

# The Right-Price Consultants

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## Introduction

In recent years, a number of industries have turned towards innovative pricing strategies such as revenue management or dynamic pricing to manage their inventory effectively. Firms are employing such varied tools as dynamic pricing over time, target pricing to different classes of customers, or pricing to learn about customer demand. The benefits can be significant, including not only potential increases in profit, but also improvements such as reduction in demand or production variability, resulting in more efficient supply chains. Ford Motor Co. used pricing initiatives to match supply and demand and target particular customer segments, and executives credit the effort with \$3 billion in growth between 1995 through 1999 (Leibs 2000).

Dynamic pricing, where price changes over time in response to variability in supply or demand, has long been applied in retail industries, e.g., in the form of markdown pricing. For many firms, the Internet has also presented new opportunities for dynamic pricing, since price changes are inexpensive, and demand data is easier to collect. For instance, Boise Cascade Office Products has stated that prices for the 12,000 products that they offer online could change as often as daily (Kay 1998). For additional examples, see (Baker et al. 2001) for industry applications, or (Federguen and Heching 1999) or (Elmagraby and Keskinocak 2002) for academic research in this area.

Even manufacturing companies have begun to explore new pricing opportunities. A significant example is Dell Computers, who segments customers by type (industry, government, academic, etc.), where the price of a product may differ according to the segment. Furthermore, even the price of a product within a segment may change over time (McWilliams 2001).

Existing pricing and revenue management research has largely focused on industries such as the airlines, hotels, and even retail sales (see Federguen, Baker, etc. for some reviews). However, there are a number of characteristics that distinguish general manufacturing industries from other industries, including the non-perishability of products and the ability to vary production levels. Furthermore, manufacturing differs from most retail environments in its reordering and capacity characteristics.

Thus, the *integration* of pricing with production in manufacturing is still in its early stages, and coordinating these aspects with the supply chain offers significant opportunity to improve efficiency and profits. This is especially true for manufacturers who sell through electronic channels, since this medium offers additional flexibility for price and demand management.

In this case study, we focus on dynamic pricing in manufacturing, where the pricing decision is coordinated with production (see (Chan et al. 2002) for a review of this area). We develop a simple operations model, and present computational results obtained from a number of experiments. We focus on motivating general insights for

managers, such as when it makes sense to use dynamic pricing, and what impacts it has on a supply chain or organization.

## Case Study

Natasha Lee, VP of Operations at JJT, Inc.<sup>1</sup>, left the meeting deep in thought. She was a little shocked at the ideas that she had just heard, and she had to admit the ideas made her a little nervous.

The consultants at the meeting had just suggested that JJT consider a new dynamic pricing strategy, where prices of their products would fluctuate over time in response to system variability. It wasn't just the new strategy that made Natasha nervous; it also was the thought of JJT, an established manufacturer of widgets, being the first in the industry to try such a strategy. She also knew that the new strategy had the potential to impact the supply chain she managed, and she was worried that the consultants hadn't considered all of the potential impacts of the strategy.

Company JJT had manufactured widgets and similar products for thirty years. They were a corporate conglomerate, selling many kinds of products in a variety of different markets. The company had established itself early in the industry and held the largest market share in many areas, as well as a good reputation among its clients. Yet the management at JJT knew that business models at many traditional companies were beginning to change, driven in part by the expansion of e-commerce, and they wanted to make sure that JJT continued to be successful. JJT had hired outside consultants to help position the company for the future, and the consultants were given a broad mandate to consider many aspects of business at Company JJT.

"Their ideas certainly are bold," Natasha thought to herself, as she walked the corridor to her office. She knew that some industries used dynamic pricing, but the idea had not yet established itself in traditional manufacturing firms. The consultants' idea was simple though: allow prices to change over time while trying to maximize the profit of the system. The consultants had coordinated the pricing and sales decisions with production as well, taking into account inventory holding costs, production costs, and production capacity during each period of time.

Natasha suddenly remembered where she had just heard about dynamic pricing. Her daughter had told her at dinner not long ago that Amazon.com had tried dynamic pricing, with customers paying different amounts for the same DVD based on demographics or even the browser they used. Customers had responded negatively to the strategy, and Amazon.com had stopped the pricing tests. "But that's not the same as the pricing strategy the consultants are suggesting," Natasha realized. Amazon.com tried pricing based on differences among customers, really a form of differential pricing rather than dynamic pricing. However in the consultants' pricing strategy, all customers paid the same price at a particular time, and the prices could vary over time.

In her office, Natasha began to look at the material prepared by the consultants. The consultants first explained the nature of the relationship between price and demand. Generally, as the price of a product increases, the demand for the product decreases. JJT, like many companies, assumes that the structure of this relationship is linear, yielding linear demand curves for each product. An example of a linear demand curve for a

particular product as a function of price is shown in Figure 1. In this case the linear demand curve is such that  $D = -10 * P + 30000$  (where  $D$  = demand and  $P$  = price)<sup>ii</sup>. JJT has limited the price to be between \$1200 and \$2200, so the corresponding limits on demand are 18000 and 8000 units; these bounds may be determined because of concerns about market share or about the accuracy of the demand model outside of a reasonable range.

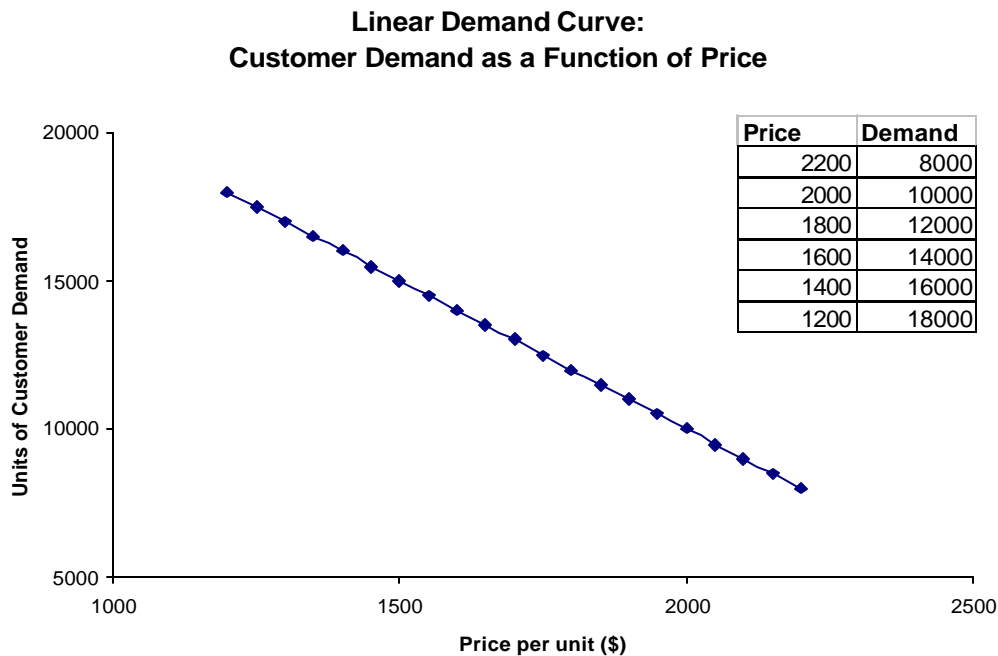


Figure 1: Example of a Linear Demand Curve

The demand curve also takes into account customers’ sensitivities towards the price, often measured in the form of “demand elasticity”, which is the percentage change in quantity / percentage change in price. Natasha knew that customers were quite sensitive to the price of some of their products (luxury gifts, with elasticity around 3.5), especially if substitutes for the products were available, but in other cases price changes didn’t affect demand as much (brand-name beer for which many customers had loyalty, e.g., elasticity = .25).

The material prepared by the consultants continued. The revenue generated by sales of the product is  $R(D) = D * P$ , or  $-10 P^2 + 30000 * P$ . Figure 2 shows revenue as a function of product price, within the bounds indicated before. If the production capacity was not limited, then the revenue curve indicates that setting the price to be \$1500 (thus selling 15,000 units of demand) provides the maximum amount of revenue (\$22,500,000). However, this is not the demand level that provides the most profit, since costs also need to be considered. With unlimited production capacity, the demand that provides the most profit can be calculated using derivatives, and for this example the optimal price is \$1750 (corresponding to demand of 12500). The consultants also called this the *optimal uncapacitated demand*. However, JJT only has the capacity to produce 12000 units of this product in a particular month, so the optimal price for this production period alone is \$1800.

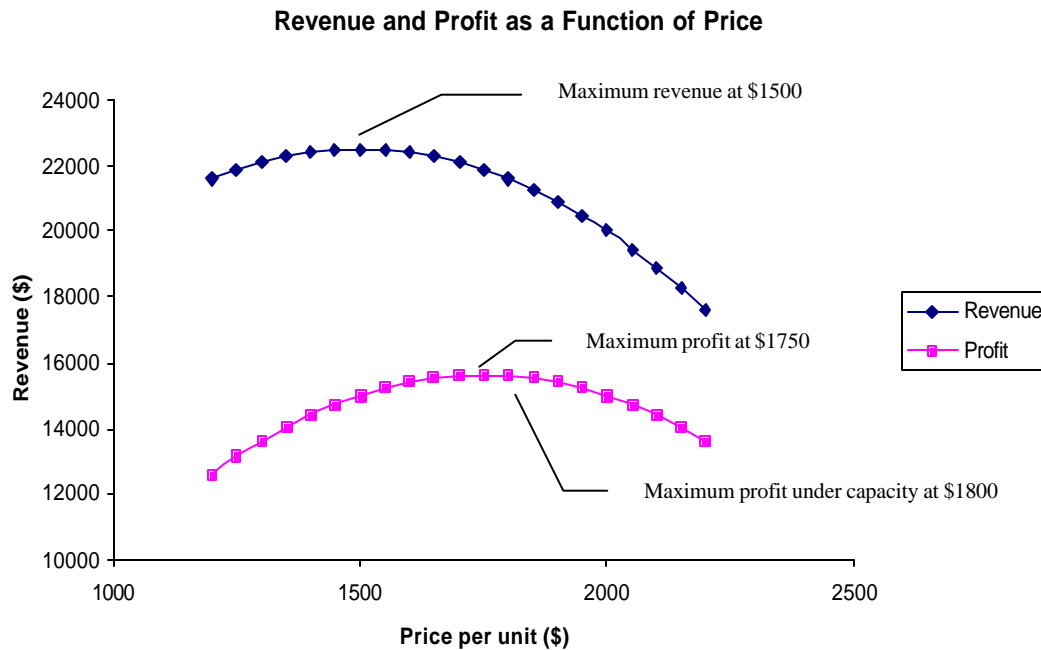


Figure 2: Revenue and Profit as a Function of Price

Of course, Natasha realized this representation was just for a particular month out of the year. For many of their products, JJT experienced significant variability in sales over the course of the year. The consultants classified the products at JJT into five categories and focused on general characteristics of products within these classes to demonstrate this effect. The consultants first estimated linear demand curves in each month where the parameters were multiplied by seasonality factors, then calculated the optimal uncapacitated demand in each period. The result, shown in Figure 3, demonstrates the nature of the variability of the classes of products over a year.

The first class of products, Seas1, includes items like tennis racquets—generally demand is low in the winter, higher in late spring and summer, and lower again in the fall. The second class of products (Seas2) exhibits the opposite effect, where demand is generally higher in the winter and lower in the summer, e.g., sports equipment. Both classes include quarterly seasonality factors, as well as additional variability from month to month. Some of the products at JJT experience a learning or word-of-mouth effect, where sales increase over the year, musical CDs for instance might fall into the IncMean class. High technology products like computers generally see decreasing demand over their lifetime, where sales decline as new products cannibalize sales of older products (DecMean class). For comparison, the consultants also created a class called Sawtooth with some randomness, which is not motivated by particular products but was chosen as a contrast to the other demand scenarios.

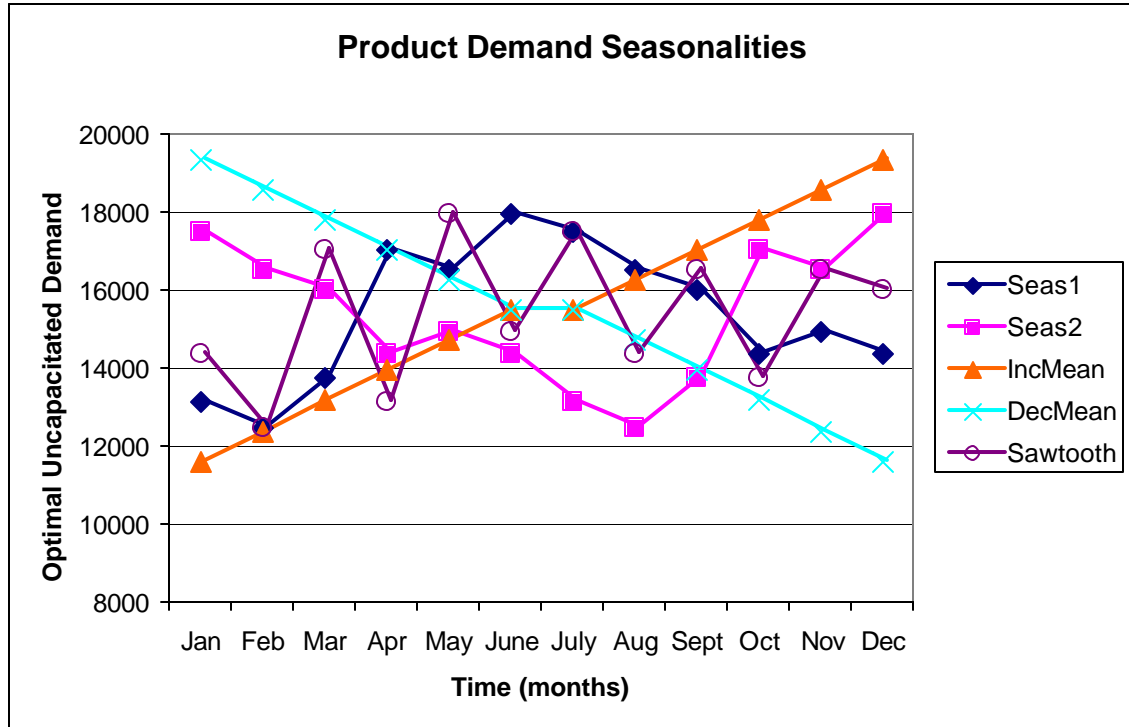


Figure 3: Demand Variability by Product Class

Natasha mulled over the report as she headed to the cafeteria for lunch. The consultants claimed that dynamic pricing could significantly increase profit, particularly under certain kinds of demand variability. Natasha saw that--the strategy allowed for a better matching between system capacity and customer demand. The consultants had even tried to quantify the increase in profit from dynamic pricing. Natasha suspected that numbers were high, but she was sure that there were gains in profit to be achieved through dynamic pricing. However, they also claimed that pricing might be able to help with the variability that JJT experienced, an idea that hadn't occurred to Natasha. That could mean an opportunity to reduce the supply chain costs at JJT, and perhaps pass the savings on to customers as well.

She continued to pore through the materials over lunch. The consultants had developed a simple mathematical model to try to quantify the impact of dynamic pricing. The objective was to maximize profit over time, represented by the following:

$$\text{Maximize Profit} : \sum_{t=1}^T R_t(D_t) - h_t I_t - k_t X_t$$

where I was for inventory, X indicated production, and h and k were the costs associated with each of the activities. The system was also subject to constraints in each period t, described as below:

- $I_0 = 0$  (1) Beginning Inventory
- $I_t = I_{t-1} + X_t - D_t$  (2) Inventory Balance
- $X_t \leq q_t$  (3) Production Capacity
- $I_t, X_t, D_t \geq 0$  (4) Positive and Integers

Natasha remembered seeing similar models when she studied Operations Management in an MBA program. Although price didn't appear explicitly in this one, the consultants explained the price was calculated from the demand curve since demand was the decision variable.

Using this model, the consultants solved for the best price that would match supply and demand, and they estimated the profit for each of the product classes. They also developed the following performance metric, which they called the profit potential:

$$\text{Profit Potential} = \frac{\text{Profit under Dynamic Pricing}}{\text{Profit under Fixed Pricing}} - 1$$

The result was an estimate of the percentage increase in profit if JJT went to a dynamic pricing strategy, and the results for the five classes are shown in Figure 4 for three different levels of variability. All remaining results are based on the case of medium variability.

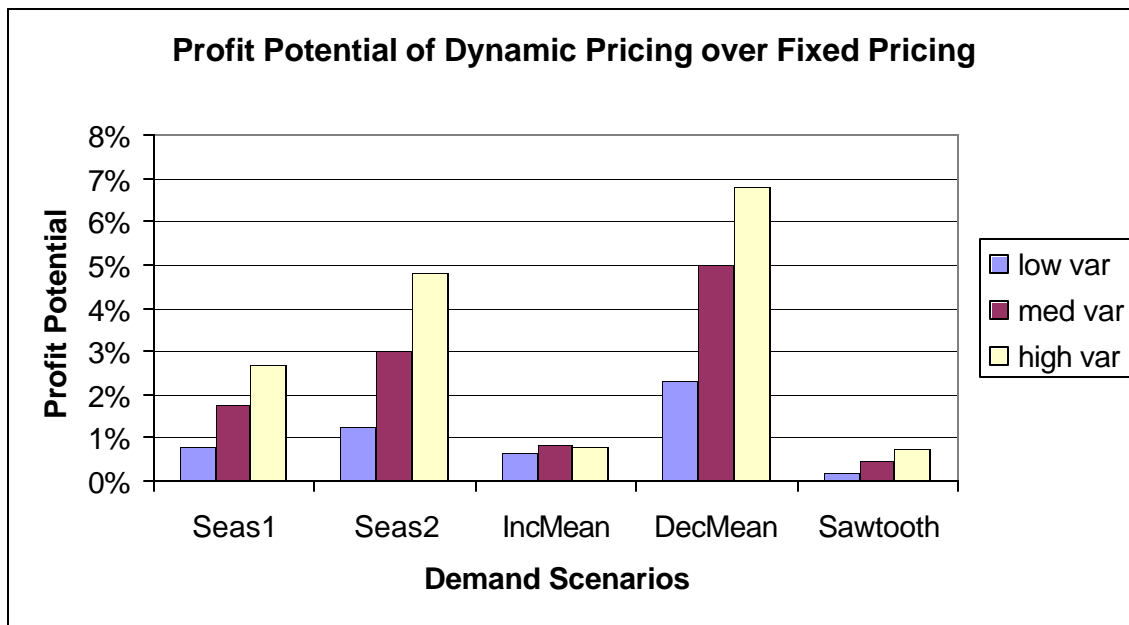


Figure 4: Profit Potential by Product Class and Variability Level

The results indicated that dynamic pricing could mean increases in profit from 1 – 5%, no small change for products with low profit margins at JJT. Of course, these numbers were a bit optimistic, for one thing the consultants assumed that the demand could be entirely predicted, and the reality was that one never knew just how many orders would come in at any time. Furthermore, they hadn't made any mention of competitors'

reactions if JJT started changing prices, or whether customers would start behaving strategically. Still, even a percentage or two improvement could mean significant gains for JJT.

Natasha also noticed that dynamic pricing had quite different impacts depending on the type of product being considered. For realistic products, the impact ranged from 1% improvement (IncMean) to a maximum of 5% profit potential (DecMean). Clearly, the nature of the demand characteristics was a significant parameter in the performance of dynamic pricing relative to fixed pricing.

Her brow furrowed as she finished off a slice of key lime pie. Where did the increase in profit come from anyway, was it just from increased sales or were there other factors? “Maybe they’re thinking too much about profit,” Natasha almost said aloud. “What would this dynamic pricing idea do to the production schedule?” She knew if dynamic pricing increased the variability it could mean real trouble for her supply chain team.

The consultant team focused on many of these questions next in the report. They carefully considered the source of the increase in profit, since changes in market share were of significant interest to JJT, as well as changes in costs. First they defined two performance metrics to calculate the change in revenue due to dynamic pricing:

$$\begin{aligned} \text{Revenue Change due to Sales} &= (\text{Dynamic Sales} - \text{Fixed Sales}) * \text{Dynamic Price} \\ \text{Revenue Change due to Price} &= \text{Fixed Sales} * (\text{Dynamic Price} - \text{Fixed Price}) \end{aligned}$$

where the Dynamic Price is calculated as the weighted average price over the horizon. They also calculated the change in production cost and inventory holding cost under a dynamic pricing strategy compared to fixed pricing. The results are shown in Figure 5; note that the total contribution to profit potential is normalized to 100%. Contributions above the x-axis indicate an increase in profit potential due to dynamic pricing; contributions below the x-axis show a decrease in profit potential. For instance, if the contribution of inventory cost appears above 0, it implies that inventory costs for dynamic pricing were lower than for fixed pricing.

As the consultants pointed out, and as Natasha saw in the figure, profit potential from dynamic pricing could come from a variety of sources. For example, in Seas1, the potential is largely due to increased revenue from increased sales volume, but in the IncMean product class, the potential is attributed to a decrease in inventory costs.

While the sources of profit potential are not the same for every product type, in most cases revenue due to sales volume shows a positive profit contribution. This implies that sales volume (and thus market share) is generally higher for dynamic pricing than for fixed pricing. Of course, an increase in sales volume is accompanied by an increase in production cost and a decrease in price. Natasha guessed that the increase in sales volume was due to the better match of supply and demand that the consultants were claiming.

Natasha was pleased to see that the team had addressed variability as an important factor. Typically, JJT had set a single fixed price over the lifetime of each product, based on demand curves, production and holding costs, and available production capacity. All of the management at JJT knew that their customer demand fluctuated over time; it was a constant source of worry for the production team. Some months their

overtime charges shot through the roof! Worse, at some times the production team was underutilized, so it was difficult to justify the expensive labor costs during other times.

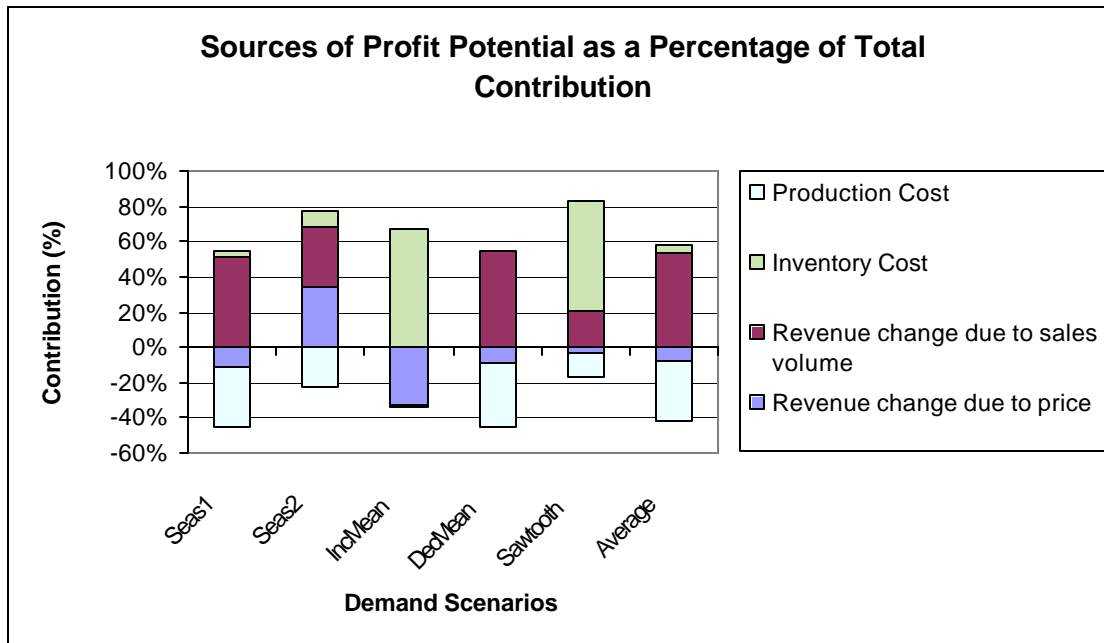


Figure 5: Sources of Profit Potential by Product Class

The consultants graphed the predicted sales over a year for each of the five classes of products under the best fixed price policy (see Figure 6). Natasha could see that the sales were all over the board, and the production schedule reflected similar kinds of variability. She was familiar with the bullwhip effect as well, which implied that the variability increased going up the supply chain, so she knew that there were hidden costs to this effect.

Using the same demand, the consultants looked at the resulting sales under the best dynamic pricing policy (displayed in Figure 7). Natasha could see that the sales variability under dynamic pricing was less, which also meant the production schedule should have less variability. The consultant's argued that pricing allowed the company to utilize their capacity more efficiently, rather than putting in overtime in periods of high demand, or rather than building up expensive inventory. Natasha thought to herself, "I certainly believe this works when capacity is fairly constant over time, but I'm not sure we'd see the same effect if capacity fluctuates, and who knows what happens if both demand and capacity are variable."

Natasha left the cafeteria and headed back to her office. "And what about our customers?" Natasha asked herself as she turned the corner to her office. She guessed they would be willing to accept some price changes, but not if they were too large or too often, especially if JJT could reduce costs through the new strategy and pass on some of the savings to the customers. She had heard rumors that Doug Ivester, the former Chairman of Coca-Cola, Co. had considered a dynamic pricing strategy (Cortese and Stepanek 1998), and that Ivester had left Coca-Cola in part due to customer dissatisfaction over the pricing strategy. She certainly didn't want that to happen to

herself! Yet, she knew that JJT needed to consider new strategies to remain successful in the changing market.

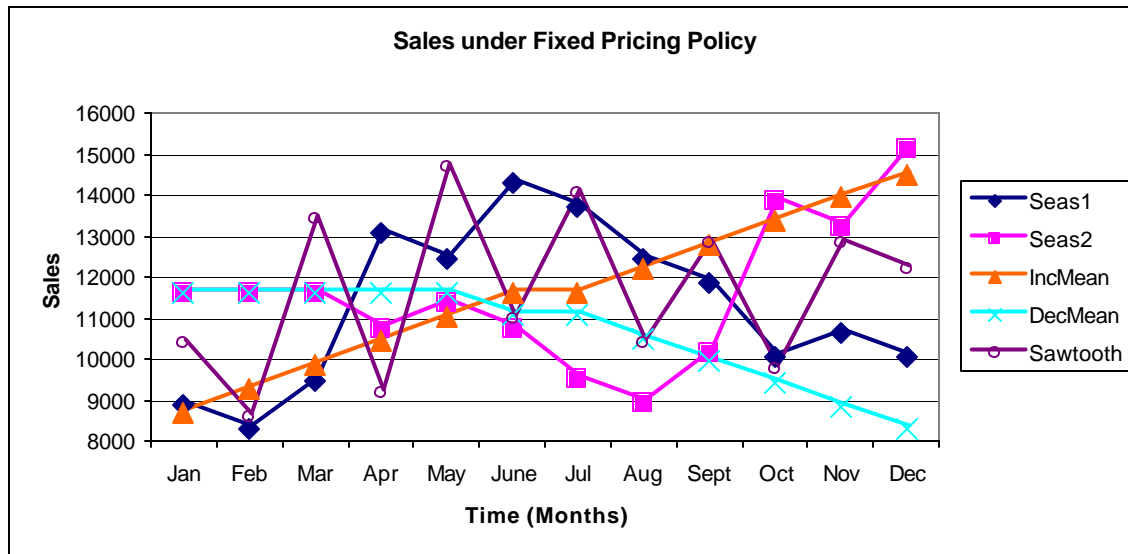


Figure 6: Variability of Sales under Fixed Pricing Policy

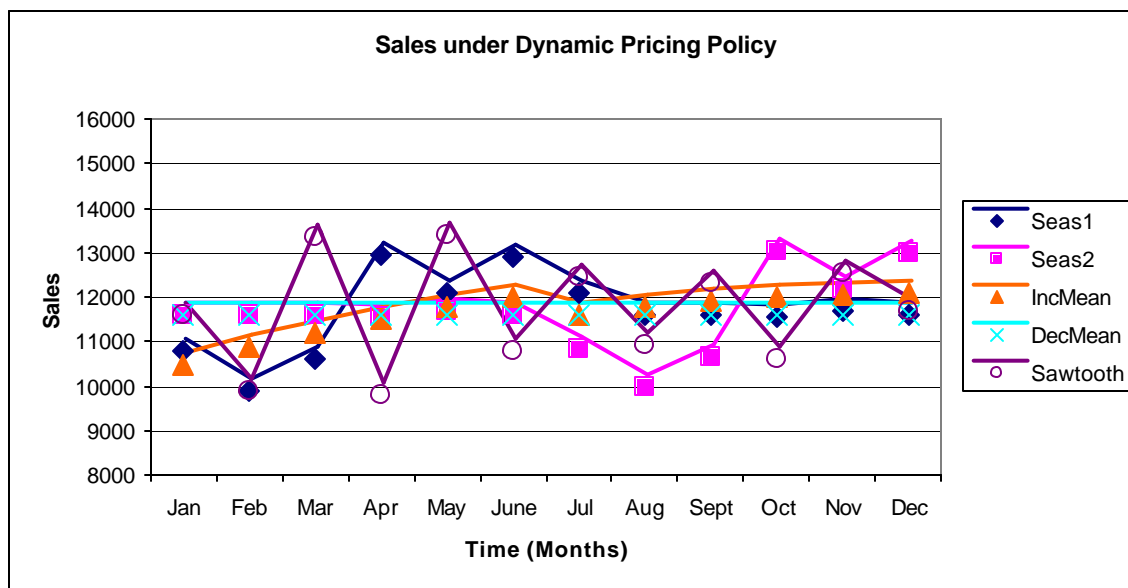


Figure 7: Variability of Sales under Dynamic Pricing Policy

She flipped through the report until she found more sections that interested him. Natasha chuckled as she saw the consultants had predicted many of her questions about price changes. The next portion of the report addressed the variability of the optimal prices under dynamic pricing (see Figure 8). For the sample products, the optimal price varied in a range as big as 11% total around the optimal fixed price. For example, Widget 5.0 had a list price of \$500, and the dynamic prices varied from about \$475 – 525, which was pretty close to the size of rebates that JJT sometimes used in promotions.

But more than just the actual percentages, which Natasha knew were affected by the sample products chosen, the graph provided additional useful information. The figure also indicated the direction of the price changes: increasing in the IncMean class for instance, but decreasing for the DecMean class. This meant dynamic pricing would probably be easier to implement for DecMean, since customers are more likely to accept price markdowns than steady price increases (e.g., laptops or fashion clothing). Of course, the price tended to follow the direction of the demand as well, so if demand really increased for the IncMean products, perhaps implementation would be okay. The consultants pointed out that this kind of price structure held for certain kinds of products, airline tickets for instance. The other classes experienced a similar effect where price tended to track the direction of demand (e.g., low, high, low for Seas1). This suggested that some rules of thumb might be appropriate for the directions of price changes.

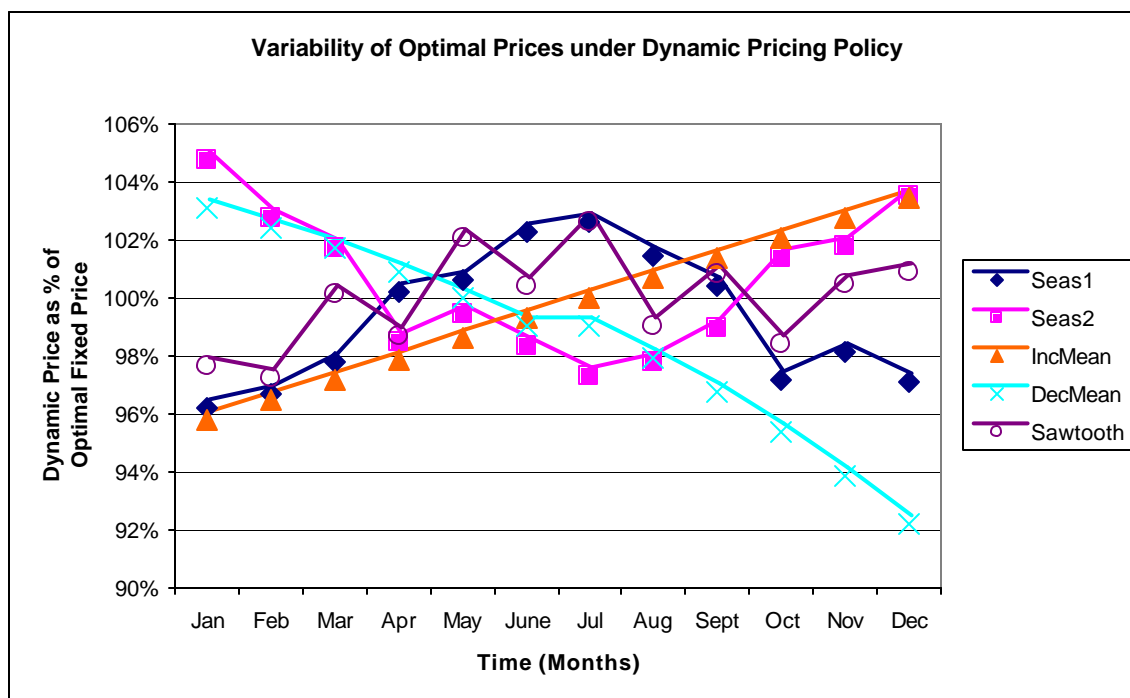


Figure 8: Variability of Optimal Prices under Dynamic Pricing Policy

The consultants also asked the question of what would happen if price changes weren't made in every production period, since customers might object to prices changing frequently. To look at this, they examined various pricing strategies for each of the product classes, where price changes were allowed 0, 1, 2, 3, 5, or 11 times during the 12 periods (0 corresponds to a fixed price, and 11 changes is full dynamic pricing). Since customers might be sensitive to the frequency of these changes, they required that the changes be evenly spaced over the entire time horizon. That is, if 1 price change is allowed in a year, the change occurs after 6 months, so the profit increase is a lower bound on the profit if the price change can occur at any time in the year.

For each of the product classes, the consultants determined the percentage of profit potential under limited price changes relative to the profit potential under full dynamic pricing (see Figure 9 for the results). The results indicate that in many cases,

significant profit can be achieved with fewer price changes. In most of the cases, a price change every 3 production periods achieved 75% or more of the total profit potential.

Natasha immediately noted that this did not hold for the Sawtooth class of products. Not only was full dynamic pricing needed for that class, in some cases fewer price changes were better! The consultants addressed the last issue by noting that they only considered price changes that were evenly spaced, so the price periods would not necessarily match the pattern of demand variability well. To address the first issue, they also provided another graph (see Figure 10), which shows the profit potential over fixed pricing (but not relative to the total dynamic pricing profit potential). The Sawtooth class, with demand alternating between high and low in successive periods, had the lowest profit potential of any of the classes (one explanation for why full dynamic pricing is needed). Since the demand changes were frequent, it is also likely that price changes are also needed frequently to match the variability. Figure 10 also demonstrates that a few number of price changes can result in significant profit potential.

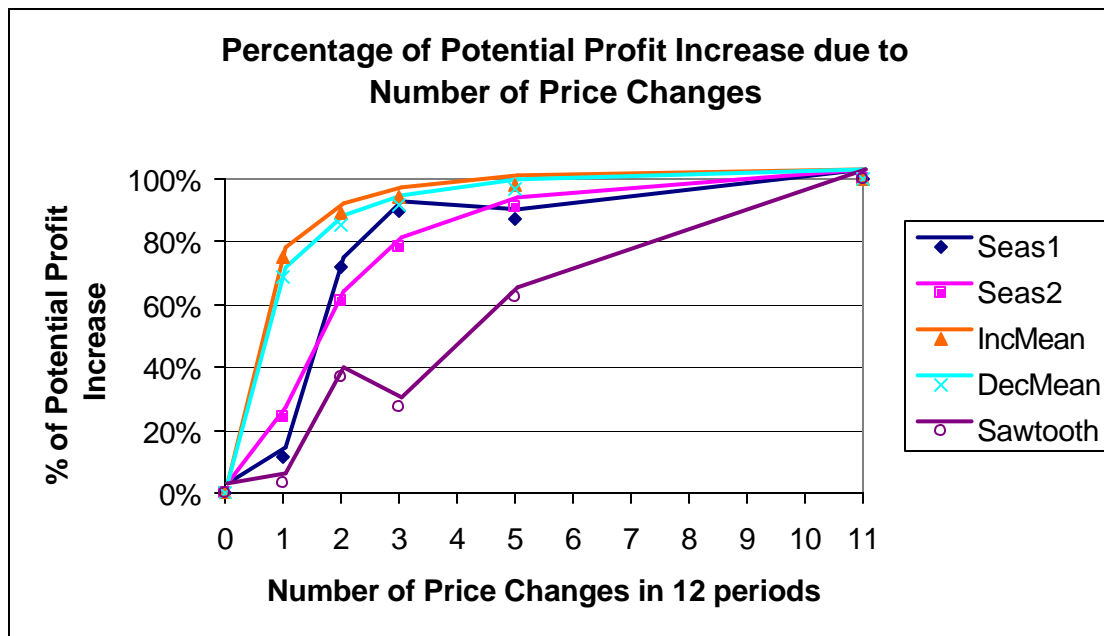


Figure 9: Percentage of Potential Profit Increase due to Number of Price Changes

Natasha was quite interested in the results so far...dynamic pricing might have some potential for JJT. However, the analysis so far considered the products completely separately. In reality, similar products often shared assembly capacity, so she didn't think this should be completely ignored. She was curious what would happen with dynamic pricing of multiple products, and she was pleased to see that the team had at least begun to address this question.

The consultants considered a portfolio of products sharing production capacity, where pricing, inventory, and production decisions were made on each product. They assumed that products sharing capacity experienced similar types of demand variability, so they were competing for limited resources at the same time. However, they also assumed that there were no demand diversions among products, i.e., that the demand for each product was independent of the prices of the other products. For some products,

Natasha felt this was reasonable—customers who wanted to buy Widget L would not substitute with Widget S, because they served different purposes. But for products such as Widget 5.0 and Widget 5.5, she was sure there were customers who wanted 5.0 but would switch to 5.5 if the price were right. The consultants focused on two of the product classes as an example (Seas1 and DecMean), and looked at the performance of dynamic pricing relative to fixed pricing as the number of products in the portfolio increased (see Figure 11).

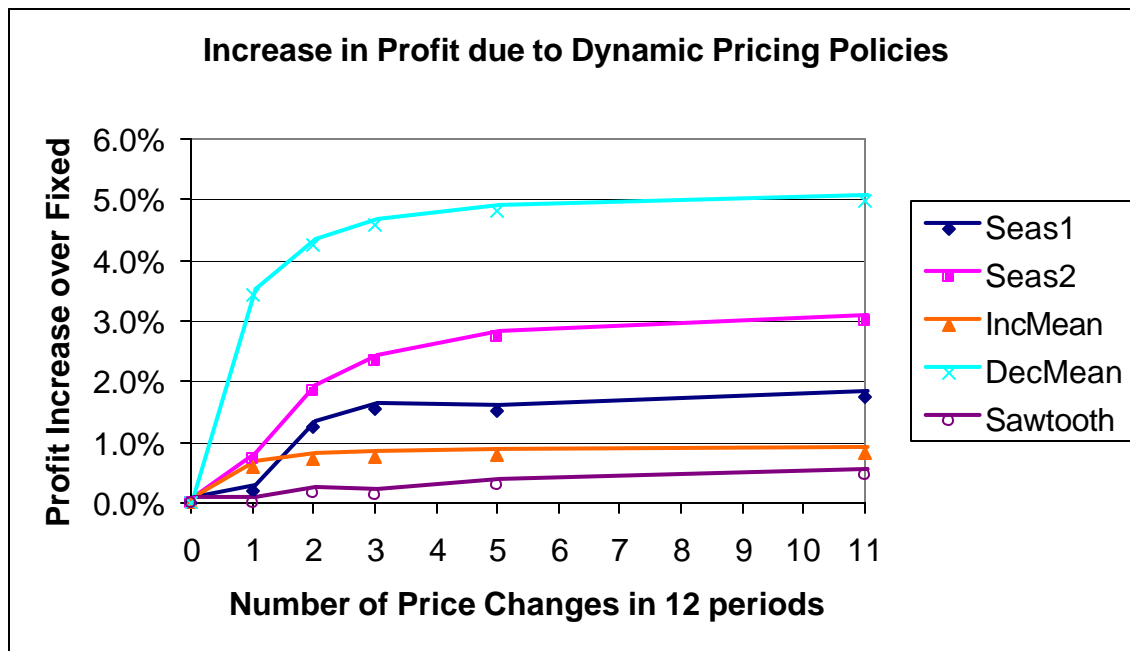


Figure 10: Profit Potential due to Number of Price Changes

The first thing the team pointed out was that the profit increase of dynamic pricing over fixed pricing tended to decrease with the number of products. They explained further—both fixed and dynamic pricing strategies needed to determine the mix of products in a portfolio by determining the base price of a product (and thus the level of demand). Since some products are more profitable than others based on production costs, determining the product mix is an important component of profit, particularly when the products share limited capacity. The graph suggests that determining the mix of products in the portfolio may be as important or more so than tweaking the price of each product over time, which is the additional flexibility allowed in dynamic pricing.

Of course, this doesn't hold all of the time. In particular, dynamic pricing over 2 or 3 products often has greater profit potential than only 1 product. One possible explanation is that a little flexibility may have a significant effect, as Natasha had seen for the frequency of price changes. However, much of this could also be due to the relative profitability of the products that are added to the portfolio, so the consultants considered the DecMean class with the order of products reversed as their final example.

The team also examined the Seas1 class with higher demand variability, and saw that the results were similar, except that the higher variability implied a higher profit potential as well. Finally, the consultants also pointed out that whereas the profit

potential decreased with the number of products, the potential by product class may stabilize. This is likely due to the idea that a little flexibility helps a lot, but the marginal contribution of flexibility probably decreases.

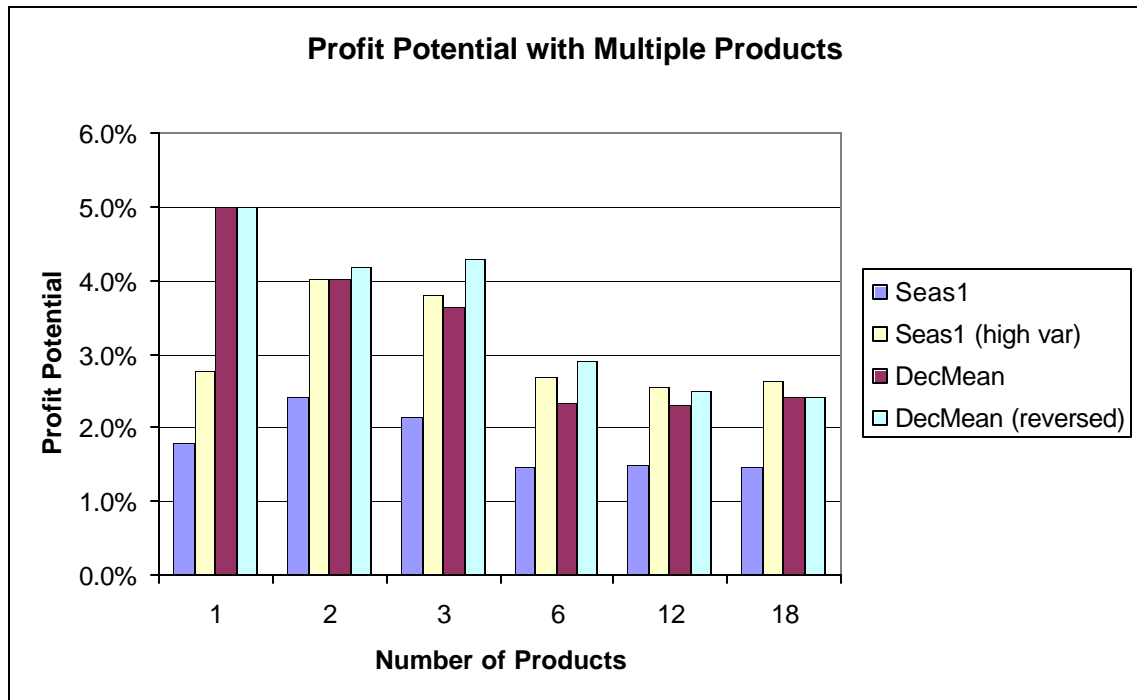


Figure 11: Profit Potential for Multiple Products Sharing Capacity

Natasha closed the binder to the report and leaned back in her chair thoughtfully. She certainly was intrigued with some of these innovative pricing strategies, and she thought some of them had potential applicability for this firm. She didn't want to accept the consultant's recommendations immediately however; they had a vested interest in convincing her to try the new strategy, since JJT would probably pay the same company to implement it if they moved forward! Plus, she still had plenty of questions she wanted them to address. She turned to her computer and began composing an email with some of her many questions to the consultants.

## QUESTIONS

Below are some of Natasha's questions outlined to you, a member of the consultant team.

1. Why do different product classes exhibit different results (particularly for profit potential, sources of profit potential, etc.)?
2. What would happen if some of the assumptions were relaxed? For instance, what if customers planned their buying strategically, what impact would this have on the pricing strategies and results? Competition from other firms?
3. What are some guidelines on when it might make sense to use dynamic pricing and when it wouldn't make sense? What would JJT need to think about if they wanted to implement dynamic pricing?

**Note:**

The graphs and some other portions of this case study are based on research that appears in (Biller et al. 2002). An industrial partner provided the initial data set that we use for the experiments, and the data was further manipulated for the study. Related research by the author and others also appears in (Chan et al. 2002).

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<sup>i</sup> The case is loosely based on discussions with several companies.

<sup>ii</sup> The linear demand curve in the function  $D = a * P + B$  can be derived from the definition of demand elasticity. This curve is formed with a demand elasticity of  $-2.0$ , a base price of \$2000, and a base demand of 10000.