The Price is Right Mysterious

by R. Preston McAfee

I want to start out with an insight so obvious that you'll probably think, "Everyone knows that." Only everyone doesn't. The insight is this: If you offer discounts to your rival's customers, it will cause your rival to fight to hold onto his customers, and he will do this by cutting prices. He will then take some of your customers away from you. In the end, you'll get some of his customers, he'll get some of yours, and you'll both be selling at lower prices. If, on the other hand, you reward loyalty by offering a better deal to customers that have been with you for a while, you make your customers expensive to poach. Your rivals are discouraged from poaching them, and tend to respond in kind.

This is a pretty trite insight, but some cell-phone companies have gotten it dramatically wrong, and it's cost them billions of dollars. Both Verizon Wireless and T-Mobile offer discounts to new customers that are not available to their old customers. If you go to their websites to sign up for a phone plan, you're told "Prices exclusive to T-Mobile.com and valid only with new service activation" and "All phone prices are offered only with activation of a new line of service with Verizon Wireless, under the terms and conditions of selected service plan." The obvious thing this does is to encourage their own customers to leave, if for nothing else than to get the other companies' discounts. Cingular is neutral; if you're a customer and your contract has expired, you qualify for every discount offered. Sprint is the only cell-phone company that gets it right. If you've been with them for 18 months, you get a discount on a new phone that no one else is offered. This is good business.

Here's another obvious insight along the same lines: If you reward your sales force on quantity, such as giving them a commission per unit sold, it encourages the sales force to cut prices wherever they can in order to sell more units, and they don't bear the costs of this price-cutting. If, instead, you reward the sales force on net profits, or even on rev-

enue, you reduce the incentive to cut prices. There are always going to be some price-sensitive customers for whom you eventually have to lower the price, but you should do that by reducing the quality in some way (and we'll talk more about that), or by offering them a bundle of products that makes it hard to compare their deal with any alternative deal. This makes it easier to sustain different prices for different customers so that you can continue to charge your better customers (the ones with the highest willingness to pay) higher prices.

There's a simple formula that characterizes the price that maximizes the profits of a monopoly:

$$\frac{p-m}{p} = \frac{1}{\varepsilon}.$$

This says that the proportion of the price charged, p, that is the markup over the marginal cost, m, equals one over the elasticity of demand, ε. The last two terms are explained in the sidebar.

A monopoly should therefore charge higher prices to customers with inelastic demand, and lower prices (a lower markup over marginal cost) to customers with elastic demand.

The formula works even for companies facing competing products, provided the elasticity is understood to reflect demand for the company's own product and not market demand. Demand for a company's product is more elastic than market demand. For example, if Exxon increases its gasoline price by 10 percent and the other companies do not, it might experience a 40 percent reduction in sales, for an elasticity of 4. In contrast, if all the companies raise their prices by 10 percent, their sales would generally fall only by about 4 percent, for an elasticity of market demand of 0.4. In this case, the market demand is very inelastic, while the demand facing one firm is quite elastic, because an increase in price by one firm drives some customers to switch to competing firms.

The formula can be rearranged as:

$$p = \frac{\varepsilon}{\varepsilon - 1}\, m,$$

and this version has been widely used—or rather, abused—to justify a "constant percentage markup" policy. After all, that's what it says: Price should be a constant number, elasticity over elasticity minus one, times the marginal cost. But the formula doesn't justify that way of thinking, since the elasticity of demand, and hence the constant number, depends on the type of customer. The marginal cost should be marked up according to customer's elasticity, with markups higher for inelastic customers—and we'll talk about who they are below—and less high for elastic ones.

How can companies go about doing that? One way is to have different charges depending on who the customers are, such as the discounts offered by movie theaters to senior citizens and students, both relatively elastic types of customer. For another example, try logging into Amazon with your own identity and asking for a price on something. Then clear your cookies (so Amazon cannot access your personal information and purchasing history) and search again anonymously for the same item. Sometimes you will be quoted a different price, because when Amazon looks at your past spending pattern, and sees that you have not always gone for the lowest price, they will treat you as a poor searcher—a more inelastic customer—and make you a less attractive price offer.

This is known as direct price discrimination, and you can expect to see more of it in the future. Direct price discrimination means charging different customers different prices for the same good. Most companies prefer to call it value-based pricing, since discrimination sounds unappealing.

Marginal Cost

The marginal cost (m) is the cost to a company of producing one additional unit. If I ordinarily run a fast-food restaurant serving a thousand meals per day, my marginal cost would be the cost of an additional meal per day, or, alternatively, the savings of producing one meal less. For an integrated circuit manufacturer with a $3 billion factory, the marginal cost of a $100 chip might be 25 cents—the cost of the additional labor and materials required to produce an extra chip—until the capacity of the plant is reached, at which point the next chip, which requires building another factory, has a marginal cost of $3 billion.

Elasticity of Demand

The elasticity of demand, ε, is the percentage decrease in quantity sold (Q) associated with a one-percent increase in price (p):

$$\varepsilon = -\frac{\%\Delta Q}{\%\Delta p},$$

and it measures the responsiveness of customers to price changes, that is, their price sensitivity. If customers are very price sensitive, the elasticity of demand will be a large number, and a price cut will produce a large increase in sales. A price increase, on the other hand, will cause a large decrease in sales.

A problem with direct price discrimination is resale among customers, or arbitrage. Customers who can buy something at a lower price may sell the goods to others; Americans who travel to Mexico or Canada to buy prescription drugs are a good example of this. But there's another way to charge different prices to different people that doesn't involve having to observe customer's spending records, and that prevents arbitrage—indirect price discrimination.

Direct price discrimination means charging different customers different prices for the same good. Most companies prefer to call it value-based pricing, since discrimination sounds unappealing.

Indirect price discrimination enlists the help of the customer in the effort to charge customers a different price. Take coupons, for example. Coupons are available to anyone willing to spend time reading the newspaper coupon flyers or the coupon books found at the entrance to many grocery stores, cutting out the coupons, and remembering to give them to the cashier at the checkout (something I always forget to do). Coupons can save 50 cents or $1 off a $3 item, which is a pretty big percentage price cut, yet many shoppers do not use them. So coupons are one way of enlisting the customer in the effort to charge more elastic customers lower prices, while getting other customers—those who place a high value on their time and don't want the work involved in clipping coupons—to volunteer to pay the higher price. The success of coupons relies on the fact that price-sensitive customers are more likely to use coupons than less price-sensitive customers, because lower wages tend to induce price sensitivity and make the time spent on coupons worthwhile.

A quantity discount is analogous. Suppose a company takes 48 rolls of paper towels, wraps them up together in plastic, and charges half the price per roll than for one individual roll. People with small apartments and people with small cars won't buy the 48-roll bundle, and more price-sensitive families with seven children constantly spilling things will. Since large families also tend to be more price-sensitive, it's a good deal for the manufacturer, because it achieves the price discrimination of offering a discount to the more price-sensitive customer.

For a remarkable example of indirect price discrimination, go to the Dell website. The first thing you are asked is what type of customer you are. It gives you four choices: You can be a medium to large business, a home, a small business, or a government agency. A few months ago, I searched for the price of a 512-megabyte memory module, part number A0193405, under each of these headings, clearing my cookies in between my choices. I was quoted $289.99 for a large business, $266.21 for a government agency, $275.49 for a home, and $246.49 for a small business. (At the time of writing, the prices are $334.99 for medium and large businesses and government, and $267.99

Grocery store customers who don't use coupons are inadvertently volunteering to pay higher prices.

for home and small business.) Dell didn't verify what sort of purchaser I was. In fact, they don't care. As a Dell spokesperson said, "Each segment sets its own prices and the customer is free to pick the one that's cheapest." So this is an example of using information provided by the customer to discriminate for or against them. As mentioned above, this is known as "value-based pricing," but where's the value for the large business that paid $43.59 more than a small business? I suspect few large companies are using coupons, either, so they're paying more in two different ways.

Another example of price discrimination occurs when you book a hotel room. If you call a hotel to ask for a room and they quote you a price, ask them if they have a better rate—the answer is almost always yes. These hotels discriminate between customers purely on the basis of whether or not they know to ask.

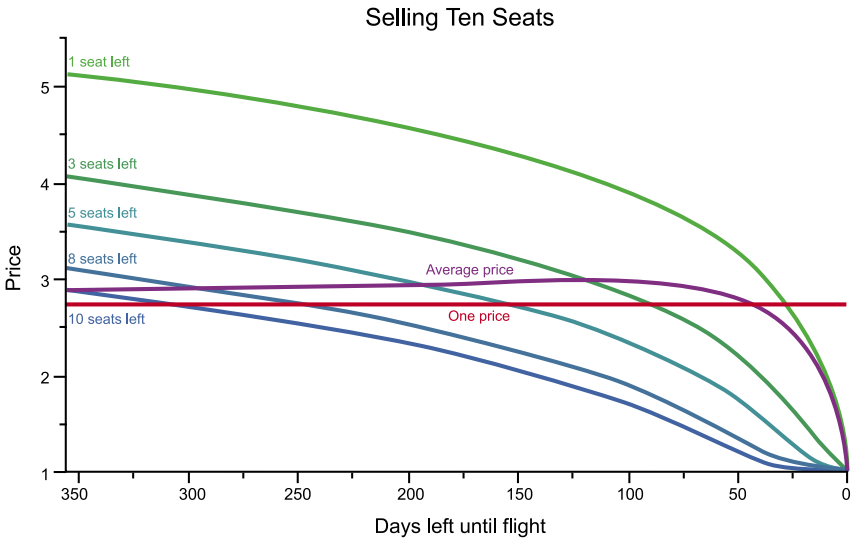
Companies can also charge more price-sensitive customers less by offering them less, such as giving them a lower-quality product. And an easy way of lowering the quality is to damage the goods. IBM came up with an interesting way to do this. In 1989, Hewlett-Packard came out with the first consumer-oriented laser printer, affordable for small businesses and home use, which printed at five pages per minute. IBM's LaserPrinter printed 10 pages a minute and was almost twice as expensive as the new HP. The problem for IBM was that although it had the better product, many of their customers didn't need the speed, especially when not having it cut the price of the printer in half. IBM was going to lose a huge portion of their market unless they reduced the price of the Laserprinter, but at the same time they didn't want to lose those profitable customers willing to pay extra for the faster speed. So they launched a "new" printer, the LaserPrinter E, a 5-page-a-minute printer that sold at about the same price as the HP printer. It was, in fact, the regular LaserPrinter, but with seven chips added. These chips introduced "wait" states into the processing of the pages. Printing instructions came down the line, reached one of the chips, the chip received the instruction, ticked the clock for a few milliseconds, and then passed the instruction on. That's all the chip did. And that's all the six other chips did as well. IBM had taken a fully functional 10-page-a-minute laser printer and added chips to slow it down so that they could charge just slightly more than half the price for it. It's analogous to a refrigerator salesman who takes a ball-peen hammer and whacks a part of his inventory, then sells those units as "warehouse damaged" at a reduced price.

There are many other examples of manufacturers intentionally damaging a portion of their production. The Intel 486SX processor was just the regular 486 processor with the math coprocessor disabled, and was sold for about two-thirds the price. The Sony MiniDisc comes in two sizes, a 60-minute version and a 74-minute version.

At the top is the expensive way to commute from Austin, Texas, to work in Los Angeles from Monday to Thursday and get back home to Texas for the weekend. By buying the tickets another way, below, it's much cheaper, because both tickets involve Saturday-night stayovers.

They're exactly the same except that the 60-minute version has a software instruction that prevents writing on a portion of the disc, cutting its length by 14 minutes. If you buy an inexpensive DVD player from a company that also makes expensive ones, such as Sony, and pop off the top of the remote, you'll often find hidden buttons that provide functionality not accessible on your unit because you didn't pay enough for it. The DVD player and remote possess the functionality, but the company has hidden it from you, so they can sell the player for less.

The airline industry offers some extreme examples of price discrimination. In the process of moving to Caltech in early 2004, I had to commute from Austin, Texas, for several months, flying out to Los Angeles every Monday morning and returning to Austin on Thursday evening. There were two ways to book the trips. The straightforward way was to buy a return ticket from Austin to L.A. on Monday, returning Thursday, and another return ticket to L.A. the next Monday, returning the following Thursday. If I did that, a pair of trips would cost me $2,200. When I booked the tickets another way, buying one round-trip from Austin to L.A., leaving Monday and returning the



Airlines practice dynamic price discrimination, also known as yield management, by placing a different value on each airline seat depending on how many seats are left to sell. This graph shows the standard textbook model of how it works when there are 10 or fewer seats left to sell from a year before the departure date to day 0.

Thursday a week later, and also buying a second round-trip from L.A. to Austin, leaving L.A. on the first Thursday and returning the next Monday, it cost me $420, less than a fifth of the previous price. The gap between those numbers has narrowed since then, but the cost of a return ticket is still much lower if there's a Saturday night stayover. This stayover requirement is exactly the same thing as damaging the goods. The restriction doesn't save the airline any money, because exactly the same seats are being occupied, but it deters some of the business travelers who don't want to spend the weekend away from their families, which allows the airline to charge them more.

If you call a hotel to ask for a room and they quote you a price, ask them if they have a better rate—the answer is almost always yes.

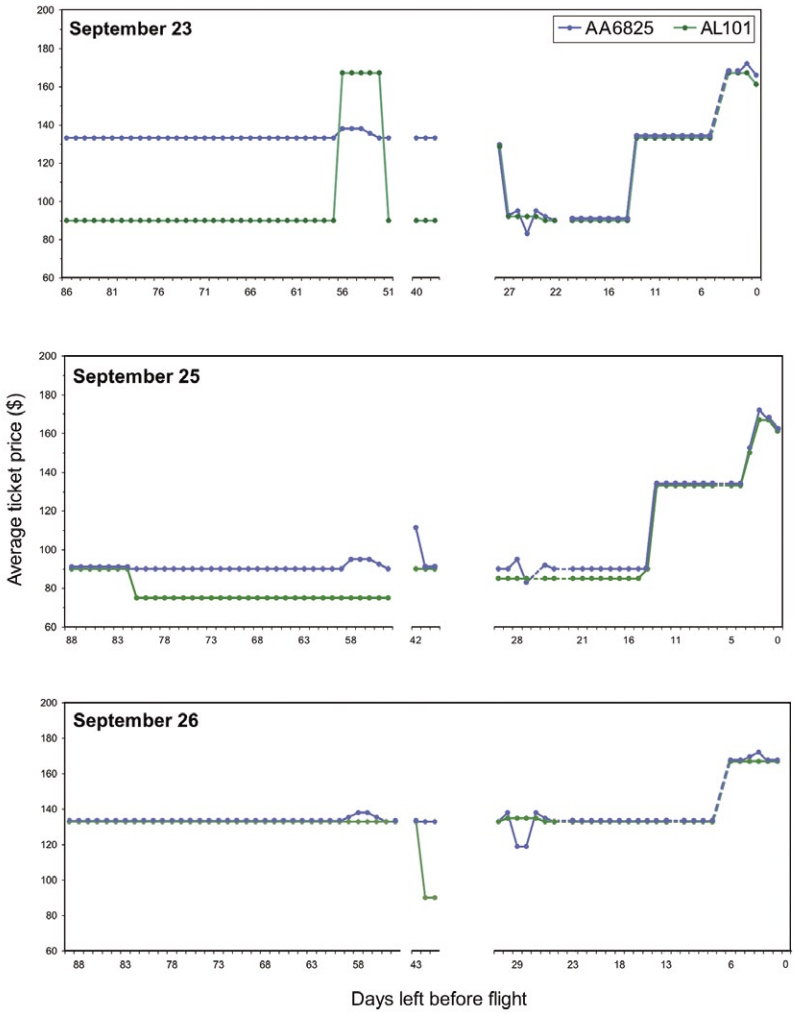
Why do airlines have such complex pricing systems? When American Airlines owned the yield-management company Sabre Corporation, one estimate said that yield management, which is the technical term for dynamic price discrimination, was worth $500 million a year to the airline in added revenue. That was more than 5 percent of American Airline's revenue at the time, so I was intrigued to find out how such an obviously valuable system worked. I began by reading the literature, and that's when I noticed that many of the academics writing papers on yield management tended to disappear from the pages of the journals. It seemed like a John Grisham novel—was American Airlines murdering these people? They weren't. The professors wound up working for the Sabre Corporation and no longer published their work.

A simple example of yield management is when airlines set aside a number of seats in case some really high-value people, usually business people, need them at the last minute and are prepared to pay a very high price. This means that even when there is a lot of tourist demand, the airline doesn't have to turn away passengers willing to pay a large premium. On the negative side, if those last-minute, full-fare-paying passengers fail to materialize, tourists who would have filled those seats have been turned away.

The graph above shows how the ticket price for 10 seats or fewer varies from a year before takeoff to the day of departure. When there are 10 seats left, the price falls along the dark-blue curve, but if two more seats are sold, the price jumps up to another curve associated with having eight seats left. Then if at some point three more seats are sold, the price jumps up to the curve for five seats, and so on. The airline has a different price path for every possible number of seats. As time goes by, all prices tend to fall, because the closer it gets to the departure date, the lower the value to the airline of having a lot of unsold seats.

If there are a lot of seats to sell (and planes are getting bigger all the time—the new Airbus A380 will seat 800), the price will be pretty close to the average price most of the time—this proximity to the average is a consequence of the statistical fact known as the law of large numbers. An implication is that most of the value associated with charging different prices based on the number of available seats occurs with the last 15 or 20 seats. The graph only shows ten seats, but there are similar calculations for 200 seats or more. For most of the time and most of the seats, prices will be pretty steady, and that means the airlines don't do much better than if they'd just picked the average price and stuck with it until they sold all the seats (the red line). Or, put another way, an airline doesn't gain very much with this system if it has 100 or more seats per plane to sell.

So theoretical models of yield management fail to explain how American can make $500 million a



The average daily price of a single ticket from Oakland, California, to Portland, Oregon, was tracked over 86 days for American Airlines AA6825 (blue) and Alaska Air AL101 (green) for three different departure dates in September 2004. It's a mystery why there's such a variation in price between the two airlines, especially on September 23, because AA6825 and AL101 are actually the same flight. (The reason there are gaps in the graphs is that undergrad Vera te Velde's information-gathering efforts were misinterpreted by the Institute as a "denial of service" attack, and her computer connection was temporarily shut down—twice.)

year with the Sabre system. I'm currently working with Caltech undergraduate Vera te Velde to test the standard textbook model of yield management against what is happening in the airline industry, and I can give you a quick summary of what we've learned so far: Everything we knew is wrong.

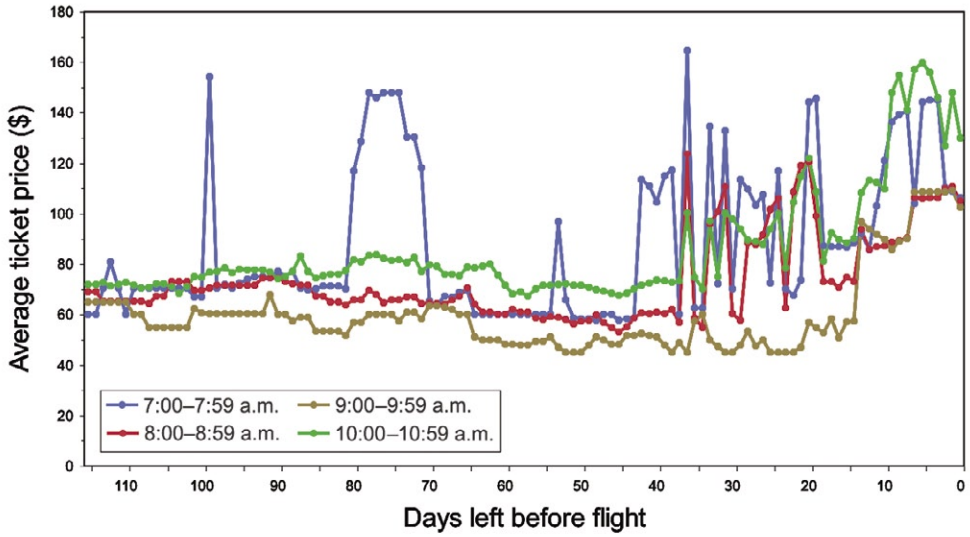
For many months we've been collecting data on ticket prices on a very fine grid, the way financial data is collected, by checking the prices quoted on Orbitz several times a day. The top graph on the left shows the results of tracking two scheduled flights from Oakland to Portland that were close alternatives—that is, flying between the same airports, at about the same time—American Airlines flight AA6825 and Alaska Air flight AL101. The first noticeable feature of this graph is that, for the first 30 days, AA6825 costs about $50 more than AL101. Then at some point, for reasons I don't know, Alaska almost doubles its price and American's price goes up by $5. After a few days American's price comes down followed by Alaska's, and both trade at their former level until 28 days before departure, when Alaska's price jumps up steeply, and American's comes down a bit, so that, on day 27, they both trade at the same price. After that they both drop down a lot and remain in lockstep until departure, apart from an odd downward blip by American on day 25.

The next graph tracks prices for the same flights leaving two days later, on September 25. This time, American Airlines starts by pricing at the Alaska level, then Alaska drops for a while, comes back up, goes down by a much smaller amount, and then they continue in lockstep until the end.

The third graph is for the same two flights departing September 26. Prices are steady and in lockstep for much longer, but again, there's the same puzzling American Airlines $5 blip between 60 and 56 days before takeoff that we saw in the other two graphs. (Even two months later, American still had that same blip. Other blips in the graphs aren't repeated.)

I said these two flights were close matches, but they're a little more than that—they're the same airplane. This flight is operated by Alaska but code-shared with American. Orbitz is quite open about this, offering a choice of flying for $90 on Alaska 101, or for $135 on American Airlines 6825, and it clearly indicates the flight is code-shared with Alaska 101. Why are people choosing American? To earn frequent-flyer miles? But these companies also share their frequent-flyer program, and the miles earned on either flight can be applied to either airline. So it's a mystery to me why, in the first graph, American is selling the same seats, on the same airplane, for 30 days at a price $50 higher than Alaska.

Most existing economic analyses of airlines, and all antitrust analyses for evaluating airline mergers, are based on the assumption that airports in the same city, different times of flight, and different airlines can be considered close substitutes,



The graph shows the average ticket prices of flights departing from Oakland to Portland between 7 and 7:59 a.m., 8 and 8:59 a.m., 9 and 9:59 a.m., and 10 and 10:59 a.m., plotted against days before takeoff. There was no correlation between the prices quoted for the different time slots except in the two weeks before departure. This is a time when all tickets tend to become more expensive, because the airlines can charge more for unplanned travel. (Unplanned travel is often by business people.)

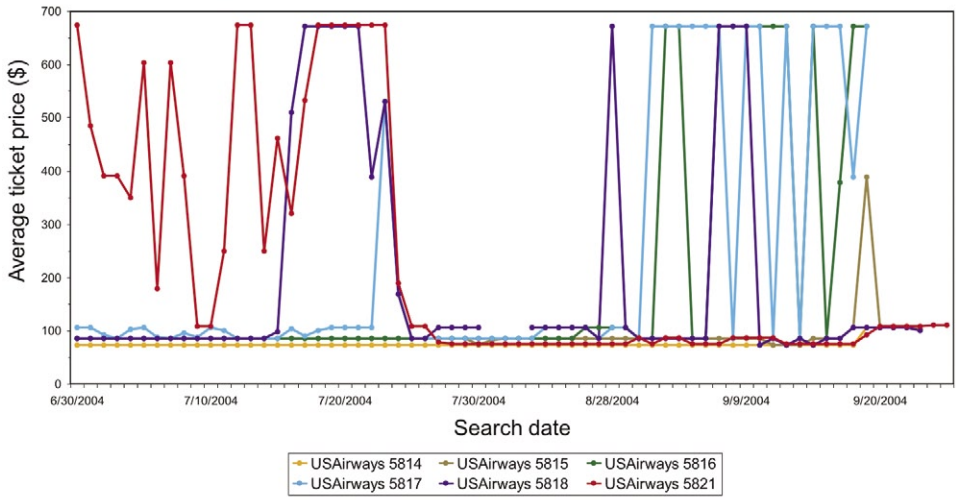
meaning customers view them as good alternatives. Vera and I found that this wasn't the case at all. For example, when we charted the ticket prices of flights taking off between 7 and 7:59 a.m., 8 and 8:59 a.m., 9 and 9:59 a.m., and 10 and 10:59 a.m. on the same route between Oakland and Portland (above) we saw some correlation in the last month prior to takeoff—when all prices moved up—but before that the prices were not closely correlated, as good substitutes must be.

These price fluctuations are not just in economy flights, we're finding the same thing on first-class, one-way, full-fare, refundable tickets—the most expensive way to fly. In the graph below, we plotted the average price of a first-class ticket from Los Angeles International Airport (LAX) to Las Vegas on US Airways, as quoted on Orbitz, at five different departure times on September 23, and at 8:10 a.m. on September 25. It's just a short hop from LAX to Vegas, but depending on the day of booking, and the time of the flight, a ticket could cost either $680 or $90. Before I started this research, I would have guessed that first-class fares were pretty steady, and I would have been wrong.

Most of the assumptions people make about airline pricing don't seem to be borne out by our data (which is the first of its kind), and it's possible that there may be randomization built into airline pricing. Vera and I are currently testing that theory.

My main advice for buying airline tickets is to always book more than a month in advance, as prices rise in the last month—especially during the last two weeks, when our data show that they go up by $70 on average. Flexibility in the time of day in which you travel and the airport from which you fly can be worth 50 percent. And finally, even if you're committed to flying on a particular flight with a particular airline, it still pays to search if you've got two months before the flight takes off. Check the price every day, and if it falls by 20 percent, book it. A saving of 20 percent simply by monitoring the price on Orbitz for two weeks is an enormous return on invested time.

Some unlucky high-rollers heading for Las Vegas from Los Angeles on September 23 and 25 with US Airways might have paid almost $700 for their first-class seat while the person next to them had paid only $90. Ticket prices for the flights monitored here even changed dramatically several times a day. Because the graph shows average daily prices, a plot of $400 may well reflect a price of $700 for half the day, and $100 for the other half.



If Airlines Sold Paint

Buying paint from a hardware store

Customer: Hi, how much is your interior flat latex paint in Bone White?

Clerk: We have a medium quality, which is $16 a gallon, and premium, which is $22 a gallon. How many gallons would you like?

Customer: I'll take five gallons of the medium quality, please.

Clerk: That will be $80 plus tax.

Buying paint from an airline

Customer: Hi, how much is your paint?

Clerk: Well, sir, that all depends.

Customer: Depends on what?

Clerk: Actually, a lot of things.

Customer: How about giving me an average price?

Clerk: Wow, that's too hard a question. The lowest price is $9 a gallon, and we have 150 prices up to $200 a gallon.

Customer: What's the difference in the paint?

Clerk: Oh, there isn't any difference; it's all the same paint.

Customer: Well then, I'd like some of that $9 paint.

Clerk: Well, first I need to ask you a few questions. When do you intend to use it?

Customer: I want to paint tomorrow, on my day off.

Clerk: Sir, the paint for tomorrow is the $200 paint.

Customer: What? When would I have to paint in order to get the $9 version?

Clerk: That would be in three weeks, but you will also have to agree to start painting before Friday of that week and continue painting until at least Sunday.

Customer: You've got to be kidding!

Clerk: Sir, we don't kid around here. Of course, I'll have to check to see if we have any of that paint available before I can sell it to you.

Customer: What do you mean check to see if you can sell it to me? You have shelves full of the stuff; I can see it right there.

Clerk: Just because you can see it doesn't mean that we have it. It may be the same paint, but we sell only a certain number of gallons on any given weekend. Oh, and by the way, the price just went to $12.

Customer: What! You mean the price went up while we were talking?

Clerk: Yes sir. You see, we change prices and rules thousands of times a day, and since you haven't actually walked out of the store with your paint yet, we just decided to change. Unless you want the same thing to happen again, I would suggest that you get on with your purchase. How many gallons do you want?

Customer: I don't know exactly. Maybe five gallons. Maybe I should buy six gallons just to make sure I have enough.

Clerk: Oh no, sir, you can't do that. If you buy the paint and then don't use it, you will be liable for penalties and possible confiscation of the paint you already have.

Customer: What?

Clerk: That's right. We can sell you enough paint to do your kitchen, bathroom, hall, and north bedroom, but if you stop painting before you do the bedroom, you will be in violation of our tariffs.

Customer: But what does it matter to you whether I use all the paint? I already paid you for it!

Clerk: Sir, there's no point in getting upset; that's just the way it is. We make plans based upon the idea that you will use all the paint, and when you don't, it just causes us all sorts of problems.

Customer: This is crazy! I suppose something terrible will happen if I don't keep painting until after Saturday night?

Clerk: Yes, sir, it will.

Customer: Well, that does it! I'm going somewhere else to buy my paint.

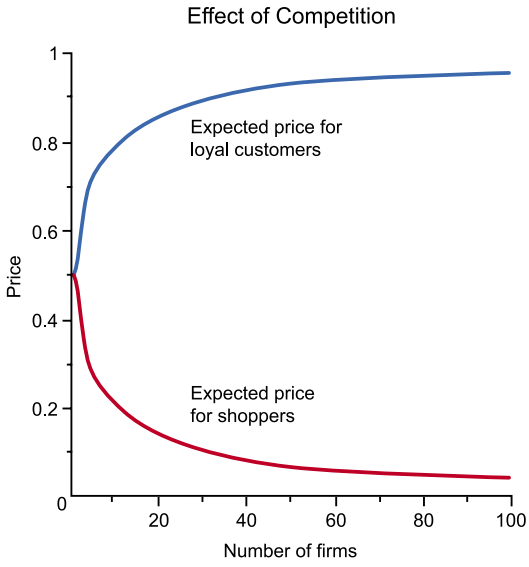
Clerk: That won't do you any good, sir. We all have the same rules.

Cheerful newspaper flyers announcing items on sale are actually weapons in a sophisticated price war.

An area of pricing where we already see randomization is that of sale items in grocery stores presented in those garish advertisements that have probably annoyed you when they fall out of the newspaper and scatter all over the floor. These flyers indicate that something quite mysterious is happening to prices. For example, a 12-pack of diet Coke can go from $4.99 down to $2.50, and then back up to $4.99 the week after. Bounty paper towels at $2.89 go down to $1.19, then back up to $2.89, and Smuckers grape jelly, normally $2.49, can be on sale for 98 cents. These are very dramatic price changes. In most cases no coupons are required, and the flyers document a temporary sale price. Consider the Smuckers jelly. What is mysterious about this sale is that the manufacturing costs didn't change, the set of jelly manufacturers didn't change, there was no grape shortage or glut, and the demand didn't change. But the price changed a lot. It's puzzling. Maybe it's not on the quantum-theory scale of puzzling, but it probably has more important effects on the pocketbooks of most Americans than the quantum theory does. So why does the price fluctuate? The answer turns out to be very simple: *It has to*. There are no stable prices once the products of different grocery stores are advertised on the same day. Let me explain.

Two types of people shop in grocery stores. One type, whom I'll call loyal customers, go to one store and don't shop around. They may or may not buy a product, depending on its price, but they are not shopping around. The other type shops in different stores for bargains. I'll call these customers "shoppers." A grocery store that's a penny cheaper than its rivals picks up most of the shoppers. So if an item is priced at 98 cents, a rival store will either want to price the item at 97 cents to pick up those shoppers, or it will not even try to compete for the shoppers and just charge its loyal customers $2.50. One thing a rival store won't do is match the price; it'll either want a much higher price, or it'll undercut slightly. In the kind of world that has shoppers and loyal customers, a store's prices mustn't be predictable, because rival stores can exploit predictability. Companies must randomize their sale prices, and the products they put on sale, to stop them being predicted by their rivals.

The only thing that's stable is the statistical distribution of prices, which economists call an equilibrium price dispersion. Conceptually, an equilibrium price dispersion is analogous to how children play the game Rock, Paper, Scissors. In



Loyal customers—those who don't shop around for the best buys—are affected by competition among grocery firms in a much less favorable way than shoppers who look for bargains. As more and more firms compete for the bargain hunters, prices come down (red curve). But lower prices reduce profits, so stores begin to opt out of the price war and rely on recouping lost income from their loyal customers—by charging them more (blue curve).

When stores compete for an ever-increasing proportion of bargain-hunting shoppers as opposed to loyal customers, prices for bargain hunters drop (red curve). For loyal customers, however, prices stay much higher (blue curve) until the last loyal customer becomes a shopper. Then prices plunge to the same level as the shoppers pay.

this game, two children choose one of three items simultaneously, and if each chooses the same item, the game is a tie. If they choose different items, paper beats rock, rock beats scissors, and scissors beat paper. The only stable play of this game is an even split among the three items, because any other play can be exploited by rivals. In an episode of *The Simpsons* in which Lisa and Bart played this game, Lisa guessed that Bart would always play rock, which could smash things, so she played paper and won every time. Unpredictable sales have an effect similar to random play in Rock, Paper, Scissors. The distributional strategy of sales prevents rivals from exploiting the store's pattern of pricing and leads them to also choose randomized prices. Another aspect of equilibrium price dispersion is that the profits are always the same, no matter what prices are charged in any particular week.

There are no stable prices once the products of different grocery stores are advertised on the same day.

What's the effect of competition in a market with both loyal customers and shoppers? The graph on the facing page shows that when more and more stores compete for customers, it gets progressively harder for any one of them to win the competition for the shoppers, even with substantial price cutting, so as the number of stores grows, most of them stop competing for shoppers except on rare occasions. This means that loyal customers get soaked most of the time, because they're more likely to be shopping in a store that didn't bother to try to win the shoppers in that particular week. Shoppers, on the other hand, continue to do better than the loyal customers because there are still a lot of stores competing for their business. So competition is good for shoppers, and bad for loyal customers. If you're a loyal customer, you really want to do away with all the competitors to your store except one. You want one rival to remain, because if your store had the monopoly, it could charge whatever price it wanted.

The effect of shoppers on other buyers is shown by the graph above. As the proportion of shoppers increases, competing for them becomes more attractive to the grocery stores, and prices fall for both types of customers, but in different ways. Prices for shoppers fall smoothly down to the competitive level, which is reached when everybody is a shopper. Prices for loyal customers stay high until the last loyal customer is gone. Another way of putting this observation is that if most people are shoppers, a single loyal customer does a huge amount of damage to any other loyal customer. Loyal customers damage shoppers as well, but they harm their own kind much more.

Grocery-shopping models predict that prices are unpredictable and should vary from week to week, often by as much as 50 percent. Items on sale should be things price-sensitive customers care about, but price-insensitive customers don't—which is why you don't often see expensive olives on these sales flyers, but see milk, paper towels, and whole chickens instead. There's also a negative correlation of price over time: If prices are low one week, shoppers stock up, so the next week there are fewer shoppers buying, leading to higher average prices. When the shoppers' inventories run down, they're back in the market again, leading to more competition among the firms for the shoppers, and an increased likelihood that prices will be low.

So what can we learn from the economic analysis of pricing? My best advice to consumers is to search for the best prices, both because the savings can be significant and because the search for good deals contributes to making markets more competitive. Prices for goods as disparate as airline tickets, diet Coke, and gasoline vary a great deal, both geographically and temporally, and the savings from shopping around can be significant.

It pays to shop around for gas, as some pumps can be significantly cheaper. These prices were photographed at lunchtime on August 5, at gas stations a short distance from Caltech.

Gasoline is an interesting example because prices vary significantly over short distances. Part of that difference is due to the mistaken impression that the quality varies across brands, when in fact air-quality regulation standardizes the product to the point where the tiger in that tank is merely marketing hype. Drivers who don't shop around should not complain about the price—not shopping encourages gasoline companies to use high prices.

Pricing is a central aspect of a firm's profitability, yet by and large much of American industry just uses a straight markup on the cost of producing the item. These companies also make the organizational mistake of giving the job of pricing to the marketing department. Marketing departments tend to focus on increasing demand and pay little attention to the science of pricing. Pricing should not be an afterthought of a marketing department, but involve a separate division within a company.

In summary, the economic analysis of pricing offers a variety of lessons for businesses, which may have a substantial impact on the bottom line. Companies should reward loyalty. It took the cell-phone companies a long time to understand this and only Sprint is currently getting it right. If a company is selling goods that expire or go bad, like airline seats, hotel rooms, restaurant meals, or fresh fruit, yield management can increase profits by a couple of percent. It also often pays to sell the same goods at different prices, especially by producing them in different qualities, or by deliberately damaging a portion of the output; in some cases customers will pay more simply out of ignorance. Quantity discounts, even for dissimilar items bundled together, can be an effective means of price discriminating.

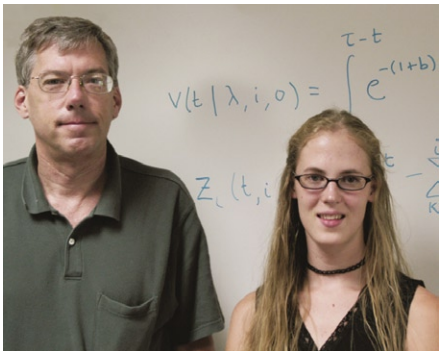
It pays, however, for the business to think about the basis for price discrimination: What causes some buyers to be price sensitive, and how can a price cut be targeted only to that group? Then pricing can be optimized for various groups, a process that has important implications for marketing channels, promotional vehicles like introductory offers, record-keeping, product design, and packaging.

I'll close with the example of a South Carolina retailer who offered an innovative twist in quantity discounts by advertising "Shoe: buy one, get one free." □

R. Preston McAfee joined Caltech in January 2004 as the J. Stanley Johnson Professor of Business Economics and Management. A recognized expert in industrial organization and auctions, he has advised the U.S. government on matters such as collusion, price-fixing, electricity pricing, bidding, procurement, and sales of government property. He was the codesigner of an auction for the FCC to sell off radio frequencies for digital cell phones and pagers, which netted the federal government $17 billion, and has since advised on similar auctions in Mexico, Canada, and New Zealand. As an expert witness for the Federal Trade Commission and the Antitrust Division of the Department of Justice, he analyzed the mergers of Exxon and Mobil, BP and ARCO, and Oracle and PeopleSoft.

McAfee holds a BA in economics ('76) from the University of Florida, plus master's degrees in both mathematics and economics ('78) and a PhD in economics ('80) from Purdue. He taught at the University of Western Ontario from 1981 until 1990, then moved to the University of Texas at Austin to become the Baker Professor of Political Economy and then, in 1997, the Murray S. Johnson Professor of Economics. He first taught at Caltech as a visiting professor from 1988 until 1990, and has also taught at MIT and the University of Chicago.

This article is based on a talk given on the 68th Annual Seminar Day in May, arranged by the Caltech Alumni Association. If you would like to learn more, check out McAfee's book, Competitive Solutions: The Strategist's Toolkit, *and his* Introduction to Economic Analysis, *an open-source text available to all at http://www.introecon.com.*



Above: Preston McAfee has been working with Vera te Velde, a junior majoring in math and economics, to study pricing in industries such as the airlines. This is Vera's second Summer Undergraduate Research Fellowship (SURF) with Preston. Last summer, her data-mining program collected over 12 million different data points.

PICTURE CREDITS: 34-35, 39-42 – Doug Cummings