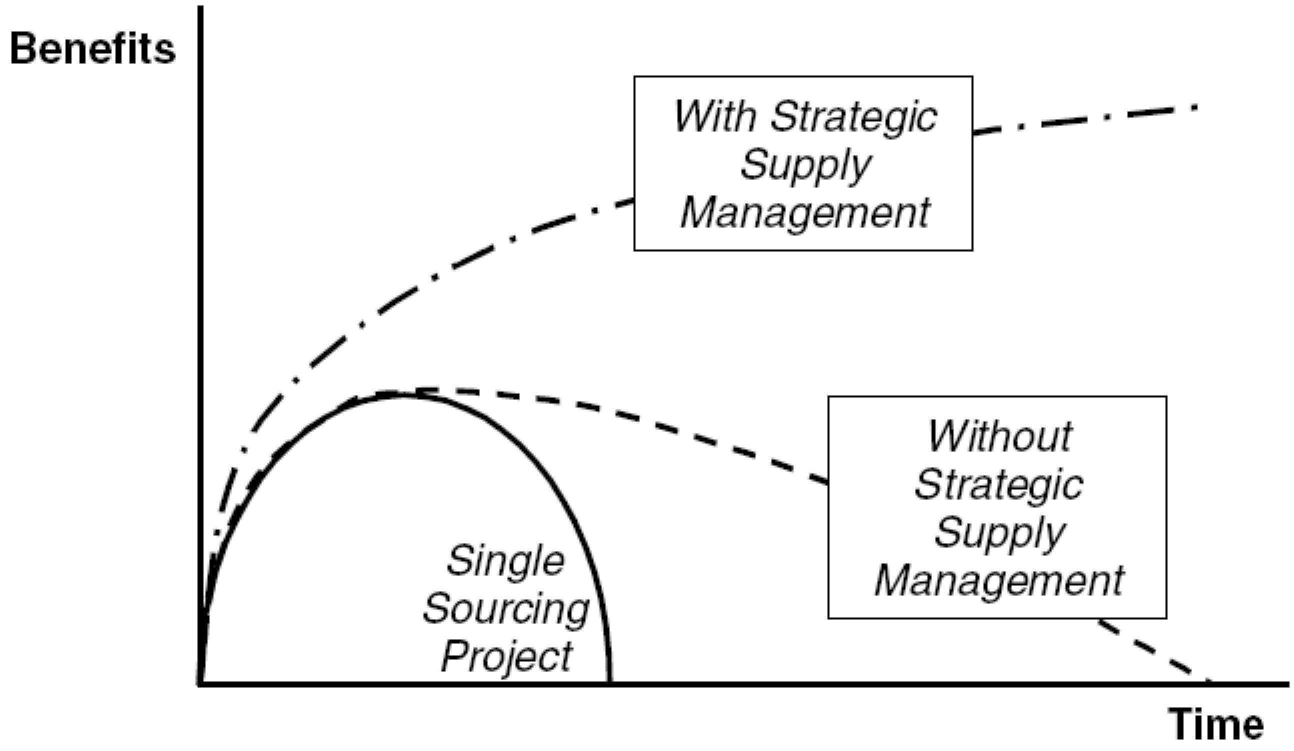
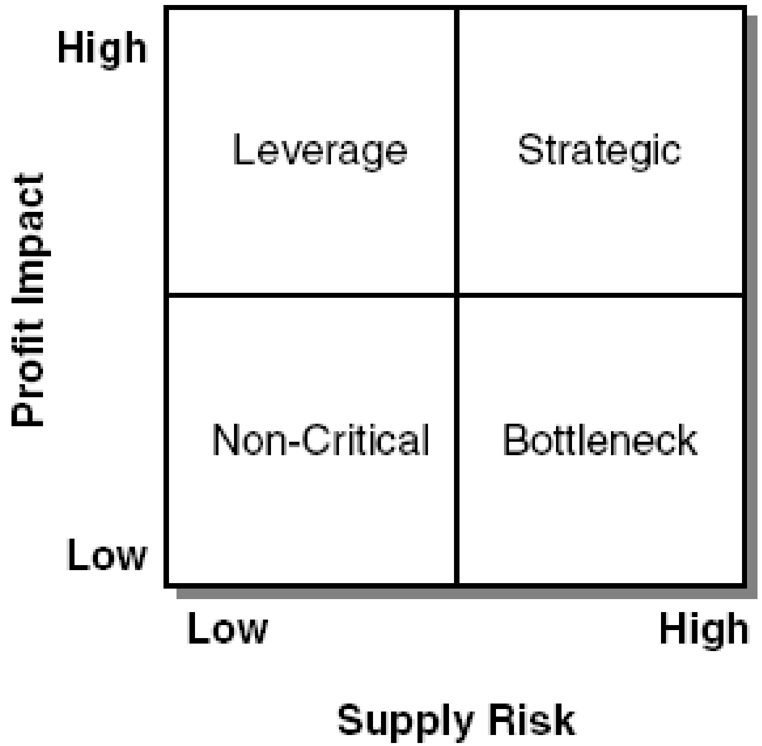
SUPPLY CHAIN , PURCHASING

The functions of purchasing, sourcing, and procurement are essential to the success of a supply chain management effort. With an unrelenting emphasis being placed on an area that occupies so much space in the profit and loss statement, it is inevitable that the function evolves and provides greater benefits as the firm progresses with its supply chain initiatives. Using a matrix model to help define the appropriate strategies based on supply conditions and importance to the company is one way to enhance the effort. Involving key members of the internal business units and other functional areas increases the importance and viability of such a matrix, which must also be matched with the tactics that are taken to achieve the intended benefits. Key suppliers must be in the center of whatever becomes the guiding instrument so valuable insights are not overlooked. Above all, collaboration with key constituents across the supply chain and the application of technology will become the factors that differentiate one network from another in the marketplace.


Benefits
With Strategic Supply Management
Without Strategic Supply Management
Single Sourcing Project
Time



Kraljic introduced a simple matrix intended to help purchasing managers decide on strategy by applying a portfolio type of analysis

EXTENDED STRATEGY MATRIX

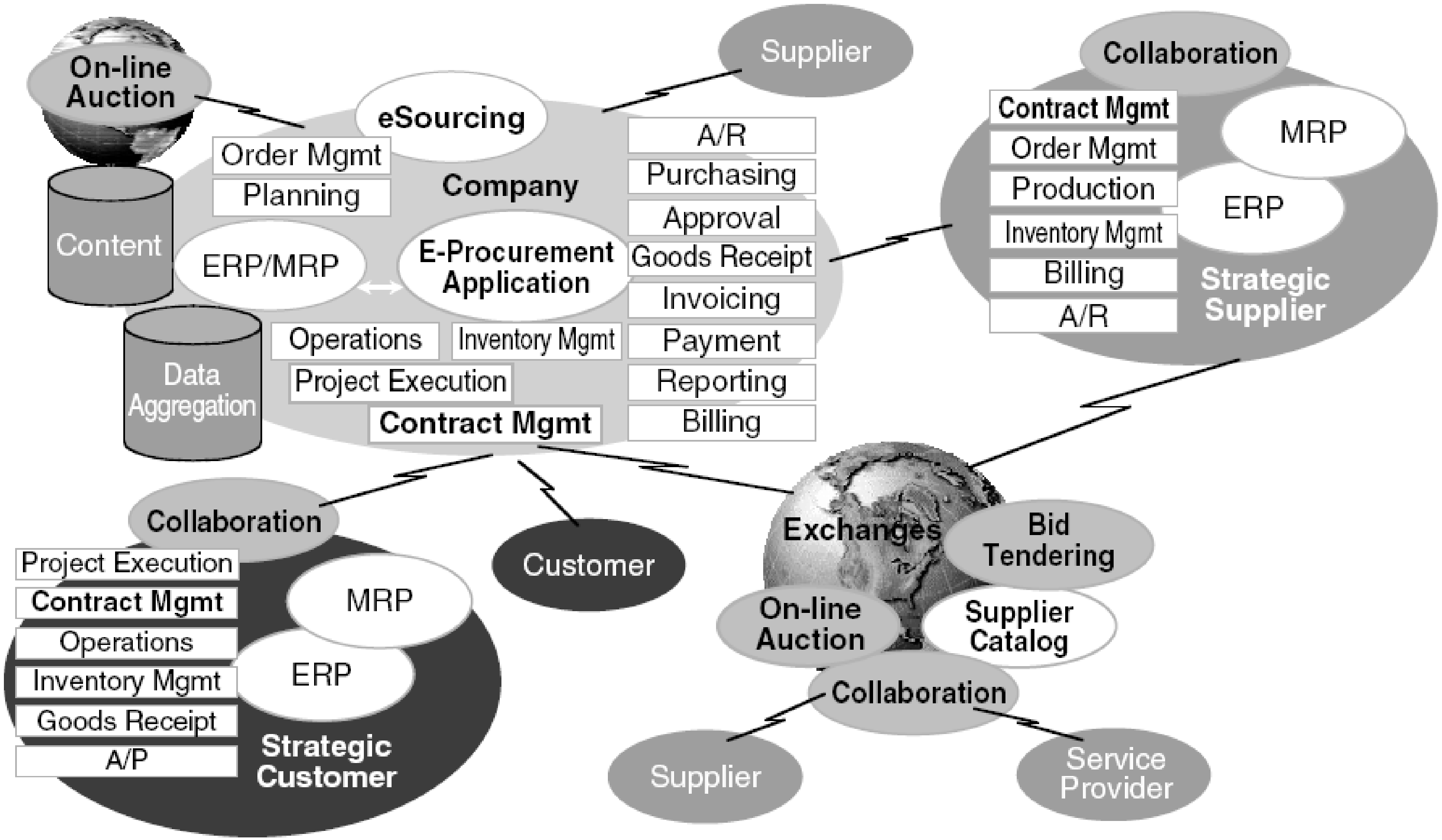
Profit Impact	Low Supply Risk	High Supply Risk
High	**Bottleneck** *Reduce Business Risk* • Level 3 circumstance • Buyer dependence • Supply matched to need • Alternative sources advisable • Long-term relations established • Reviews of supply necessary • Relationship-based contracts with volume assurance	**Strategic Conditions** *Build Competitive Advantage* • Level 4 & 5 circumstances • High mutual dependence • Strategic partnerships • Network involvement • Technology-based solutions • Collaborative product development • Mutual revenue generation
Low	**Routine Conditions** *Purchasing Efficiency* • Level 1 & 2 circumstances • Low mutual dependence • Process automation is feasible • Suppliers have similarities • Company-wide spend should be leveraged	**Leverage** *Optimize Total Cost* • Level 3 circumstance • Supplier dependence • Competitive market conditions • Strategic account status preferred • Consolidation by category • Evaluation of total cost

Supply Risk

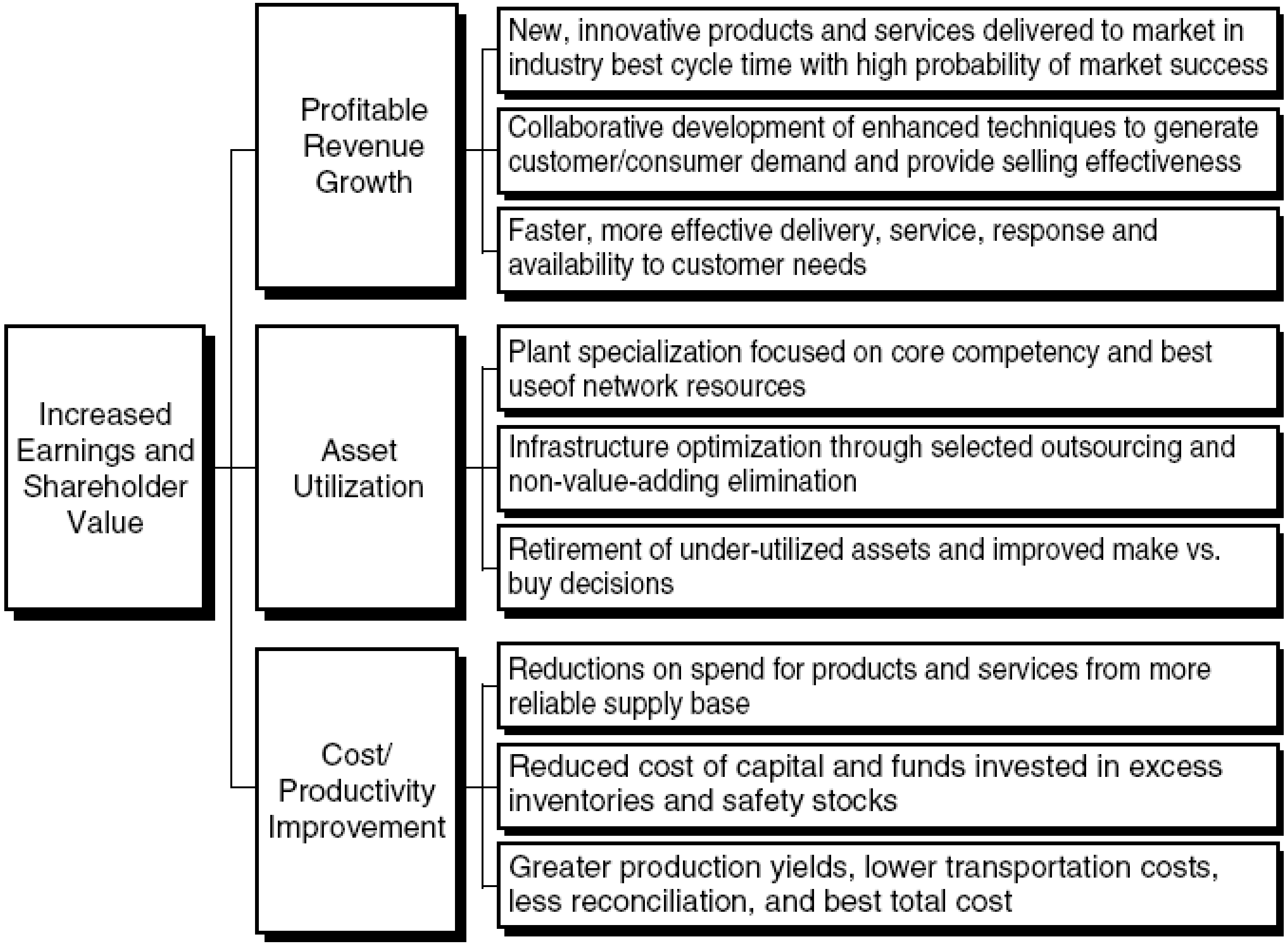
Level of Sourcing

Level 1 *Flat Pricing*	Level 2 *Total Cost Focus*	Level 3 *Supply Management*	Level 4 *Strategic Sourcing*	Level 5 *Network Management*
• Tactical focus on price • Fragmented spend • Decentralized organization • Lack of knowledge for spend categorization • Minimal authority within procurement organization • Order processing	• Focus on total cost • Decentralized/ centralized organization • Knowledge of spend categorization • Starting to achieve some level of authority within procurement organization	• Major spend areas under global, source contracts • Center-led procurement control • Use of technology to support efforts • Procurement organization recognized as value-adding contributor to business • Selective outsourcing	• All spend areas under global, sourced contracts with routine review schedules • "Best business unit"-led procurement control • Technology embedded throughout the sourcing process • Procurement organization integral to business strategy	• Global, sourced contracts leveraged across supply network • Outsourced non-core activities • "Best network member"-led procurement control • Technology extended across supply network • Cooperative network procurement organizations

TECHNOLOGY SUPPORT OF SOURCING



PAY OFF OF PROCUREMENT OPTIMIZATION



SUPPLY GAME

simple problems assume an added complexity when the supply chain environment is considered.

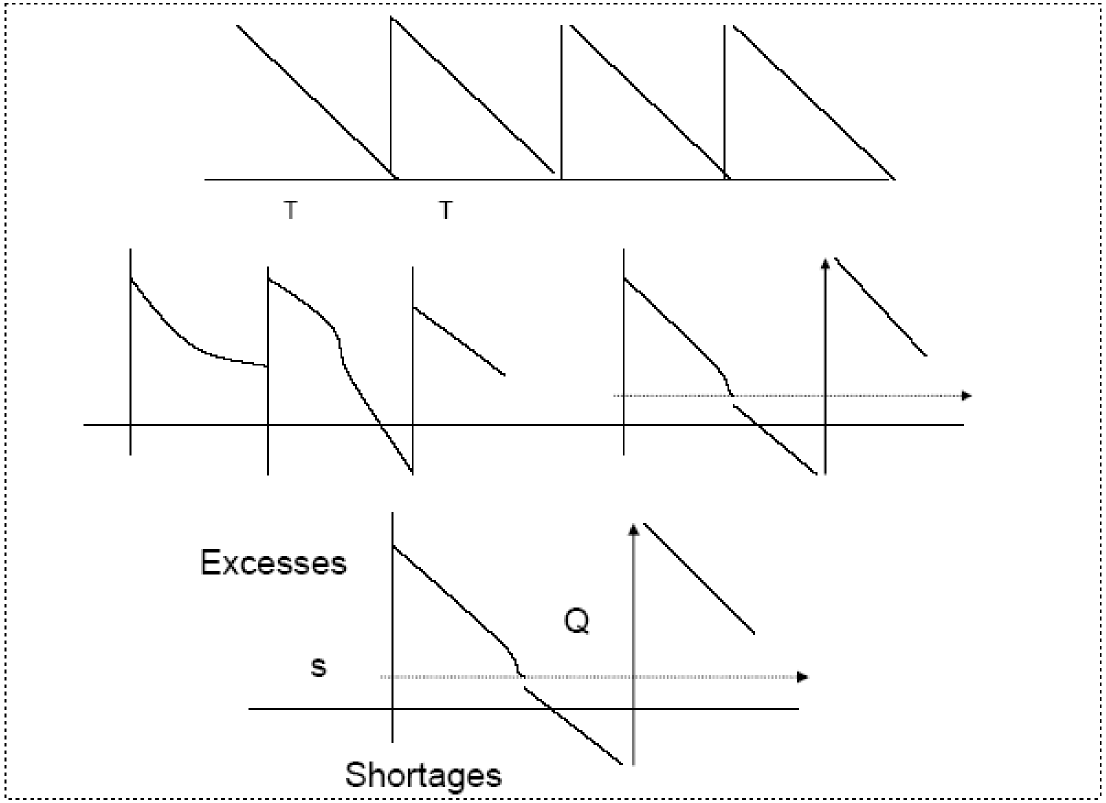


Figure 1.8. Models of Inventory Management

Consider an inventory model with K the set up cost and c_1 the unit holding cost. No shortages are tolerated. In such a case the optimal order policy can be shown to be the EOQ and based on the minimization of the average "inventory system costs". The solution is thus:

$$\text{EOQ: } Q = \sqrt{2xK / c_1}\ ;$$

$$\text{Cycle time: } T = \sqrt{K / c_1 x}\ ;$$

$$\text{Average cost } AC = \sqrt{2xKc_1}\ .$$

Note that this model implies that a number of business functions intervene in determining the inventory policy. For example, financial considerations arise about the interest rate paid on money which is tied down; manufacturing can have an effect by seeking investments in a flexible manufacturing technology which reduces the set-up costs marketing has an effect based on the requirements it imposes on demand satisfaction (i.e. the cost of shortages). The relative dominance of each of the business functions will determine the inventory policy. While the EOQ formula is simple to apply, it is most revealing in integrating multiple strategic functions of business.

These functions include

- marketing, through determination of the demand x
- purchasing, through the effects of the fixed order
- finance, through the cost of money, or inventory holding c_1
- Tech SMED through the fixed cost K

Some elementary calculations, based on our assuming a departure from the centralized solution (consisting in optimizing the average total inventory cost) would reveal a departure from such a solution and the effects of multiple interests at play in a supply chain environment. Explicitly, consider a demand to be set to kx instead of x, and reflecting the desire of a marketing manager who supplies such information to assure larger inventory levels. In this case, since the EOQ formula resulting from an average cost minimization:

$$AC = \frac{K + c_1 QT/2}{T}, \quad T = \frac{Q}{x}$$

yields

$$Q^* = \sqrt{2xK/c_1} \text{ and } AC^* = \frac{Kx}{Q^*} + \frac{c_1 Q^*}{2} = \sqrt{2xKc_1}$$

Thus, by a mis-specification (or weighted inventory cost, by k, we have:

$$Q' = \sqrt{2xK/kc_1}, AC_1 = \sqrt{2xKkc_1}.$$

When we compare this to the centralized solution (k=1), we obtain the following costs:

$$\frac{AC_1}{AC} = \sqrt{k}$$

and therefore

$$\frac{AC_1 - AC}{AC_1} = 1 - \sqrt{1/k}$$

In other words, the percentage growth in average inventory costs is indeed a function of stating (over or under) the true demand, imposed by the party who has the responsibility and potentially, the power to do so. Generalizing to multiple parties, in other words to additional departures from the centralized solution, it is easy to show that:

$$Q_1^* = \sqrt{\frac{2(k_1 K)(k_3 x)}{k_2 c_1}},$$

game can be stated as follows:

$$\underset{k_1}{Min}\, F_1(k_1, Q_1^*), \quad \underset{k_2}{Min}\, F_2(k_2, Q_1^*), \quad \underset{k_3}{Min}\, F_2(k_3, Q_1^*)$$

Subject to: $Q_1^* = \sqrt{\dfrac{2(k_1 K)(k_3 x)}{k_2 c_1}}$

- What are the rules of leadership? Who is leading? Who has the information? Who has the power and can exercise it or not?
- What are the supply priorities, guarantees and related issues associated with products and goods transferred from one party to the other?
- What are the information flows? Who gets what and when and by whom?
- What are the objectives of the members of the supply chain?
- What are the principles of equity, distribution and control?
- What are the policy variables that each of the parties can exercise?
- Who controls what?
- What are the sources of uncertainty? Are they internally induced or do they occur externally?
- What are the constraints on each of the parties? The individual? The collective?
- What are the objectives that each of the parties optimizes?

SUPPLY GAMES

As a departure point, consider the classical deterministic pricing game due to Bertrand's price competition model . This games involves two vertical participants in a supply chain. For example, a single supplier might sell a product to a single retailer over a single time period . Let the retailer face an endogenous demand, $q(p)$, a downward-sloping function of the retail price p, i.e., $\frac{\partial q}{\partial p} < 0$. We assume that the supplier incurs a unit production cost c and sells the unit at the wholesale price w. The retailer's price per unit is $p=w+m$, where m defines the retailer's margin. Thus, the supplier's profit is

$$J_s(w,m)=(w-c)q(w+m)$$

while the retailer's profit is:

$$J_r(w,m)=mq(w+m).$$

Q (p)

In the Bertrand pricing model, both the supplier and the retailer seek to maximize profits—the supplier by choosing the wholesale price and the retailer by selecting the retail price, p, and hence the order quantity $q(p)$.

Quantity as a function of price

A similar problem, dealing with the quantity to produce and production competition is defined by the well known Cournot model. Two essential features distinguish this model compared to the Bertrand pricing game described above. In this model, we represent a product price as a function of demand, $p=p(q)$, $\frac{\partial p}{\partial q} < 0$, or $q=q(p)$, $\frac{\partial q}{\partial p} < 0$, i.e., using an inverse demand function. A second feature deals with the types of competition presumed by the Cournot model. In the supply chain under consideration, we assume two horizontal participants (two independent firms reaching their own decisions independently), consisting of a manufacturer and a supplier (or both manufacturers and suppliers). Assume two manufacturers, each incurring the unit production cost c when producing the same (or substitutable) product type. Further, assume that both compete in selling to the same retailer.

The retailer employs the so-called vendor-managed inventory policy and thus will not interfere in the manufacturers' competition. This implies that both manufacturers, say "1" and "2" decide on production quantities q_1 and q_2 respectively, supplied in turn to the retailer. (It is assumed that the retailer relies on the manufacturers' decisions and that sales are transparent to both manufacturers-suppliers.) Consequently, the product price is a function of aggregate demand, $p=p(q_1+q_2)$. In other words, a manufacturer selecting a production quantity, will necessarily affect the other's profit. The resulting game is as follows: both manufacturers set the quantities to produce and supply to the retailer. The retailer will then sell the products at a price which is an aggregate function of these quantities. In a supply chain with a collaborative environment, a number of issues can then be raised.

Price as a function of quantity

The simplest single-period inventory problem is a "Newsvendor problem" consisting of a producer or retailer deciding to order to stock a fixed product quantity q , when the period demand is assumed to be uncertain. Such a problem is subject to numerous modifications and extensions

there is no initial inventory on hand; the demand, d, is exogenous with a known probability distribution function; the setup (or order) cost is negligible; the purchasing price is fixed; and the decision to order q units is made at the beginning of the period. Since the true demand D is known only by the end of the period, it is likely that either we incur a shortage (D-q>0) whose unit cost is denoted by h^- or an inventory excess (q-D>0) whose unit holding cost is denoted by h^+ . A retailer's objective is then a "linear regret" objective, seeking to minimize the least weighted shortage and holding costs (see also Tapiero, 2004, 2005).

In a game framework, the supplier sells at a wholesale price w, incurs a production cost c, and maximizes the profit $J_s=(w-c)q$. This profit function is deterministic. However, due to the random demand, the retailer's profit will be uncertain. Therefore, either an expected profit is maximized, $E[.]$, (in which case, we assume that the retailer is risk neutral) or a risk sensitive objective is defined, leading to a "robust" ordering policy, which will be insensitive to some of the actions that the suppliers may take. In this framework, the game consists in the following: after the supplier chooses a wholesale price, w, the retailer determines the order quantity, q. The supplier then produces the products and delivers them by the end of the period. Of

Quantity as a function of purchasing price

Outsourcing consists in the transfer of previously in-house production or other activities to a third party. This problem has been the subject of considerable analysis due to the current awareness that a large segment of industrial, logistics and service activities are outsourced both nationally to local firms and internationally. A simplistic version of this model, based on the classical make-buy decision problem can be construed as a single-period newsvendor model with a setup cost added. The assumed setup cost C, is a fixed irreversible cost which the manufacturer incurs for each in-house production order. In addition, a variable per unit cost c_m, is assumed. The outsourcing decision is presumed to relieve the industrial firm from the fixed costs it assumes, augmenting thereby reactivity to market demands and reducing its aggregate costs.

Quantity as a function of set up cost

The resulting outsourcing game is defined as follows: the supplier sets the wholesale price and then the manufacturer decides whether to outsource or to produce in-house. If the decision is to outsource, the manufacture responds with an order quantity, which the supplier delivers by the end of the period. If the decision is to produce in-house, then the manufacturer decides on the quantity to produce and initiates the production. This game, simple in a static framework, becomes elaborate in an inter-temporal framework.

Price and internal manufacturing cost

Inventory Game with Buy-Back, Sell-Back and other Options

The game is defined as follows: the supplier sets a wholesale price w and a buy-back price $b(w)$; the retailer orders quantity q, which the supplier delivers, contracting for surplus products (if any) at the end of period, once the optional decision by the “buyer-manufacturer” is reached ex-post when demand is revealed.

The Inventory Game with a Purchasing Option

The game is defined as follows: the supplier chooses the wholesale and purchasing option prices, then the retailer and supplier choose quantities for their regular orders, the supplier then delivers the regular order. When the demand is realized, if there is a shortage, the backlogged units are urgently delivered to the retailer.

The Inventory Game with a Purchasing Option

Similar to the sell-back and buy-back options, a purchasing option provides a supplier with the means to mitigate the retailer's risk associated with uncertain demands. To do so, an agreement regarding inventory shortage costs sharing rather than surplus costs may be assumed. Specifically, the supplier may agree to carry additional inventories by providing the retailer a purchasing option, complementing the regular order at the wholesale price, w. The option allows the retailer to issue an urgent or emergency order at a predetermined price, $u(w)>w$, $\frac{\partial u(w)}{\partial w} \geq 0$, close to the end of the selling season and to be shipped immediately. The retailer, of course, will exercise this option only if customer demand exceeds its inventories. The quantity, which is the difference b
order) and the supplier's inventory position at the end of period, will be delivered then as an emergency order. If the supplier is not able to satisfy

Operational Risk	External Risks	Strategic Risks	Risk Externalities
Supply delay risks Synchronization and delays risks Measurement risks Inventory risks Quality risks	Political Regulation Financial markets Macroeconomic Risk Bias (Leptokurtic, chaos etc.) Measurement risks	Dependence Outsourcing Exchange Information asymmetry Moral hazard Adverse selection Non-transparency Measurement risks	Environmental risks Non detection risks Collective risks Ethics-Social Regulation

BACK GROUND

by each of the players respectively. In two-persons zero-sum games, additional assumptions are made: (1) $A_1, A_2, A_3, \ldots\ldots, A_n$ as well as $B_1, B_2, B_3, \ldots\ldots, B_m$ and O_{ij} are known to both players. (2) Players do not know with what probabilities the opponent's alternatives will be selected. (3) Each player has a preference that can be ordered in a rational and consistent manner. In strictly competitive games, or zero-sum games, the players have directly opposing preferences, so that a gain by a player is a loss to its opponent. That is;

The Gain to Player 1 = The Loss of Player 2

The concepts of pure and mixed strategies, minimax and maximin strategies, saddle points, dominance etc. are also defined and elaborated. For example, two rival companies, A and B, are the only ones. Company A has three alternatives A_1, A_2, A_3 expressing different strategic while B has four alternatives B_1, B_2, B_3, B_4. The payoff matrix to A (a loss to B) is given by:

	B_1	B_2	B_3	B_4
A_1	.6	-.3	1.5	-1.1
A_2	-7	.1	.9	.5
A_3	-.3	0	-.5	.8

-1.1
-7
-.5

This problem has a solution, called a *saddle-point*, because the least greatest loss to B is equal to the greatest minimum gain to A. When this is the case, the game is said to be stable, and the pay-off table is said to have a saddle-point. This saddle-point is also called the value of the game,

.6 , .1,1.5,.8

Non-Zero Sum Games

Consider the bimatrix game $(\mathbf{A},\mathbf{B}) = (a_{ij}, b_{ij})$. Let $\mathbf{x}$ and $\mathbf{y}$ be the vector of mixed strategies with elements x_i and y_j, and such that $\sum_{i=1}^{n} x_i = 1,\ 0 \le x_i \le 1$, $\sum_{j=1}^{m} y_j = 1,\ 0 \le y_j \le 1$. The value of the game for each of the players is given by:

$$V_a = \mathbf{xAy^T}, V_b = \mathbf{xBy^T}$$

and an equilibrium is defined for each strategy if the following conditions hold $\mathbf{Ay} \le V_a, \mathbf{xB} \le V_b$. For example, consider the 2*2 bimatrix game. We see that

$$V_a = (a_{11} - a_{12} - a_{21} + a_{22})xy + (a_{12} - a_{22})x + (a_{21} - a_{22})y + a_{22}$$
$$V_b = (b_{11} - b_{12} - b_{21} + b_{22})xy + (b_{12} - b_{22})x + (b_{21} - b_{22})y + b_{22}$$

Then, for an admissible solution for the first player, we require that

$$V_a(1,y) \le V_a(x,y); V_a(0,y) \le V_a(x,y),$$

$$A(1-x)y - a(1-x) \le 0;\ Axy - ax \ge 0,$$

where, $A = (a_{11} - a_{12} - a_{21} + a_{22}); a = (a_{22} - a_{12})$. That is when,

$$\begin{cases} x = 0 & then \quad Ay - a \le 0 \\ x = 1 & then \quad Ay - a \ge 0 \\ 0 < x < 1 & then \quad Ay - a = 0 \end{cases}.$$

In this sense there can be three solutions (0,y), (x,y) and (1,y). We can similarly obtain a solution for the second player using parameters B and b. Say that $A \ne 0$ and $B \ne 0$, then a solution for x and y satisfies the following conditions:

$$\begin{cases} y \le a/A & if \quad A > 0 \\ y \ge a/A & if \quad A < 0 \\ x \le b/B & if \quad B > 0 \\ x \ge b/B & if \quad B < 0 \end{cases}$$

$$y^* = \frac{a}{A} = \frac{(a_{22} - a_{12})}{(a_{11} - a_{21} - a_{12} + a_{22})}$$

$$x^* = \frac{a}{A} = \frac{(a_{22} - a_{12})}{(a_{11} - a_{12} - a_{21} + a_{22})}.$$

In this case, the value of the game is:

$$V_a = (a_{11} - a_{12} - a_{21} + a_{22})xy + (a_{12} - a_{22})x + (a_{21} - a_{22})y + a_{22}$$

$$V_b = (b_{11} - b_{12} - b_{21} + b_{22})xy + (b_{12} - b_{22})x + (b_{21} - b_{22})y + b_{22}$$

$$x^* = \frac{a}{A} = \frac{(a_{22} - a_{12})}{(a_{11} - a_{12} - a_{21} + a_{22})}$$

$$y^* = \frac{b}{B} = \frac{(b_{22} - b_{12})}{(b_{11} - b_{12} - b_{21} + b_{22})}$$

Consider a supply chain consisting of one supplier, s, and one retailer r. The supplier offers products at wholesale price w and the retailer buys q product units and sets retail price $p=w+m$. This is the classical pricing game where the two firms want to maximize their profits. Let the supplier and retailer costs be negligible and the demand is linear and downward in price, $d=a-bp=a-b(w+m)$, $a>0$, $b>0$. Then the retailer's optimization problem is

$$J_r(m,w)= m(a-b(w+m)) \to \max ,$$

$$0 \leq m \leq \frac{a}{b} - w$$

and the suppliers problem is

$$J_s(m,w)=w(a-b(w+m)) \to \max ,$$

$$w \geq 0.$$

First we observe that both objective functions are strictly concave in their decision variables. Thus, the first-order optimality condition is necessary and sufficient. Using the first-order optimality condition we have

$$a\text{-}bw\text{-}2bm=0 \text{ and } a\text{-}2bw\text{-}bm=0.$$

If our constraints are not binding, the two best response functions are

$$m=m^R(w)=\frac{a-bw}{2b} \text{ and } w=w^R(m)=\frac{a-bm}{2b}.$$

Solving these two equations (or equivalently the previous two) we find a unique Nash equilibrium

$$m^n=\frac{a}{3b} \text{ and } w^n=\frac{a}{3b}.$$

The equilibrium is evidently feasible and all constraints are met, as $\frac{a}{3b}>0$,

hence, $m^*>0$, $w^*>0$, and $\frac{a}{3b}<\frac{a}{b}-w^n=\frac{2a}{3b}$, hence, $m^n<\frac{a}{b}-w^n$.