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1 Introduction

Production and operations management research has provided a number of classic models such as the EOQ formula (Harris 1913), the news vendor model (as in Arrow et al. 1951), the HMMS model (Holt et al. 1960), the Wagner-Whitin model (Wagner and Whitin 1958), Clark and Scarf’s (1960) echelon inventory model, and more recent examples such as Lariviere and Porteus’s (2001) selling-to-a-news vendor and the various channel coordination models described in Cachon (2003), among many others. Common themes in these models are the assumptions of infinite liquidity (i.e., sufficient cash for any expenditure) and the absence of risk considerations (at least as related to operational decisions) in the evaluation of cash flows. Both of these assumptions conflict with practical observations of finite liquidity and premiums applied to cash flows on the basis of risk contribution (that cannot be eliminated by diversification).

In certain situations, such as the perfect market assumed in Modigliani and Miller’s classic work (1958), the available liquidity assumption is not constraining since any firm with a value-enhancing project can obtain financing (whether in debt or equity, which makes no difference as Modigliani and Miller show). This observation yields a separation of operational from financial decisions that would justify the operational models that ignore liquidity concerns; however, as Modigliani and Miller later observed (1963), market imperfections, such as tax, distress, transaction, and agency costs, negate the irrelevance result and remove the wedge separating operations from finance.

In addition to illuminating the need to consider liquidity in practical situations, the financial market also provides information on the value of future cash flows that explicitly considers the role of risk in those cash flows. The relevant risk level generally depends on a firm’s operational decisions so that valuing uncertain cash flows then depends explicitly on operational considerations such as production, procurement, and capacity. In this case, the valuation of uncertain cash flows for an operational decision requires specific consideration of how those decisions would affect financial valuation.

This chapter briefly explains the issues involved in the interactions between the operational and financial decisions of firms. This chapter also covers some of the results in the area in terms of models that provide a structure for a firm’s consistent decision making, that uncover properties of decisions and how they differ from results ignoring the financial context, and empirical results.
POM and Finance

that explore how finance and operations interact in practice. The intent of the chapter is to be instructive while giving examples in many areas and not an exhaustive list of results.

The chapter also focuses on work that explicitly recognizes financial market conditions and the distinction between market and unique risks (i.e., that do not treat all variations in cash flows as equivalent). The following section presents the basic theory surrounding the integrated nature of finance and operations in imperfect markets. Section 3 describes how the valuation of future cash flows depends on operational considerations and the inconsistency in approaches based on exogenously determined discount rates. Section 4 describes how supply chain decisions and interactions between firms are also affected by financial considerations and how these issues impact supply chain efficiency and how operational “hedging” activities differ from financial market hedging activity. Section 5 considers the role that operations management plays in the financial risk of a firm (i.e., the causality from operations to finance). Section 6 describes some of the empirical results that have appeared on the topic. Finally, Section 7 summarizes the results and provides directions for further work for modelers, theorists, and empirical researchers.

2 Impact of Financing Needs on Single Firm Operational Decisions

As a starting point for operational models, consider the basic EOQ model to determine the optimal order quantity \( Q^* \) solved as

\[
Q^* = \sqrt{\frac{2aK}{h}}
\]

of a firm facing constant known demand at rate \( a \) with a fixed charge \( K \) for every order and an inventory holding cost proportional to the amount of inventory as \( h \) times the amount of inventory. An implicit assumption for that model is that the firm has sufficient liquidity to finance an initial \( K + cQ^* \), assuming a constant marginal cost \( c \) for each unit ordered in addition to the fixed order cost. Even if the assumption (sometimes mentioned) that the selling price or other value from the product will be sufficient to cover the total ordering cost (and ensure a profit) is met, the firm may still not have sufficient cash to finance the initial working capital.

In a perfect market world, as explained by Modigliani and Miller (1958), the firm’s lack of liquidity alone would not affect the EOQ (again assuming sufficient return in each order period to cover the total ordering cost). The firm can obtain funding either by offering some share (equity) of the total profits or by borrowing whatever amount the firm is short (debt). The perfect market ensures that a willing investor or lender would be available and would not interfere with the firm’s profits from the ordering decision.

As noted above however, in reality, markets are not perfect and the firm would face some additional cost for financing this inventory. If no external financial market exists (i.e., the cost of additional debt or equity is infinite), the firm could order no more than its initial cash can support but may then only order up to the free cash flow from the cycle that ends when inventory is depleted. That may not be sufficient to cover the ordering cost. A model to determine the minimum long-run average cost now takes a different form. First, the firm can determine a sustainable cycle that will support the ordering cost indefinitely and then, it can decide whether a strategy exists to build up sufficient capital to finance this policy or, if more than sufficient capital is available, whether larger order quantities can be sustained.

For the minimum average cost self-financing cycle with revenues of \( p \) per unit of demand, the firm would solve:

\[
\min_{Q \geq 0} \frac{aK}{Q} + \frac{bQ}{2} \quad (1)
\]
\begin{equation}
\text{s.t. } K + cQ < pQ - \frac{hQ^2}{2a},
\end{equation}

where we assume the revenue and holding charges occur at the end of the period. This then implies that, if the positive \( Q \) satisfying the constraint, given by:

\begin{equation}
Q^\text{min} = \left( p - c \right) h/(2a) + \sqrt{\left( p - c \right) h^2 + 4aK/h/(2a)},
\end{equation}

is smaller than \( Q^* \), then \( Q^\text{min} \) becomes the optimal feasible strategy, assuming that the firm can support an initial order and policy to reach a cash level of \( K + cQ^\text{min} \). Another strategy is then needed to build sufficient cash or to maximize the amount of cash that can be supported (and, hence, a lower overall \( Q \) than \( Q^\text{min} \)). This then requires an additional optimization.

If the firm has more than \( K + cQ^\text{min} \) available, then the firm can order up to \( Q^{\text{cash}} \) that solves (1 and 2) with \( K + cQ^{\text{cash}} \leq C \), where \( C \) is the firm’s initial cash position. This value then increases with \( C \) until \( Q^{\text{cash}} > Q^* \), at which point, the original EOQ is again optimal.

The result is that, with no external financing possibility, the EOQ can change substantially. When the firm can obtain financing with some costs or perhaps benefits (for example, from the tax deductibility of debt), the results for the EOQ would then be reflected in a change in the formula. As long as the overall average profit is positive, the original EOQ formula applies if all the quantities remain fixed and known. A lender may also guarantee payment by securing the debt with some form of collateral, such as a debt covenant requiring sufficient assets (i.e., cash, inventory, accounts receivable, or fixed assets that are pledged to the lender). Buzacott and Zhang (2004) show how such asset-based financing can affect a firm’s operating decisions. Alan and Gaur (2011) provide another example of a study of how a firm’s operational decisions are affected by this form of financing. Babich and Sobel (2004) also consider a firm (deciding a time for an IPO) with a riskless loan and an extension that assumes losses in fixed assets in the event of inadequate liquidity for loan repayment. A dynamic version of repeated losses in the event of inadequate liquidity also appears in Li et al. (2013). In contrast to these models, when demand has risk and the firm may default on any unsecured loan amount, operational and financial decisions then interact with the broader financial market as described in the following section.

### 3 Impact of Financial Markets on Single Firm Operational Decisions

When firms face risk, operational decisions should reflect risk preferences consistent with the decision maker’s objective. Firm managers are generally obligated to make decisions in the best interest of the firm owners. As agents of the owners, or principals, agents may act otherwise, requiring the principal to apply penalties or some form of monitoring to control the agent. In such cases, principal-agent theory (e.g., Hölmstrom (1979) and Plambeck and Zenios (2000) for an operational example) provides a process to design a mechanism that ensures the agent acts according to the principal’s goals. Assuming a firm-owner objective, if the owners are shareholders of a public firm, then the decisions should reflect risk preferences consistent with those of the financial market. This observation implies that uncertain cash flows affected by the operational decisions of a public firm should be viewed from a financial market perspective.

As a simple example with uncertain cash flows, consider the basic news vendor model in which a firm must commit to a purchase or order decision in advance of observing demand. The cash flow revenue is then uncertain and requires consistent evaluation. A basic assumption of a market without financial frictions (e.g., no transaction or other costs for trading) is that the cash...
flows from these decisions cannot be exchanged costlessly with other cash flows in the market with zero current net cash flow to produce non-negative net cash flows in all future states of the world with strictly positive cash flows in some non-trivial (positive probability) set of states (i.e., the market does not admit arbitrage possibilities). This assumption provides the basis for the financially consistent valuation of uncertain cash flows from operational decisions (see Birge (2015) for an explanation).

The absence of arbitrage in a market with no frictions is the ability to adjust the probability distribution of the future cash flows to reflect risk so that then all future cash flows can be discounted with the market’s valuation of risk-free cash flows (i.e., discounted with the so-called risk-free rate that applies to assumed zero-risk investments such as US treasury bills). This probability distribution is known as a risk-neutral or equivalent martingale measure. The equivalence of its existence with the absence of arbitrage is known as the Fundamental Theorem of Asset Pricing and is a result of linear programming duality (see Harrison and Kreps (1979) for a general discussion and Birge (2015) for a simple derivation in the operational context).

For the news vendor context, we consider an initial purchase quantity \( x \) at cost \( c \) and future sales \( y(\xi) = \min(x, \xi) \) at price \( p \) (for now, assumed known or representing a price commitment from the seller) that depends on a random demand \( \xi \) with original (or natural) cumulative distribution function \( F \). The financial market’s value for the future cash flows \( py(\xi) \) can reflect risk by finding the market’s utility for this future cash flow. The Fundamental Theorem of Asset Pricing states that this is possible by transforming the distribution \( F \) to an equivalent risk-neutral distribution \( F_n \) and then treating the expectation, \( E_{F_n} [py(\xi)] \), as a certain cash flow.

This process requires finding the equivalent representation of \( F_n \). As explained in Birge (2000) and Birge (2015), this distribution can be found using the capital asset pricing model (CAPM) described in Sharpe (1964) and Lintner (1965). A key point in this derivation is to recognize that investors can diversify against idiosyncratic risks, which only relate to a specific investment and, therefore, can be fully diversified by investors, and systematic risks that cannot be diversified. This distinction particularly means that a utility that does not distinguish between these forms of risk is inconsistent for valuing the cash flows of any public firm (Birge 2015). The CAPM implies that the transformation of the distribution to a risk-neutral equivalent form only depends on the systematic risk of the cash flow.

An example from Birge (2015) to illustrate the difference in values considers two identical cash flows (\( A \) and \( B \)) that occur at a time \( t = 1 \) where both have mean $100 and standard deviation of $20. In the news vendor context, we might imagine that \( \xi \) for Cash Flow A actually depends on a single salesperson’s effectiveness, which is not related to the market but only depends on the salesperson’s unknown idiosyncratic ability. Cash Flow B, however, is the result only of consumer reaction to the firm’s posted prices and is the result of (certain) production at a fixed posted price in response to uncertain demand, which is highly correlated with the market. From the CAPM, the cash flow in \( A \), because it has zero correlation with market risk, is simply discounted with the risk-free rate as having value:

\[
\nu_A = \frac{100}{1 + r_f},
\]

where \( r_f \) is the risk-free rate.

Cash Flow B, however, is correlated with market risk. The CAPM implies that Cash Flow B should be discounted for the amount of market or systematic risk as follows:

\[
\nu_B = \frac{100}{1 + r_f} \left( 1 + \frac{\lambda \sigma V\left( \frac{\hat{B}}{100}, r_f \right)}{1 + r_f} \right),
\]
where $\tilde{r}_m$ is the market return, in which the overhead tilde ($\sim$) denotes a random variable with a mean value denoted with an overhead bar as $\bar{r}$, and $\lambda_m$ is known as the market price of risk, given as:

$$\lambda_m = \frac{\bar{r}_m - r_f}{\sigma_m^2}. \quad (6)$$

The difference in the additional discounting in $(1 + r_f - \lambda_m \text{CoV}(\tilde{B}/\tilde{r}_m))$, between $A$ and $B$ can be 3% annually for typical products such as trucks. Products with higher correlation with the market could have annual premiums higher than 10% above a cash flow with equivalent variance but no market correlation.

From the equivalence with a risk-neutral distribution, this result implies that the expectation of $B$ with respect to the equivalent risk-neutral distribution is given as:

$$\mathbb{E}_n[B] = \mathbb{E}_r[B](1 + r_f - \lambda_m \text{CoV}(\tilde{B}/\mathbb{E}_r[B], \tilde{r}_m)) \quad (7)$$

Finding $F_r$, will permit solving for future cash flows that maintain a consistent correlation with the market return. As Birge (2000) describes, this occurs when the future demand distribution evolves as a lognormal distribution where the mean follows a geometric Brownian motion with constant correlation with the value of the market portfolio. The result is that the equivalent risk-neutral distribution can be found by discounting the cash flow by shifting the mean of the future cash flow by the additional premium $\delta = \lambda_m \text{CoV}(\tilde{B}/\mathbb{E}_r[B], \tilde{r}_m) - (1 + r_f)$ while maintaining the cash flow's volatility or variance. With $r_f$ corresponding to continuous compounding (i.e., using $e^{r_f}$ in place of $(1 + r_f)$ for the news vendor problem (see Birge and Zhang (1999)), setting $r_f = 0$ for simplicity, this implies for continuous $F$ that the classic optimal solutions $x^* = F^{-1}\left(\frac{p - \ell}{\mu}\right)$ is replaced by:

$$x_r^* = F_r^{-1}\left(\frac{(1-\delta)p - \ell}{(1-\delta)p}\right). \quad (8)$$

where $1-\delta$ is replaced with $e^{-\delta}$ for continuous discounting and the subscript $r$ indicates that the solution includes risk aversion consistent with the market’s premium for risk.

This form of adjustment for risk then involves identifying uncertainties that correlate with the market and adjusting for the risk premiums in their expectations to obtain risk-neutral equivalence. This applies to the price and cost parameters as well as to demand. Berling and Rosling (2005) provides examples showing how market risk in these parameters can affect EOQ and news vendor solutions, noting that the decision can be more sensitive to selling price and cost risk than to demand risk. The approach also applies in dynamic models over multiple periods. Birge (2000) shows that, in linear models, the risk-neutral equivalence allows solution of linear models for incorporating risk in long-term capacity plans where demand risk may be quite substantial and that the risk-neutral equivalent distribution can be obtained by adjusting constraints in this structure instead of transforming the probability distribution.

While these results apply for markets without imperfections, the general principles can be applied in imperfect markets assuming that the imperfections are idiosyncratic (and, hence, not priced in the market). As an example, we consider a news vendor with limited cash (less than $c_x$) to support initial investment, following Xu and Birge (2004). This model assumes a proportional tax rate $\tau$ on profit and that a fraction $\alpha$ of any remaining assets of the firm are lost in the event
that the firm defaults on a loan (following Leland (1994) and other work in financial econom-
ics). The firm can finance the inventory either with debt or by selling shares to other investors 
(equity). We assume that interest payments \( i \) can be deducted (assuming positive profits).

The news vendor problem in this case is to maximize the value of the firm. Assuming full 
information (or that bankers can monitor or control the firm manager’s actions costlessly), the 
news vendor model becomes:

\[
V^* = -\min_{x, \gamma, \sigma, y} cx + \int_{x}^{y} \gamma pg(y)dy - \int_{x}^{y} pg(y)dy
\]

\[
- \int_{y}^{\gamma} (\gamma - \tau (\gamma - \alpha - iD)) g(y)dy
\]

\[
\int_{y}^{\gamma} (x - \tau (x - \alpha - iD)) g(y)dy
\]

s.t. \( D - \int_{y}^{\gamma} pg(y)dy = 0 \) 

\( s_b - D(1 + i) = 0 \) 

\( s_p - \alpha - iD = 0 \) 

where \( g \) denotes the density of demand, \( \gamma \) is the fraction recovered in the event of default on 
the debt, \( s_b \) is the bankruptcy point or minimum demand level to re-pay the loan, and \( s_p \) is the 
profit point or minimum demand level to earn positive profits (and to owe taxes). The objective 
represents the (negative of the) net value of the firm overall where \( \alpha \) is expended and then 
returns fall into one of four groups according to the demand realization: default, losses without 
default, taxed profits with production below capacity, and taxed profits with production at 
capacity. The complicating factor in this model is the constraint (10) that represents fair pricing 
of the loan. This constraint effectively assumes that the financial market is competitive and that 
no information asymmetries exist (or the bank can costlessly monitor production and infer the 
demand distribution) so that the interest rate \( i \) is set to make a loan of value \( D \) have a zero net 
present value.

We can write the optimization problem in (9)–(12) in terms of \( x \) and \( D \) with \( i(D) \) determined 
by (10) after substituting for \( s_b \) and \( s_p \) with the expressions in (11) and (12). The result is that 
an interior optimal solution occurs at the solution of the following two first-order conditions:

\[
(1 - \tau) \int_{x}^{y} g(s)ds + \tau \int_{x}^{y} g(s)ds - c = 0;
\]

\[
\tau \left( i + D \frac{\partial i}{\partial D} \right) \int_{x}^{y} g(s)ds - (1 - \gamma) \left( 1 + i + D \frac{\partial i}{\partial D} \right) s_{p} g(s) = 0.
\]

The first condition (13) includes the standard news vendor optimality condition with the 
addition of \( \tau (1 - \gamma) s_{p} \) as the marginal value of the tax deduction for the cost of the capacity \( x \) 
which only has value when the firm is profitable. The absence of a deduction in the event of 
a loss creates a distortion to reduce investment below a no-tax solution even in the absence of 
debt. With debt, the breakeven point rises, reducing the effective tax deduction of the capacity
cost and further reducing investment; expected profit, however, increases as the firm gains the interest rate deduction. The second condition reflects the marginal benefit of this debt for tax purposes in the first term and the marginal cost from the deadweight loss in the event of default on the debt in the second term.

As shown in Xu and Birge (2004), these conditions lead to a capacity on debt such that firms cannot borrow beyond an upper bound $D$, regardless of interest rate. The conditions also imply a first order impact of the capacity decision on the optimal debt level through the tax benefit term while the debt level has effectively a second-order impact on the optimal capacity level since it is only the change in the break-even level from the interest payment that enters the first equation in (14). As explored in Xu and Birge (2004), this difference in relative influence implies that, while operational and financial decisions are dependent in this framework, correctly identifying the operational decision $x^*$ is more critical than determining the optimal financial structure through optimal debt $D^*$.

The equations in (14) also lead to a potentially non-monotonic relationship between the leverage ratio, $D^*/V^*$, and $\epsilon$ (or the profit margin) in which high debt levels can occur at both low and high margins since, at low margins, $x^*$ is also low, leading to little variation in revenues and low default risk to support higher leverage, and at high margins, low chances of losses overall reduce default risk and again can support high leverage. Section 5 discusses predictions from these observations and empirical results that support these observations.

Relatively few papers in the literature explicitly consider such tradeoffs and particularly the firm’s operational commitment to a production or capacity level (and selling price) in advance of realizing demand. Dotan and Ravid (1985) is an example that considers a model in which production and financing decisions are endogenous, but the variation in revenues is not affected by the production scale (i.e., higher variation with higher capacity as in the news vendor framework). Lederer and Singhal (1994) also consider operational and financial decisions in a model of financing and technology choice in which production follows demand realizations. Additional examples include Mauer and Triantis (1994), whose model also assumes instantaneous production and, while including market imperfections, predicts a limited connection between financial and operational decisions. Among other papers, Hennessy and Whited (2005) provides a dynamic tradeoff model that includes capital investment. While these models assume competitive capital markets for loans as generally assumed in financial models, Dada and Hu (2008) considers a situation with a single lender who can strategically offer an interest rate to a producer.

These results are generally related to risk management of the firm and incentives for firms to reduce risk or to hedge positions. Hedging can enhance value by ensuring that firms can profitably take advantage of investment (or production) opportunities. Froot et al. (1993) provides a basic model of how investment and borrowing are interrelated in this framework. Financing can also exercise control over management actions to prevent over- and under-investment (and hence increase value) as in Stulz (1990).

Operational actions, such as shifting production from one region to another to take advantage of favorable exchange rates (see, e.g., Kogut and Kulatilaka 1994; Huchzermeier and Cohen 1996; Dasu and Li 1997; Kazaz et al. 2005; Aytekin and Birge 2009) can also be viewed as a hedging mechanism. In general, these models consider the valuation of flexible forms of capacity investment that enable production to shift in response to demand, rate, and price changes. Van Mieghem (2003) provides an overview of this literature and discusses how such operational hedges can interact with financial instruments. Combinations of operational and financial hedges are also discussed in Ding et al. (2007) and compared in Chod et al. (2010), Chowdhry
and Howe (1999), and Hommel (2003). The general conclusion is that operational hedges that can adjust quantities in response to demand or price changes have an advantage over financial hedging instruments that generally have payoffs depending on prices alone. Their payoffs are then generally not directly available in the market and, hence, provide some rent to the firm as owner of the relevant assets.

4 Impact of Financial Considerations on Supply Chain Operations

Financial considerations can affect interactions among firms in a supply chain in different ways from the impact on a single firm. In particular, as observed in Rajan and Zingales (1995), financing from supply chain partners (trade credit) is the leading source of short-term borrowing for public firms. While many theories for trade credit exist (e.g., Petersen and Rajan (1997)), an operationally important aspect of trade credit is that it can improve supply chain efficiency by reducing issues such as double marginalization (the addition of margins from both retailers and suppliers that can result in inefficient production quantities) and improving coordination. As shown in Yang and Birge (2011), trade credit can provide a risk-sharing mechanism so that upstream firms share in the risk of the downstream firms’ demand and can use the leverage of their trade credit offer to induce the downstream firm to order an efficient quantity.

In the model in Yang and Birge (2011), which follows the selling-to-a-news vendor model in Lariviere and Porteus (2001), a supplier offers a two-part contract with two prices to the buyer; \( w_c \) if the buyer pays immediately upon delivery and \( w_t \) if the buyer delays payment until after demand is realized and revenues are collected. The buyer solves a problem similar to (9)–(10) with now an additional source of financing from the supplier, potentially in addition to external debt from a third party such as a bank. In a model without taxes or equity financing, their result is that, like other two-part tariffs in the operations management literature (Cachon 2003), the two-part trade credit contract can enable channel coordination and eliminate double marginalization. In addition, trade credit is used before bank lending. Again, this has empirical implications that are discussed in Section 5.

Models of trade credit usage in supply chains appear as early as Haley and Higgins (1973), which only considers the suppliers’ financing incentive (as opposed to external financing). In general, the overall coordination of product and cash flows across a supply chain represents a complex optimization problem that is explored in Gupta and Dutta (2011), which focuses on the timing of trade credit payments and cash management. A paper that considers both trade credit and bank financing in comparison is Kouvelis and Zhao (2012), which does not include costs of financial distress. In this case, Kouvelis and Zhao (2012) also shows that trade credit is preferred to bank financing (while not considering a portfolio of both bank and trade credit financing). Gupta and Wang (2009) and Lee and Rhee (2011) also consider models of trade credit in the news vendor framework without distress costs and, in which, the supplier can vary the financing terms. Supply chain financing and inventory risk are considered with potential default in Lai et al. (2009), in which, if the supplier is willing, the buyer can pre-order products at a fixed wholesale price or wait for demand realization and sell on consignment. In the presence of financial constraints, the supplier may choose to offer pre-ordering even if this would not be offered otherwise. Deferred payment as a form of trade credit is also considered in Caldentey and Haugh (2009), which examines the buyers’ advantage in engaging in financial hedging to assist in fulfilling the supplier’s payment obligation. Other papers on trade credit influence in the supply chain are reviewed in Seifert et al. (2013).
5 Impact of Operational Decisions on Financial Asset Prices

The previous two sections concerned the influence of financial market theory on operational decisions. Operational decisions can also have an impact on financial asset prices. These impacts can be viewed as directly implied by the results above. For example, as a firm increases capacity, it increases its exposure to the broader market and, hence, its correlation with the market. That should then increase the discount that investors apply to this firm's expected cash flows according to CAPM. This implies that firms with a higher capacity relative to demand than others should also have higher returns to their shares.

Similar reasoning implies that firms with more flexible resources or alternate suppliers have a natural operational hedge that should lower their exposure to market risk. The result of lower market risk should then be lower returns for firms with larger hedges. This again has empirical implications that are discussed in Section 6.

The key observation in this process is that operational hedges, such as alternative suppliers and flexible production resources, can improve value both in terms of future expectations and in the present value of those expectations (due to lower market risk exposure). Operational hedges often take the form of options that are contingent on future realizations of random variables. Aytekin and Birge (2009), for example, consider the valuation of capacity in multiple markets with different currency and random exchange rates. The option to produce in a market with favorable exchange rates creates an operational hedge that has value for the firm.

While techniques from financial option valuation also apply to operational options, most traded financial options are functions of the price of an underlying resource and not of an underlying demand. A direct option on an asset that correlates perfectly with the underlying demand is generally not available. An option could be constructed that mimics a factor proportional to the market risk fraction, but market imperfections may make such an option expensive relative to the firm's operations (indeed, otherwise, the firm could add no value from its unique resources). Using unique resources, operational hedges then generally provide incremental value relative to a corresponding financial hedge. As Chowdhry and Howe (1999) observe, it is the combination of price and quantity flexibility that underlies the operational value.

6 Empirical Results in Operations and Finance Interactions

The results mentioned above have a variety of testable empirical implications. The news vendor model and supply chain generalizations, such as Graves et al. (1998) and Chen and Lee (2009), for which Bray and Mendelson (2015) provides empirical support, have implications for the capital structure of firms. As noted above, the results in Xu and Birge (2004) imply that a potential U-shaped relationship exists between firm profitability (as a fraction of sales) and firm leverage (its fraction in debt). Xu and Birge (2006) provide some evidence that this is the case by using the leverage and reported (positive) operating margin of public US firms. The model in Xu and Birge (2004) is expanded in Birge and Xu (2011) to include fixed costs that act as operating leverage and effectively replace debt in the firm's capital structure. That paper also argues that firms with highly negative operating margins (which were not explored in the empirical results in Xu and Birge (2006)) must have high future expectations to support their continued existence. Those expectations must then involve relatively higher future expected margins for surviving firms with current highly negative operating margins. This logic then implies a cubic form of the relationship between profitability and leverage in which leverage first increases as profits increase from highly negative to zero and then follows the U-shaped pattern previously observed. The paper
presents empirical evidence that this pattern appears in the cross-section of all public firms and is persistent across time.

One could try to do this historically for similar cash flows, e.g., previous years’ sales of the same product and to provide the sales estimates as rates of increase over the previous years’ sales. Indeed, Gaur and Seshadri (2005) find that such estimates can be quite useful in predicting sales. A key implication of this modeling framework is that the capacity decision endogenously determines the firm’s cash flow risk and, hence, the cost of debt. In models where firm value evolves exogenously or price risk is simply a multiplier on production capacity, this effect is lost. Operational decisions of the firm, such as capacity levels, are bound with the firm’s risk and should not be separated from other decisions that affect firm risk. Recognizing this interdependence reveals relationships that do not appear in exogenous-value driven firm models.

Much of the empirical evidence of operational and financial interactions has appeared in the finance literature. Direct evidence of the impact of financial markets, for example, appears in Kashyap et al. (1994), which shows that firms reduce inventories when credit tightens. Other papers address the issue of hedging and firms’ use of operational resources. Financial hedging’s effect on firm values is supported in the study in Allayannis et al. (2001), which examines the use of foreign exchange derivatives. Kim et al. (2006) consider both financial and operational hedging and show that firms with more operational flexibility use less financial hedging and that hedging increases value. Blome and Schönherr (2011) provide case studies that demonstrate the value of supply chain risk management strategies.

The impact of supply chain disruptions on firm value is explicitly considered in Hendricks and Singhal (2005), which uses an event study of disruptions to show that supply chain issues have a lasting impact on a firm’s financial performance as reflected in its stock return. The impact of customers on a firm’s performance is also examined in Cohen and Frazzini (2008), which show that shocks to a firm’s customers have a delayed impact of that firm’s returns, indicating a form of slow diffusion of information. Both supplier and customer effects are considered in Wu and Birge (2014), which show that supplier shocks may also have a lagged impact on a firm while, after the publication of Cohen and Frazzini (2008), customer effects may no longer exhibit a delay. In addition, Wu and Birge (2014) provide evidence of the impact of a firm’s hedging policies by relating returns to overall position in the network of all firms. The results indicate that manufacturers, which have an additional incentive to that of downstream retailers to hedge operationally to protect against individual suppliers’ disruptions affecting all operations, have lower returns as they become more central in the network of firms while retailers, wholesalers, and distributors have higher returns for higher centrality. The implication of these findings is that manufacturers’ hedging incentive reduces their exposure to systematic risk (and hence the risk premium associated with that risk) while retailers and logistics providers have incentives to build on existing relationships and increase systematic risk as they become more central in the network.

Many papers have also examined the impact of trade credit on firms’ operational performance. Petersen and Rajan (1997) show that firms with less access to financial institutions use more trade credit and that firms may use trade credit as a form of price discrimination. Cuñat (2007) examines the extent of trade credit in UK firms and shows higher trade credit for emerging firms. Yang and Birge (2011) show that trade credit is generally used by firms before short-term borrowing in support of its role in supply chain coordination. Boissay and Gropp (2013) consider a different effect of trade credit across a supply chain in terms of absorbing liquidity shocks, demonstrating this effect for French firms. In contrast to these papers focused on buyers’ borrowing, for a supplier financing perspective, Klapper (2006) considers factoring in which a supplier may use accounts receivable to obtain financing from a financial institution, showing that factoring increases in countries with greater development and accessible credit information.
7 Conclusions and Future Research Directions

Due to unavoidable market imperfections including taxes and financial distress costs, operational and financial decisions are interconnected. This chapter discusses the reasons for these connections and their implications for the operational decisions of firms individually and collectively within a supply chain. The relationships also have implications for the performance of firms and their valuations in the financial market. Models of these effects provide insight into firm decisions and hypotheses that can be tested empirically as discussed in Section 6.

The discussion above does not address competition, which can also have an influence on a firms’ operational and financial decisions and their interrelationship. Competition can, however, have an impact on firms’ operational decisions such as supplier choices as in Babich et al. (2007). This area has received relatively little attention in the literature overall and provides significant potential for further research. Interactions of multiple suppliers and their competing interests to provide financing to firms represents a related area of high potential.

Relatively little work has also considered the interaction of agency issues, such as managerial control, in relationship to operational and financial control. Such issues as those discussed in Jensen and Meckling (1976) also play a role in the interactions of firms’ financial and operational decisions (as, for example, in Xu and Birge (2006)) and may guide decisions such as the form of managerial compensation. This area also represents fertile ground for additional research.

Joint consideration of financial and operational interactions is essential for effective management. Modeling these interactions requires an appreciation of the structure of operational decisions, including the commitment and deployment of resources and prices, as well as understanding of market consideration of risk and financial flows. Combining these elements provides perspective on firms’ decisions and can help in guiding and improving them. Research has, however, been limited to date in comparison to specific operational decisions of a firm. As such, the area of operational and financial decisions provides many opportunities for further research, new insights, and impact on operational practice.

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John R. Birge

372

