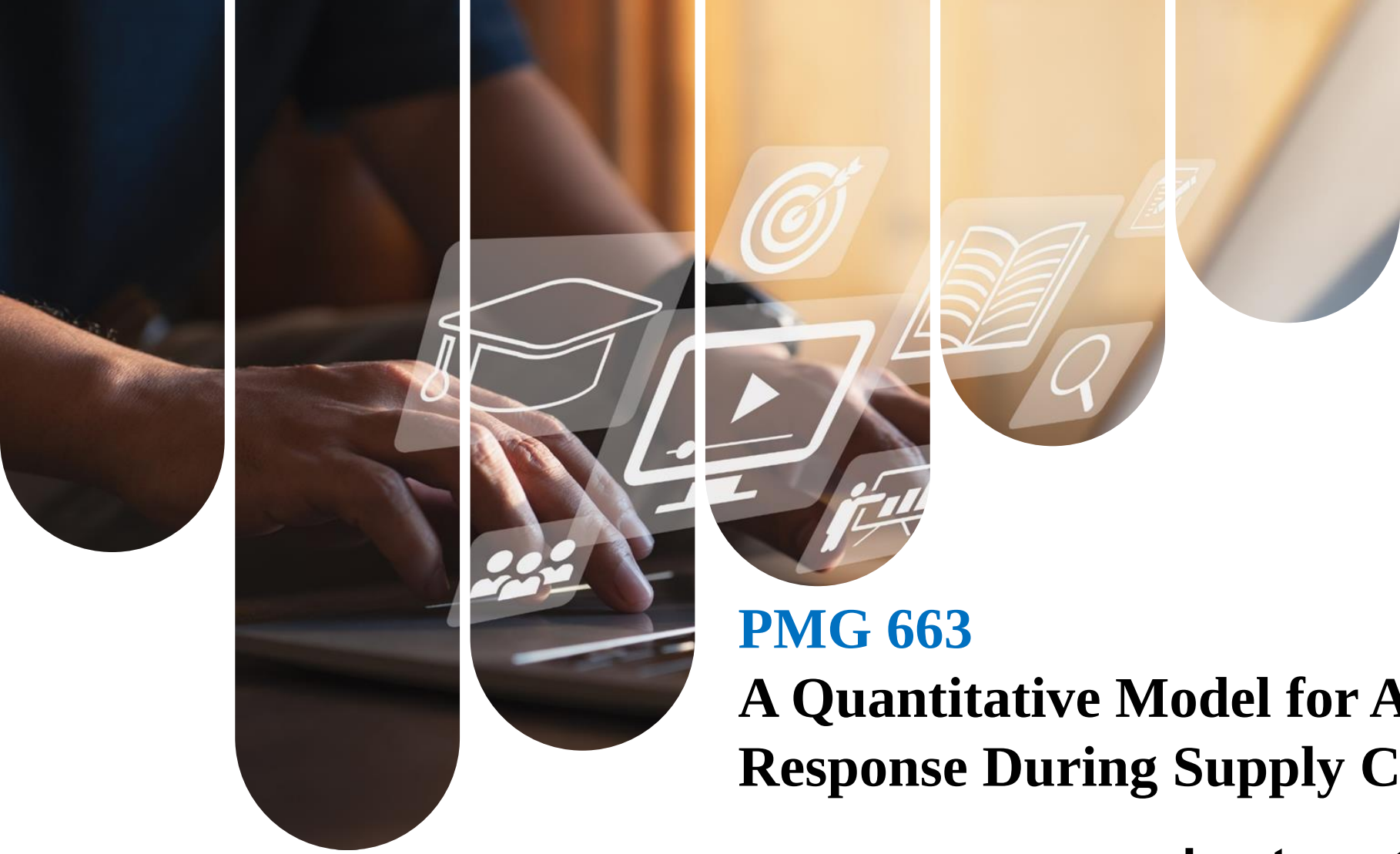


The background features a series of vertical panels with rounded ends. The leftmost panel shows a person's hands typing on a laptop. The subsequent panels contain various white line-art icons on a semi-transparent background: a graduation cap, a play button, a target with an arrow, an open book, a magnifying glass, and a person at a computer. The overall color scheme is warm, with shades of orange and yellow.

## PMG 663

# A Quantitative Model for Analyzing Market Response During Supply Chain Disruptions

## Lecture 6

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**Model Framework**

**Production Capacity Considerations**

**Calculating the Firm's Post-impact Revenue**

**Risk Management Insights**

Supply chain disruptions can lead to firms losing customers and consequently losing profit. We consider a firm facing a supply chain disruption due to which it is unable to deliver products for a certain period of time.

When the firm is restored, each customer may choose to return to the firm immediately, with or without backorders, or may purchase from other firms

Supply chain disruptions have garnered increased attention, both in academia and in practice, since the early 2000s. Modern production methodologies, globalized supply chains, shorter product life cycle, and the emphasis on efficiency have increased the risk faced by many supply chains. Managing the risk facing a supply chain is vital to the success of any company.

A supply chain is an integrated system of companies involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customers..

A supply chain will ideally maximize the total value generated from customers and minimize the cost of meeting consumer demand

Figure 9.1 presents a basic supply chain model from the firm's perspective

A supply chain is characterized by the flow of resources—typically material, information, and money—with the primary purpose of satisfying the needs of a customer, who are the source of revenue for a firm

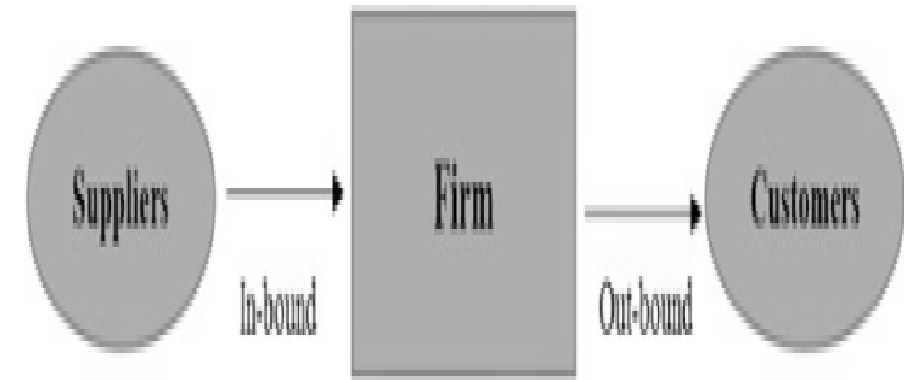


Fig. 9.1 A simple supply chain model

Major disruptions, such as those that occur from natural disasters, terrorist acts, and labor strikes, can interrupt the flow of materials for several firms. categorized supply chain risk into supply risks, process risks, demand risks, and corporate-level risks.

These risks often materialize all together during a major supply chain disruption, and decision makers need to consider all of these risks.

## Definitions of SCRM

There are ten different definitions of SCRM.

SCRM defined as “the management of risk that implies both strategic and operational horizons for long-term and short-term assessment.”

As implied by this definition, decision makers need to consider both the long-term and short-term impacts from a supply chain disruption

The marketplace or customers can play a significant role in the long-term impacts as their needs, values, and opinions will affect the firm's decisions during the disruption. The volatility of consumer demand is a major form of risk.

Firms face a risk of being penalized by their customers if their suppliers default and firms are unable to deliver on their obligations.

Assessing how consumers react to such disruptions helps to forecast the long-term profits for the firm and can help it make sound risk management decisions. Modeling consumer behavior is useful not only when a disaster occurs but also to build flexibility within the supply chain as a proactive measure to anticipate such threats and quickly respond.

This chapter presents a probabilistic model to quantify the risk from a severe supply chain disruption with an explicit focus on how consumers or the marketplace's demand for a product should influence a firm's risk management strategies. Many supply chain disruption models assume some type of demand function, which may be constant or random

However, that demand function does not usually change when the disruption occurs, or simple assumptions are made about whether or not customers are willing to wait for a final product.

Less research has focused on how the final customers should influence how a firm determines what risk management strategies are appropriate

## A probabilistic model

The model assumes that a disruption causes a supplier to default, and a firm is unable to deliver its product to consumers. The market responds with defined probabilities and time delays. The model attempts to measure the extent to which a firm can be penalized due to a default from its supplier and recommends strategies or practices to build resilience to such disruptions

Supply chain management has seen a variety of trends, including Just-in-Time, global sourcing, and outsourcing. These methods are aimed at cutting costs in a firm's supply chain and enabling the firm to compete more effectively. Increasing supply chain efficiency can also make supply chains more vulnerable to disruptions. In the race to increase their market share, firms may ignore that their supply chains are susceptible to disruptions

A wide variety of events can disrupt a supply chain, including supply-side difficulties, demand-side variability, operational problems, and large-scale disruptions such as natural disasters. Qualitative studies to manage these disruptions recommend excess inventory, additional capacity, redundant suppliers, flexible production and transportation, and dynamic pricing

Managing one type of risk may exacerbate another risk, and identifying the best strategy relies on the manager's ability to identify the most crucial risk and understand the trade-offs in SCRM . Quantitative studies in SCRM generally model the trade-off between purchasing from alternate suppliers and holding inventory, or they model the interaction between suppliers and customers

## The Model

This section presents an overall profile of a supply chain disruption and develops a probabilistic model to focus on the market response to the disruption. A supply chain disruption occurs when a firm's supplier defaults. A major disruption impacts a firm in distinct phases . It may take time for the final consumer to be impacted by the supply disruption. If the firm does not have enough inventory or cannot purchase from alternate suppliers, it will not be able to satisfy demand for its goods

Consequently, consumers may choose to purchase from other firms. The consumers' loyalty depends on a number of factors such as their relationship to the product. To get back to standard performance levels, a firm may adopt various response actions such as working at over-capacity levels. If the firm is prepared for such a disruption (e.g., having multiple suppliers or having more inventory), it should be able to respond more effectively

## Model Framework

The developed a probabilistic model to quantify the reaction of customers following a supply chain disruption that causes a temporary production shut down. Before the disruption, there are  $n$  customers (they could also be retailers) who purchase from a firm in each time period before a disruption. In the base model, we assume the demand equals the number of customers. In other words, every customer buys exactly one product

This assumption, which considers varying demands from each customer. An unexpected disruptive event causes one or more of the firm's suppliers to default, and the firm is unable to satisfy any demand beginning at time period  $t = 1$ . The disruption continues for  $M$  time periods, and the firm does not deliver to its  $n$  customers for  $t = 1, 2; \dots; M$ . The firm recovers from the disruption at  $t = M + 1$  and will be able to deliver at its full capacity  $C$  orders per time period, where  $C \geq n$ .

capacity  $c$  orders per time period, where  $c \leq m$ .

In the post-disruption time period beginning at  $t = M + 1$ , each customer decides whether or not to return to the firm in each time period  $t = M + i$ . Note that

$i = 1, 2, \dots$  since the customer cannot buy from the firm during time periods  $t = 1, 2, \dots, M$ . Each customer comes back to the firm with a constant probability  $p$  in each time period. The value of  $p$  depends upon the type of product as well as the firm's response actions such as qualifying alternate suppliers and making up for lost production by running at maximum capacity. If a customer decides not to return to the firm at a particular time period, the model assumes that it will return to the firm in the next period with the same probability  $p$ . Once a customer returns to the firm, it will continue to purchase from the firm in all future time periods.

If a customer buys from the firm at time  $t = M + i$ , it will return with one of the following behaviors:

**Customers can return right away without backorders at time  $t = M + 1$ .** This category of customers might have used inventory from safety stock, not used the product, or purchased the product from other firms during the time periods 1 through  $M$ .

2. Customers who come back immediately and have backorders.
3. Customers who do not return immediately but return later to the firm with no backorders

The probability  $q$  represents the conditional probability that the customer who comes back immediately at  $t = M + 1$  will require backorders for  $t = 1; 2; \dots; M$ . In other words, given the customer has returned to the firm, the probability that he or she will have backorders is  $q$ . The revenue from backorders is accounted for at  $t = M + 1$  since backorders are taken only in that time period

The initial model assumes the firm can satisfy all the backorders. This could be because the firm is able to monitor activity and make plans to increase capacity to satisfy backorders.

If  $q$  is small, the firm can be reasonably confident the backorders will not exceed its capacity. Since this assumption may not be realistic

## Calculating the Firm's Post-impact Revenue

The revenue at time periods  $t = 1, 2, \dots, M$  is zero since the firm is not delivering any product to its customers. The total expected revenue after the firm reopens is calculated by estimating the number of customers who decide to buy from the firm at each period after it reopens at  $t = M + 1$ . Let  $X_t$  be the number of customers who decide to come back and purchase from the firm at time  $t$ .  $X_t = 0$  for  $t = 1, 2, \dots, M$

For  $t = M + 1; M + 2; \dots$  each of the  $n$  customers returns with a constant probability  $p$  and  $X_t$  follows a binomial distribution

Although it makes intuitive sense to assume that customers who did not return to the firm immediately satisfied their demand during the shutdown period,  $t = 1; 2; \dots; M$ , from another firm, a further extension to this model may consider situations where customers who do not return immediately but return later to the firm also places backorders. In that case  $Z$  would need to be indexed by time  $t$ . Since each customer orders exactly 1 product in each time period, a customer who returns with backorders is assumed to have  $M$  backorders (one backorder for each period that the firm was closed).

## Production Capacity Considerations

Similarly, the firm can estimate and forecast the production capacity levels for future time periods. Depending on the willingness of customers to wait for the backorder delivery, the firm needs to prioritize production with the goal of meeting customer needs. If customers are likely to be lost in case of a late delivery, the firm will have to consider whether it can temporarily increase its production capacity or other alternatives to meet the spike in demand due to backorders

## Illustrative Example

This model can be applied to several situations. For example, a consumer-product manufacturing firm could face a supply chain disruption forcing it to shut down production. The firm's customers could react in different ways. One, a retailer who uses inventory during this period may come back to the firm immediately with backorders to replace its inventory. Two, a retailer who temporarily switches to another supplier may decide to come back when the firm starts producing again.

The latter retailer may come back at a later stage depending on the firm's performance. By estimating the probability that the retailer takes any of these actions, the model can account for each of these scenarios.

Three, a retailer who switches to another supplier may decide not to come back when the firm starts producing again

Firms can prepare for disruptions by using this quantitative model to estimate the potential loss in revenue due to a shutdown of operations from a supply chain disruption. Moreover, the model can be used to evaluate whether preparation strategies are economical. Investments to reduce the chances of a supply chain disruption itself may not be practical or economically reasonable

In such cases, firms can use the expected lost revenue from the model to decide whether or not investments to reduce the risk of a disruption are cost effective. Preparedness measures can help reduce the probability of a disruption and/or allow the firm to regain more of its revenue following a disruption.

Even if the disruption cannot be avoided, preparedness measures could reduce the shutdown length  $M$

It is logical to assume that the probability of customers returning depends on  $M$ . Decision makers can make decisions about investing in preparedness measures based on understanding how much revenue will be lost if the disruption occurs as well as the chances of the disruption itself

For example, the cumulative expected lost revenue in the illustrative example is \$536,667. A risk-neutral firm should spend at most \$536,667 in preparing for this. type of disruption and should spend much less once the probability of a disruption is considered. Investing in risk reduction strategies such as inventory or an additional supplier could reduce the time the firm is closed

The chances of customers returning immediately to the firm are higher if the firm is not closed as long. This would increase the probability  $p$  and reduce the cumulative expected lost revenue.

In the example, increasing the value of  $p$  from 0.15 to 0.2 decreases the total expected lost revenue from \$536,667 to \$360,000. Strategies that could reduce  $p$  from 0.15 to 0.2 are economically wise if these strategies cost less than \$176,667, assuming an extremely high probability of disruption

The model is used to identify the impact of such an event on the firm's revenue. From the firm's perspective, the total expected lost revenue is a measure of the impact of the supply chain disruption and can be analyzed to draw useful insights to manage the risk of such an event

The simulation of the customer response model allows the firm to anticipate how customers might react to a supply chain disruption. The model can inform decision making to manage the risks of a supply chain disruption.

Insights from the model can reveal how a disruption can affect the firm's revenue depending on the customers' decisions and the time a firm takes to recover to its pre-disruption revenue levels

## Reference

### **Supply Chain Risk Management Advanced Tools, Models, and Developments**

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Chapter 6



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# Thank You

