Harrigan (1985) analyzing executive interviews and Sutcliffe and Zaheer (1988) experimentally find evidence that firms move more production outside the firm when exposed to demand risk. However, the dominant theoretical view is, arguably, that contractual incompleteness combined with demand risk would act to increase vertical integration (see Mahoney 1992, for

21. This 'puzzle' is not uncontroversial; see Sims (1992), for example.

22. Note that at the firm level increasing interest rates would only feed into higher short-run prices via an increase in firm costs if firms rent capital each period so that capital is a marginal cost of production. It is more standard to see capital as fixed in the short run. Our link between interest rates and prices operates regardless of the flexibility of the capital stock.

a discussion).[23] Our model suggests a force pushing against integration, which is responsive to market risk.

8. Conclusions

In this paper, we analyze a model of vertical relations between a downstream buyer and her upstream supplier. The downstream buyer is endogenously credit constrained by the level of her pledgable assets to invest at levels below the first best.

Assuming that the downstream buyer's investment technology exhibits diminishing marginal returns, the firm becomes endogenously risk averse when accumulating pledgable assets. As a result, the optimal contract between the downstream firm and her upstream supplier involves risk sharing. This holds even if the downstream firm holds debt ex ante. Conditional on remaining in business, the downstream firm seeks revenue insurance as extra pledgable assets have the biggest impact when pledgable asset levels are low. However, such insurance comes at a cost to consumers in the form of higher prices. Demand-dependent repayments to the supplier raise the downstream firm's effective marginal cost, inducing an increase in consumer prices. Thus double marginalization is a necessary feature of optimal supply contracts under credit constraints.

As supplier-insurance and lending for investment are subject to countervailing incentives, their pooling within one principal allows the downstream firm to reduce the double marginalization problem. So our model can explain why finance arms of major companies (such as GE) can lend profitably when banks cannot.

As the downstream firm's risk aversion is endogenous, it is affected by changes in market-level and firm-level parameters. Hence exogenously asset-rich firms, or firms with greater bargaining power, will have less need for risk-sharing contracts and so can be expected to set lower retail prices. Further we demonstrate that credit-constrained firms facing demand-side risk will benefit by outsourcing supply. Once outsourced, the firm can enact a value-enhancing supply contract with insurance features.

These results have all been demonstrated in a model of downstream credit constraints and demand-side risk. However, the results are more general and would apply analogously to a model of upstream credit constraints and supply-side risk. While the shape of the optimal contract between the credit-constrained (and thus risk-averse) downstream firm and her upstream supplier does not rely on the cause of the downstream firm's risk aversion, we would have been unable to obtain several of our results (finance arms, countervailing power, interest rates) without explicitly modelling the interaction between the credit constraints and risk aversion. In contrast, the results on double marginalization, slotting fees, and outsourcing arise from the risk-sharing motive of the risk-averse downstream firm. The industrial organization literature has been skeptical about modelling firms as being risk averse. Our paper shows that firms

23. Carlton (1979) offers the same conclusion but in a model of unadjustable input volumes.

are expected to be risk averse if they face investment projects with diminishing returns and there is some chance of the firms being credit constrained.

Appendix: Proofs

A.1. Proof of Lemma 2

Let $\tilde{I} = \arg\max_I \Psi(I) = \arg\max_I \pi(I) - (1 + B)I$. By Assumption 2 $\tilde{I} \in (0, I(0))$. Set $\hat{\kappa} = -\Psi(\tilde{I}) < 0$. If end-of-period-0 assets are $a \geq \hat{\kappa}$ then $\Psi(I) + a = 0$ has a unique positive root such that $I(a) \geq \tilde{I}$. This follows from the same reasoning as in the core model which defined the implicit function $I(a)$. Hence D can invest at level $I(a)$ before period $t = 1$. If $a < \hat{\kappa}$, then $\Psi(I) + a < 0$ at all investment levels I, and so D will be unable to secure a loan.

A.2. Proof of Proposition 2

Define $R(Q, z) = Qp(Q/z)$. We have that $R(Q, z) > 0$; $\partial R/\partial Q > 0$; $\partial^2 R/\partial Q^2 < 0$; $\partial R/\partial z > 0$; $\partial^2 R/\partial Q \partial z > 0$. D's problem is given by Program Bank with $B \cdot I(\cdot)$ replaced by $V^{\text{debt}}(R(Q_i, z_i) - W_i - d)$ as given in equation (8). Following Hart (1983, Result 1) we first confirm that Q_i must be weakly increasing in the state i. (5) implies that

$$R(Q_i, z_i) - R(Q_i, z_{i-1}) \geq R(Q_{i-1}, z_i) - R(Q_{i-1}, z_{i-1}).$$

Hence,

$$(z_i - z_{i-1})(\partial R/\partial z)(Q_i, z_{i-1}) \geq (z_i - z_{i-1})(\partial R/\partial z)(Q_{i-1}, z_{i-1}).$$

As $z_i > z_{i-1}$ and $\partial^2 R/\partial z \partial Q > 0$, we have $Q_i \geq Q_{i-1}$.

Following Hart (1983, proof of equation (18)), note that D's payoff must increase weakly in the state as

$$R\left(Q_i, z_i\right) - W_i - d \geq R\left(Q_{i-1}, z_i\right) - W_{i-1} - d \geq R\left(Q_{i-1}, z_{i-1}\right) - W_{i-1} - d. \tag{A.1}$$

The first inequality is equation (5), whereas the second inequality follows from $z_{i-1} < z_i$. This implies that D pays off her debt if the state of period-0 demand is high enough, and not otherwise. Let the lowest state at which D pays off her debt be k. Hence, k satisfies

$$R(Q_{k-1}, z_{k-1}) - W_{k-1} - d < \hat{\kappa} \leq R(Q_k, z_k) - W_k - d. \tag{A.2}$$

Combined with equation (8) we have that in any state $i < k$, D prefers her limited liability payoff of b and so shuts down before securing any input from U. For any other state $i \geq k$, we identify the binding local incentive compatibility constraints.

LEMMA A.1. *If the grid of probabilities is sufficiently fine, then in the downstream firm's problem the incentive constraints* (5) *can be replaced by* (A.2), *and*

$$Q_i \geq Q_{i-1} \quad \textit{for all } i; \tag{A.3}$$

$$R(Q_i, z_i) - W_i \geq R(Q_{i-1}, z_i) - W_{i-1} \quad \textit{for all } i > k; \tag{A.4}$$

$$R(Q_k, z_{k-1}) - W_k - d < \hat{\kappa}. \tag{A.5}$$

Proof. We have shown that equation (5) implies (A.3) and (A.2) follows from (A.1). (A.4) is immediate from equation (5). (A.5) is the condition for D to shut down in state $k-1$ and not report state k.

Now the reverse implication. Suppose we maximize the objective function in Program Bank subject to equation (4), and constraints (A.3), (A.4), and (A.5). We show that equation (5) is satisfied.

Using the structure of our model, we go beyond Hart (1983) and show that (A.4) is binding for all $i \geq k+1$. Suppose that this did not hold for some $i > k+1$ so that $R(Q_i, z_i) - W_i > R(Q_{i-1}, z_i) - W_{i-1}$. Consider D seeking more risk sharing by lowering W_{i-1} to $W_{i-1} - \varepsilon/g_{i-1}$ and raising W_i to $W_i + \varepsilon/g_i$ with ε sufficiently small that (A.4) for i continues to be satisfied. The constraint on $i-1 > k$ is satisfied as Q_{i-1} is unchanged while the transfer to U is reduced. U's participation constraint, equation (4), is unaffected. D's objective function changes by

$$\begin{aligned}
&\frac{d}{d\varepsilon}\left[g_i V^{\text{debt}}\left(R\left(Q_i, z_i\right) - W_i - \frac{\varepsilon}{g_i} - d\right)\right.\\
&\qquad \left.+ g_{i-1} V^{\text{debt}}\left(R\left(Q_{i-1}, z_{i-1}\right) - W_{i-1} + \frac{\varepsilon}{g_{i-1}} - d\right)\right]_{\varepsilon=0}\\
&= -V^{\text{debt}\prime}\left(R\left(Q_i, z_i\right) - W_i - d\right) + V^{\text{debt}\prime}(R(Q_{i-1}, z_{i-1}) - W_{i-1} - d) > 0.
\end{aligned}$$

The inequality follows from (A.1) and the concavity of V^{debt} for assets above $\hat{\kappa}$. A contradiction to the optimality of the contract.

If (A.5) is not too tight, $R(Q_k, z_{k-1}) - W_k - d < \hat{\kappa}\_$, then the previous argument yields the result for $i = k+1$. Suppose however that such a deviation cannot deliver equality in constraint (A.4) for $i = k+1$ as (A.5) is too tight: $R(Q_k, z_{k-1}) - W_k - d = \hat{\kappa}\_$. In this case consider a deviation which transfers payments to U from state k to $k+1$ and allows D pledgable assets of $\hat{\kappa}$ in state $k-1$ also. Thus we consider a deviation which sets $Q_{k-1} = Q_k$, changes the repayments to $\tilde{W}_{k-1} = \tilde{W}_k = W_k - \varepsilon$, and raises the state $k+1$ payment to $\tilde{W}_{k+1} = W_{k+1} + \eta$. For small ε, a firm in state $k-2$ will not deviate to report state $k-1$ as $\partial R/\partial z > 0$. As the payments and quantities are the same in states k and $k-1$, (A.4) is satisfied for state k. The same is true at state $k+1$ as long as ε and η are small. For U to be indifferent to this change requires that

$$\left(g_{k-1}+g_k\right)\left[W_k-\varepsilon-cQ_k\right]+g_{k+1}\left[W_{k+1}+\eta-cQ_{k+1}\right] \\ = g_k\left[W_k-cQ_k\right]+g_{k+1}\left[W_{k+1}-cQ_{k+1}\right],$$

or $g_{k-1}[W_k-\varepsilon-cQ_k]-\varepsilon g_k+g_{k+1}\eta=0$. D will see a change in its objective function given by

$$g_{k-1}V^{\text{debt}}(\hat{\kappa})+\frac{d}{d\varepsilon}\left[g_kV^{\text{debt}}\left(R\left(Q_k,z_k\right)-W_k+\varepsilon-d\right)\right. \\ \left.+g_{k+1}V^{\text{debt}}\begin{pmatrix}R\left(Q_{k+1},z_{k+1}\right)-W_{k+1}-d\\ -\dfrac{\varepsilon g_k}{g_{k+1}}+\dfrac{g_{k-1}}{g_{k+1}}\left[W_k-\varepsilon-cQ_k\right]\end{pmatrix}\right]_{\varepsilon=0} \\ = g_{k-1}V^{\text{debt}}(\hat{\kappa})+g_kV^{\text{debt}\prime}\left(R\left(Q_k,z_k\right)-W_k-d\right) \\ -\left(g_k+g_{k-1}\right)V^{\text{debt}\prime}\left(R\left(Q_{k+1},z_{k+1}\right)-W_{k+1}-d+\frac{g_{k-1}}{g_{k+1}}\left[W_k-cQ_k\right]\right).$$

As g_{k-1} tends to zero, this expression is positive as V^{debt} is concave for assets above $\hat{\kappa}$, and payments increase in the state (by (A.1)). Hence for a sufficiently fine grid of probabilities the objective function cannot have been maximized by the given choice of k (equation (A.2)) and so we have a contradiction.

Using the inductive technique of Hart (1983, Result 1) one can establish that (A.4) implies that in any state $i \geq k$ the downstream firm would not wish to misreport the state as being any other $j \geq k$. Misreporting the state as $j<k$ would necessitate shutting down. Hence, equation (5) is established for states $i \geq k$.

Finally, we demonstrate truthful behavior for states $i<k$. In such states we require D to shut down and receive the payoff of b. As $\partial R/\partial z>0$, (A.5) ensures that misreporting state k will lead to a payoff below b and so is not preferable. Next, we show that deviating to misreport $k+1$ instead of k is even less desirable. As $R(Q_{k+1},z_{k+1})-W_{k+1}=R(Q_k,z_{k+1})-W_k$, we have for $i<k$,

$$\left[R\left(Q_k,z_i\right)-W_k\right]-\left[R\left(Q_{k+1},z_i\right)-W_{k+1}\right] \\ = \left[R\left(Q_{k+1},z_{k+1}\right)-R\left(Q_{k+1},z_i\right)\right]-\left[R\left(Q_k,z_{k+1}\right)-R\left(Q_k,z_i\right)\right] \\ = \left(z_{k+1}-z_i\right)\left[\frac{\partial R}{\partial z}\left(Q_{k+1},z_i\right)-\frac{\partial R}{\partial z}\left(Q_k,z_i\right)\right]\geq 0.$$

The inequality follows as $\partial^2R/\partial z\partial Q>0$. Proceeding inductively ensures that the truth-telling condition (5) is satisfied at any state $i<k$. Hence, we have equation (5) in all states. □

Having established Lemma 4 we can invoke the proof of Hart (1983, Proposition 2) to deliver double marginalization at all states $i \geq k$, and coinsurance with U.

A.3. Proof of Proposition 3

Consider the optimal tariff solving Program Bank: $\{Q_i^*, W_i^*\}$. In state z_i, under this program, D has pledgable assets of $Q_i^* p(Q_i^*/z_i) - W_i^*$ and invests an amount $I(Q_i^* p(Q_i^*/z_i) - W_i^*)$, borrowing the difference between these two. U can replicate this contract which D would set if using a banking sector:

$$T_1^i = I\left(Q_i^* p\left(\frac{Q_i^*}{z_i}\right) - W_i^*\right) - \left[Q_i^* p\left(\frac{Q_i^*}{z_i}\right) - W_i^*\right], T_0^i = W_i^* - T_1^i,$$

where volumes $\{Q_i^*\}$ are as in the contract with the separate banks, and T_1^i is the size of the loan provided. Then, equation (9), the individual rationality constraint of U, is satisfied with equality by equation (4). By construction of T_1^i, the credit constraint is binding in every state so that the no-shirking constraint (10) always holds with equality. Finally, from the definition of the loan,

$$\begin{aligned}\pi\left(Q_i^* p\left(\frac{Q_i^*}{z_i}\right) - T_0^i\right) - T_1^i &= B \cdot I\left(Q_i^* p\left(\frac{Q_i^*}{z_i}\right) - W_i^*\right)\\ &\geq B \cdot I\left(Q_j^* p\left(\frac{Q_j^*}{z_i}\right) - W_j^*\right) \quad \text{for all } j \neq i,\end{aligned}$$

where the inequality is by the incentive constraint (5). The final term is the return available to D if her pledgable assets are $Q_j^* p(Q_j^*/z_i) - W_j^*$ and she borrows to the point at which the credit constraint binds. We wish to show that this level of borrowing is greater than T_1^j for $j < i$. This is true if and only if having assets of $Q_j^* p(Q_j^*/z_i) - W_j^*$ and borrowing T_1^j (resulting in investment equal to the level in the right-hand side of equation (11)) leaves the no-shirking constraint at the investment stage slack. This is shown by noting that, by definition,

$$\pi\left(Q_j^* p\left(Q_j^*/z_j\right) - T_0^j\right) - T_1^j = B \cdot \left[Q_j^* p\left(Q_j^*/z_j\right) - T_0^j\right].$$

Now consider increasing z_j to z_i. As $\pi' > 1 \geq B$ (see equation (3)), we must have

$$\pi\left(Q_j^* p\left(Q_j^*/z_i\right) - T_0^j\right) - T_1^j > B \cdot \left[Q_j^* p\left(Q_j^*/z_i\right) - T_0^j\right].$$

The left-hand side is the profit available if D borrows T_1^j to invest a total of $Q_j^* p(Q_j^*/z_i) - T_0^j$. Hence, borrowing T_1^j with pledgable assets of

$$Q_j^* p\left(Q_j^*/z_i\right) - T_0^j - T_1^j = Q_j^* p\left(Q_j^*/z_i\right) - W_j^*$$

leaves the credit constraint slack. We thus obtain

$$B \cdot I\left(Q_j^* p\left(Q_j^*/z_i\right) - W_j^*\right) > \pi\left(Q_j^* p\left(Q_j^*/z_i\right) - T_0^j\right) - T_1^j \quad \text{for } j < i,$$

as required. Hence, the period-0 incentive constraint (11) is actually slack.

But as the incentive constraint on the report of the demand state in period 0 is slack, there is room for the transfer of some more risk upstream. Suppose that the quantities are altered to $Q_i^* + \varepsilon$ for all $i < n$ and the tariff W_i^* is increased by εc. The payments T_1^i and T_0^i retain the form given previously. This new tariff satisfies equation (11) for small $\varepsilon > 0$. U remains indifferent, thus continuing to satisfy equation (9) with equality. By definition of T_1, equation (10) is satisfied with equality. It therefore remains to note that the objective function has grown. This follows as, by Property 2 of Proposition 1, the marginal revenue at states below n exceeds c.

A.4. Proofs of Section 6

Proof of Proposition 4. Standard algebraic manipulations using equation (12) deliver that $\partial I/\partial a = \partial I/\partial A = 1/[B + 1 - \pi'(I)]$, which is strictly positive by equation (3). Hence, differentiating equation (13) with respect to A then yields the result as $\pi''' \geq 0$, and it can be shown that $\partial^2 I/\partial A \partial a < 0$. □

Proof of Corollary 2. The bargaining program in which U requires a profit of β can be converted to Program Bank by adding β to the transfers in all states. This implies that the optimal contract can be found by reducing D's assets by β and proceeding as in Section 3. Hence the investment function the downstream firm faces, $I(a; \beta)$, is defined implicitly by

$$IB = \pi(I) - (I - [a - \beta]) \tag{A.6}$$

and so the result follows from Proposition 4. □

Proof of Proposition 5. Using equation (15) in equation (16) we have

$$\begin{aligned}\frac{d}{dr}\left[-\frac{\partial^2 I}{\partial a^2}\Big/\frac{\partial I}{\partial a}\right] &= -\frac{\partial I}{\partial r}\pi'''(I)\left[\frac{\partial I}{\partial a}\right]^2\frac{1}{1+r} \\ &\quad - 2\pi''(I)\frac{\partial I}{\partial a}\frac{1}{1+r}\frac{\partial^2 I}{\partial a \partial r} + \pi''(I)\left[\frac{\partial I}{\partial a}\right]^2\frac{1}{(1+r)^2}. \end{aligned} \tag{A.7}$$

The first line is positive as $\pi''' \geq 0$ and investment levels shrink in the interest rate. Recalling that $\pi(I)$ is concave so that $\pi''(I) < 0$, the second line is equal in sign to $2(1+r)\partial^2 I/\partial a \partial r - \partial I/\partial a$. Using equation (15) we have

$$\frac{\partial^2 I}{\partial a \partial r} = \frac{1}{1+r}\frac{\partial I}{\partial a} - \frac{1}{1+r}\left(\frac{\partial I}{\partial a}\right)^2\left(1 - \pi''(I)\frac{\partial I}{\partial r}\right).$$

Hence the sign of the second line of (A.7) is given by

$$2(1+r)\frac{\partial^2 I}{\partial a \partial r} - \frac{\partial I}{\partial a} = \frac{\partial I}{\partial a}\left[1 - 2\frac{\partial I}{\partial a}\left(1 - \pi''(I)\frac{\partial I}{\partial r}\right)\right]$$

which is positive if $\pi''(I) < 0$ is sufficiently large in magnitude. Hence, an increase in the interest rate results in a larger coefficient of (absolute) risk aversion. □

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Online Appendix for Vertical Relations Under Credit Constraints