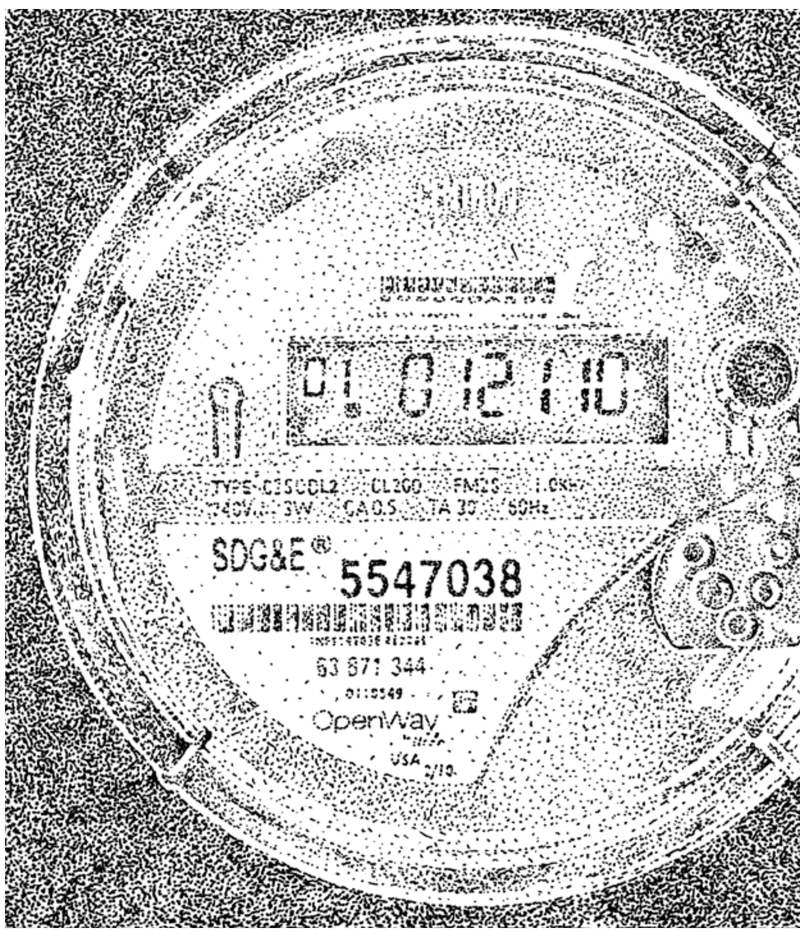
ENERGY

Dynamic Pricing and Its Discontents

Empirical data show dynamic pricing of electricity would benefit consumers, including the poor.

By **AHMAD FARUQUI and JENNIFER PALMER** | *The Brattle Group*



Dynamic pricing is the charging of different electricity rates at different times of the day and year to reflect the time-varying cost of supplying electricity. Since electricity cannot be stored and has to be consumed instantly on demand, and since demand fluctuates based on lifestyle and weather conditions, the electric system typically has to keep spare "peaking" generation capacity online for times when demand may surge on short notice. Often, these "peaking" power plants are only run for 100–200 hours a year, adding to the average cost of providing electricity.

Dynamic pricing incentivizes electricity consumers to lower their usage during peak times, especially during the top 100 "critical" hours of the year, which can account for anywhere from 8 to 18 percent of annual peak demand. Lowering peak demand in those hours means avoiding capacity and energy costs associated with the installation and running of combustion turbines in the long run and lowering wholesale market prices in the short run.

Dynamic pricing can take many forms. The most sophisticated form is the nearly instantaneous, hour-ahead pricing design, often called real-time pricing (RTP). The simplest form is the time-of-use (TOU) pricing design in which the time periods and prices are often fixed at least a year in advance. In between these extremes lies critical peak pricing (CPP), in which the prices during the top 60 to 100 hours are known ahead of time, but the actual times in which they are in effect are identified on a day-ahead (and sometimes day-of) basis, depending on

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the demand–supply balance. A variant of CPP is peak time rebates (PTR), in which the standard rate applies at all hours but customers can earn a rebate by reducing usage during the critical peak hours. In another variant, the price during the critical peak hours is based on real-time conditions, yielding variable peak pricing (VPP).

Each of the dynamic pricing options represents a different combination of risks and rewards for the customer. RTP offers consumers potentially the highest reward compared to traditional flat-rate pricing, but also the highest risk. TOU offers consumers the least potential reward at the lowest risk. Depending on their risk preferences, a pricing regime could be established in which consumers could self-select into the appropriate rate design, thereby maximizing economic welfare. The set of pricing options can be plotted out in the risk-reward space, yielding the pricing possibilities frontier, as shown in Figure 1. Consumer preferences, represented by the indifferences, would be maximized at the points of tangency shown in the figure.

FIGURE 1

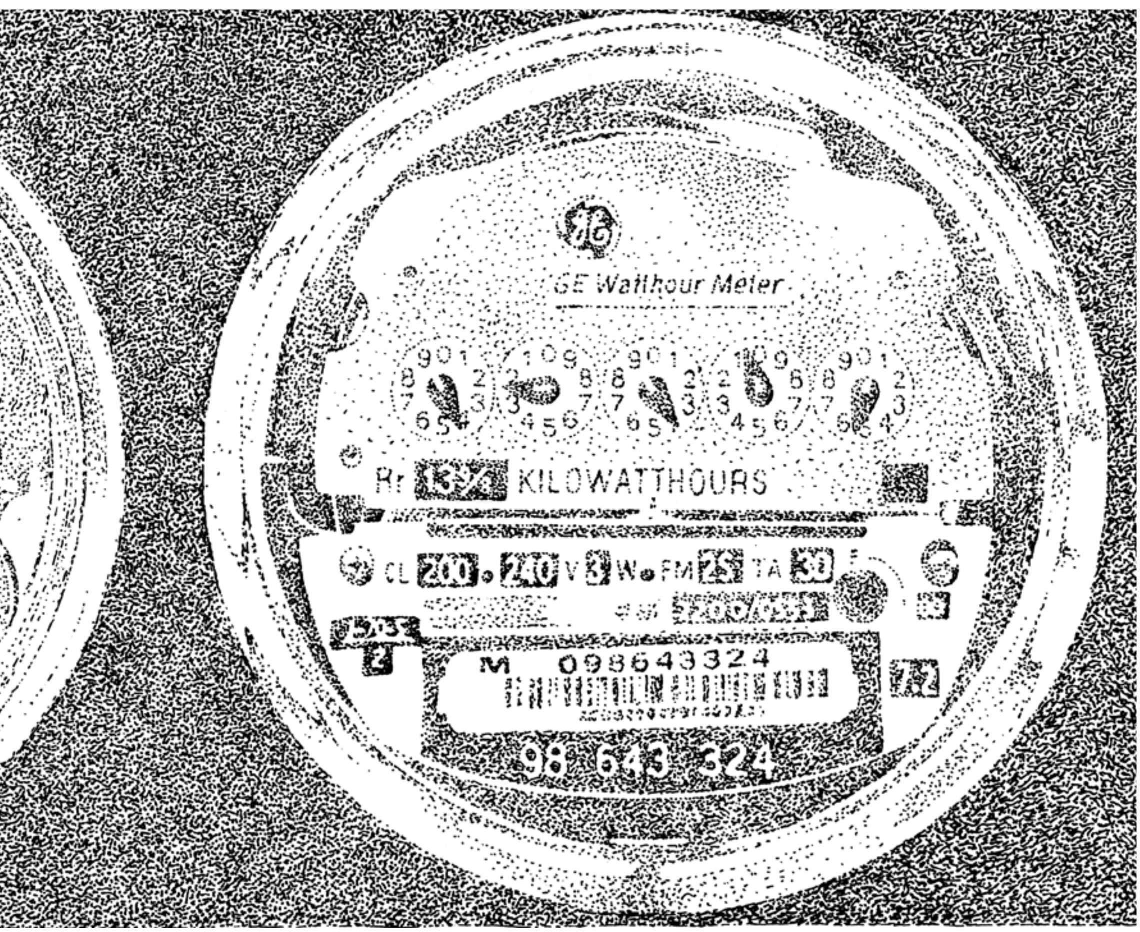
Pricing Possibilities Frontier with Indifference Curves

Just about all dynamic pricing designs require the use of "smart" meters that measure usage when different rates are in place. Until fairly recently, the lack of smart meters for residential customers posed a technical barrier to the deployment of these rate designs. As of 2009, less than 9 percent of customers had smart meters. A rapid deployment of smart meters is now underway, propelled by the need to update an aging and increasingly unreliable electricity infrastructure and assisted by nearly $5 billion in federal stimulus money for smart grid grants. By 2015, according to the Institute of Electric Efficiency, about half of the nation's 125 million residential customers will have smart meters. The institute anticipates that by 2020, nearly all customers will be on smart meters. Thus, a major technical barrier to dynamic pricing should be lifted in the next five to 10 years.

While there is wide support for dynamic pricing among academics and consultants, lingering doubts remain about its efficacy among utilities and the state commissions that regulate them. Routinely, in regulatory hearings, critics, most notably consumer advocates, contend that residential customers do not respond to dynamic pricing, that dynamic pricing will hurt low-income customers who spend a lot of time at home, and that customers simply do not want to be placed on rates that fluctuate with market conditions.

In the acrimonious atmosphere within which such hearings are often held, a negative mythology has taken root. This negativism has prevented dynamic pricing from germinating. Only four of 1,755 respondents to a 2009 Federal Energy Regulatory Commission survey of utilities indicated they had non-experimental dynamic pricing programs (excluding TOU) in place for residential customers. Traditional TOU pricing was more widespread, but even that rate design had only garnered a million residential customers, or less than 1 percent of the national population.

In this article, we assess the seven most pervasive myths about residential dynamic pric-



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ing. We do this by accessing an international database of dynamic rate experiments, *D-Rex*, that has been compiled by The Brattle Group. *D-Rex* contains empirical data on customer response drawn from 109 tests that have been carried out during the past decade across North America, Europe, and Australia.

Myth #1: Customers don't respond to dynamic pricing.

The first myth is that customers do not change their behavior when faced with dynamic rates. However, almost all analyses of pilot results show that customers do respond to dynamic pricing rates by lowering peak usage. Indeed, in 24 different pilots involving a total of 109 different tests of time-varying rates — covering many different locations, time periods, and rate designs — customers have reduced peak load on dynamic rates relative to flat rates, with a median peak reduction (or demand response) of 12 percent. Almost 30 tests produced results in the range of 10–15 percent, and many more exhibited larger responses. Figure 2 depicts the distribution of the results. In other words, the demand for electricity does respond to price, just like the demand for other products and services that consumers buy. The contention that electricity is a necessity with a zero price elasticity, and thus not subject to the normal rules by which a market economy functions, is not supported by the facts.

Myth #2: Customer response does not vary with dynamic pricing.

Not only do customers respond, but the magnitude of their response varies with the price incentive. The higher the incentive, the greater their demand response. Multiple studies have observed — and estimated — the price elasticities of the pilot participants. Baltimore Gas and Electric's pilot results revealed substitution elasticity between peak and off-peak hours of –0.096 and –0.120 in the years 2008 and 2009, respectively. Connecticut Light and Power's 2009 pilot showed substitution elasticities of –0.080 for CPP rates and –0.052 for PTR rates. Customers placed on the CPP rate in the California Statewide Pricing Pilot exhibited a substitution elasticity of –0.076, and Michigan customers in a Consumers Energy pilot showed –0.107 as their substitution elasticity. In each case, for a given elasticity of substitution, the demand response tended to increase with a higher peak to off-peak ratio, but at a decreasing rate.

Figure 3 plots the observed demand response against the peak to off-peak price ratio. It is based on results from the seven best-designed pilots (which featured the use of randomized control and treatment groups and measurements both before and after the initiation of treatments) and includes a total of 33 tests. When a linear-logarithmic curve is fit to the observations, it yields a coefficient of 0.073 with a t-statistic of 7.048. The peak to off-peak price ratio successfully explains 60 percent of the variation in demand response. The remaining variation is likely explained by factors such as weather, central air conditioning saturation and consumer attitudes, the specifics of the rate design (number of pricing periods and their timing and duration), and the manner in which the rates were marketed.

Myth #3: Enabling technologies don't boost demand response.

During the past few years, a variety of new technologies have been introduced to help customers understand their usage patterns (through web portals and in-home displays, for example), to automatically control the function of their major end-uses such as central air conditioning and space heating equipment (smart thermostats), and to manage all their other appliances and plug-loads (home energy management systems). The critics contend that such hardware is unnecessary and not cost-effective. The empirical evidence shows otherwise.

For example, Baltimore Gas and Electric, through its Smart Energy Plan pilot, tested a variety of dynamic pricing rates with and without enabling technologies in the years 2008 and 2009. The technologies included an "energy orb" that changed color

FIGURE 2

Distribution of 109 Pilot Results

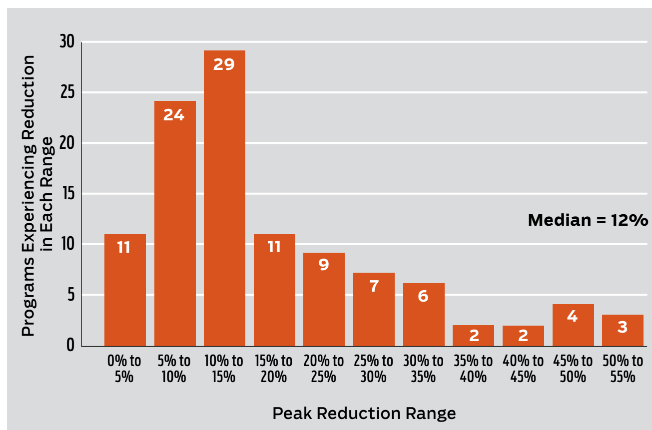
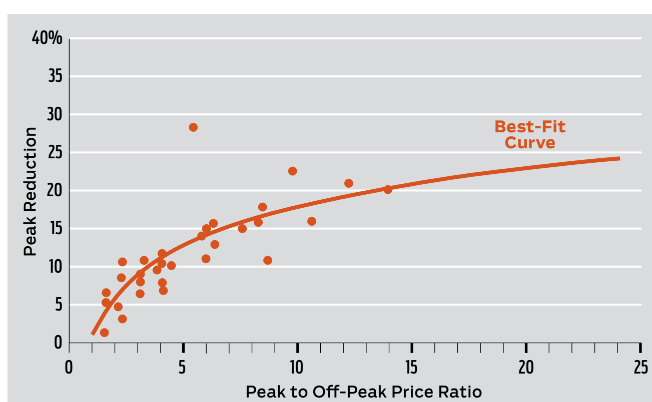


FIGURE 3

Pilot Results by Peak to Off-Peak Price Ratio

Price-only results



depending on the price of electricity and a switch for cycling central air conditioners when rates reached a specific high. It found that the peak impact with the energy orb was greater than the peak impact with price alone, and that the peak impact with the price and energy orb and the air conditioner switch was even greater. For example, in 2008, the peak reduction with the high ratio of the PTR was estimated to be 21.0 percent. Adding the energy orb led to a peak reduction of 26.8 percent, and adding enabling technology on top of that led to a peak reduction of 33.0 percent.

Similarly, Connecticut Light and Power's Plan-It Wise Energy Program, conducted in the summer of 2009, tested multiple rates with the following technologies: smart thermostats, air conditioning switches, energy orbs, and in-home displays (IHDs). While the energy orbs and IHDs were not found to have a statistically significant incremental effect above peak time pricing (PTP), PTR, and TOU rates, the presence of an air conditioning switch or thermostat increased the impacts for the PTP and PTR groups. For example, for residential customers on the "high" versions of the rates, the air conditioning switch and smart thermostat increased peak reduction to 17.8 percent from 10.9 percent for PTR customers, and to 23.3 percent from 16.1 percent for the PTP customers. Similar relationships were observed among small commercial and industrial customers.

These results are consistent with pilot results from outside the United States. In Ontario, Hydro One customers reduced load by an average of 3.7 percent during the summer months when placed on a TOU rate. Customers who were also given real-time in-home displays reduced peak load by an average of 5.5 percent in the summer months. The conservation impact also increased when IHDs were provided, increasing from 3.3 percent to 8.5 percent. While that conservation result is atypical, the marginal impact of the enabling technology is not. Over half (63 percent) of pilot participants surveyed afterward stated that they found the real-time IHDs useful for conserving energy.

Recall from the discussion of Myth 2 that peak impact and the peak to off-peak price ratio were found to be positively correlated across a series of 33 tests. Those results were obtained in the absence of enabling technology. We also have a total of 26 test results in which enabling technology was offered in conjunction with dynamic pricing in the best-designed pilots. When we plot the demand response values observed in these tests against the price ratio, we find that the curve has a steeper slope than the result with price-only tests. This is shown in Figure 4. The coefficient of the enabling technology curve is 0.120, which has a t-statistic of 5.187. The regression successfully explains 51 percent of the variation in demand response.

Looking across all 39 pilot results with enabling technologies, the median peak reduction is 23 percent, 9 percentage points higher than the median across all 109 results. This is depicted in Figure 5.

FIGURE 4

Pilot Results by Peak to Off-Peak Price Ratio

Results with enabling technology

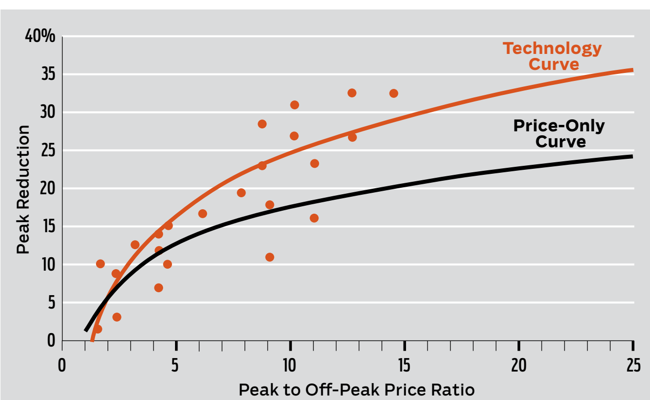
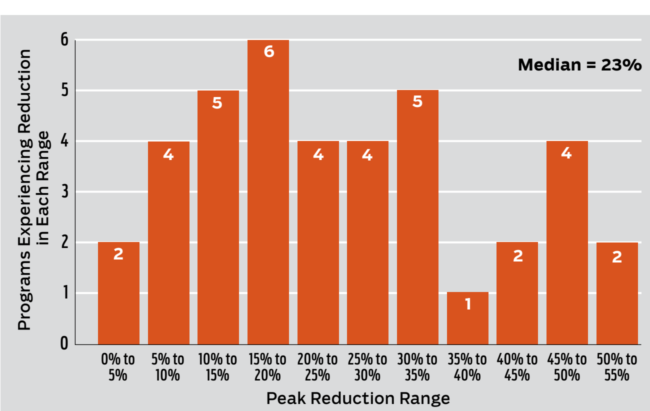


FIGURE 5

Distribution of 39 Pilot Results

Only results with enabling technology



Myth #4: Customer response does not persist over time.

Some critics accept the above evidence on customer response, but argue that responses will not last across multiple days, such as those that might be encountered during a heat wave. They also argue that customer response is a novelty that may not last across years.

Persistence in demand response across multiple years has been demonstrated in pilots in California and Maryland. California's Statewide Pricing Pilot was conducted from July 2003 through December 2004 by California's three investor-owned utilities. The pilot tested three time-varying rates: one TOU rate and two CPP rates (CPP-F with a fixed critical peak period, and CPP-V with a variable-length peak period). Because the pilot ran across two summers, comparing the results of the first and second summer sheds some light on the persistence of the impacts. Persistence was seen with the CPP-F results, which had an average peak-period energy use reduction of 13.1 percent. The difference between the two summers was not statistically significant, meaning customers in the second summer reduced consumption by roughly the same amount as customers in the first summer.

In the Baltimore Gas and Electric example discussed earlier, about 1,000 customers participated in the pilot across two summers. In order to test persistence, the PTR rate was tested during both summers on the same set of customers. Econometric analysis reveals that customers actually became more price-responsive in the second summer. Given the same temperature conditions, the substitution elasticity for rate-only participants was estimated to be –0.096 in 2008 and –0.153 in the summer of 2009. That translates into peak reductions between 18 and 33 percent. Participants who also had an orb with or without enabling technology also showed stronger results in the second summer. Not only did customers maintain their price-responsiveness, they increased it, suggesting that customers may actually learn to reduce their load more over multiple years on a dynamic rate.

Even in full-scale rollouts, significant peak reduction impacts appear to persist over time. In May 2008, a few years after the Statewide Pricing Pilot, Pacific Gas and Electric began to offer the critical peak pricing program SmartRate to residential customers as part of a full-scale rollout, exceeding 10,000 customers by the end of that year. By the end of summer 2010, 24,500 customers were enrolled. Analysis showed the average peak reduction impact to be 15.0 percent in 2009 and 14.1 percent in 2010.

Myth #5: Dynamic pricing will hurt low-income customers.

Even when people agree that dynamic pricing works and is beneficial overall, there is disagreement about the impact of dynamic pricing on low-income customers. Some people speculate that because low-income customers typically use less power, they have little discretion in their power usage and are thus unable to shift load depending on price. As a result, low-income customers would be hurt by dynamic pricing.

However, empirical evaluation of this speculation has indicated that most low-income customers would immediately save money on their electricity bills from dynamic pricing. In general, when customers are placed on a revenue-neutral dynamic rate, we expect roughly half of the customers to immediately see bill increases and half to see bill decreases. Customers who use more load in the peak hours than the average customer would see higher bills, while customers who use less load in the peak hours than the average customer would see lower bills.

Using a representative sample of residential and residential low-income customers from a large urban utility, we simulated the electricity bills on both groups of customers on flat, CPP, and PTR rates. As expected, roughly half of the residential customers had higher bills on the dynamic rates, and half had lower bills. Because the low-income customers tend to have flatter load shapes, roughly 65 percent of the low-income customers were immediately better off on the CPP rate than on the flat rate. In other words, even without any change in electricity usage, more than half of low-income customers are better off on a dynamic rate. The PTR rate has no impact on customers who do not shift their load, but after load response, 100 percent of customers would be better off. The results for the CPP rate are shown in Figure 6.

Furthermore, results from several studies show that low-income customers do reduce peak load in response to dynamic rates. Our review of 10 programs reveals that low-income customers are responsive to dynamic rates, that many such customers can benefit even without shifting load, and that their degree of responsiveness relative to that of average customers varies across the studies reviewed. Some studies found that low-income customers were equally price-responsive as higher-income customers (as in the California Light and Power, Baltimore Gas and Electric, and Consumers Energy programs); others found they were less responsive compared to higher-income customers. Figure 7 shows how the low-income customers responded relative to the average customer in each of the 10 pilots.

Myth #6: Customers have never encountered dynamic pricing.

Another objection is the simple assertion that consumers do not experience such pricing in other markets. This is clearly false; consumers experience dynamic pricing in a wide variety of everyday purchases. In his classic book on revenue management that was published in the late 1990s, Robert Cross highlighted the trend toward setting prices dynamically to maximize profit. During airline deregulation in the 1970s, Cross first used revenue management to dynamically set airline tickets so that his clients, the newly deregulated airlines, could compete in the competitive market. Today, dynamic prices are used consistently by airlines, hotels, rental car firms, and rail-

FIGURE 6

Responsiveness of Low-Income Customers Relative to Average-Income Customers

Critical peak pricing design

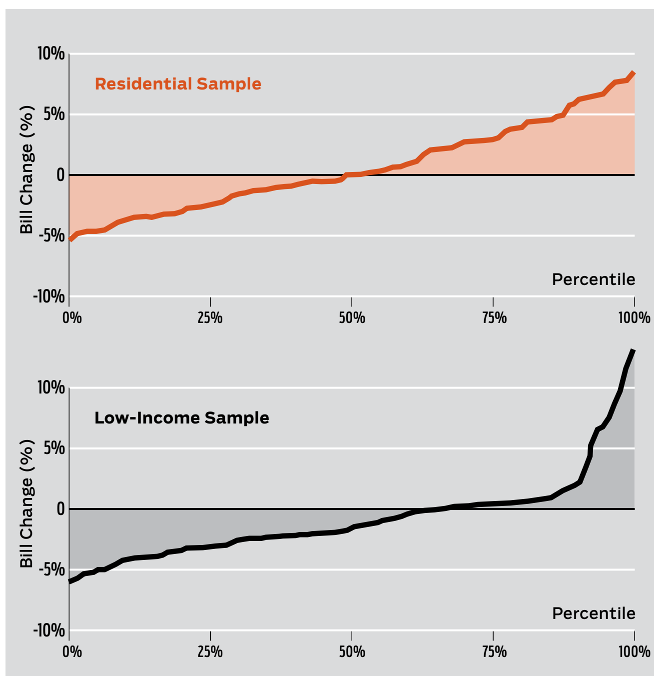
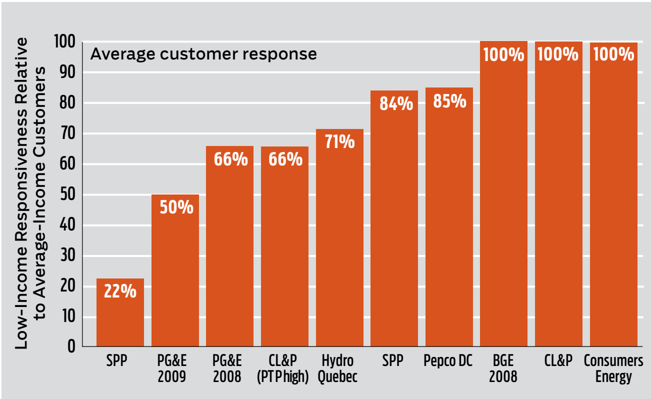


FIGURE 7

Low-Income Response Relative to Average



roads. Consumers understand that they will have to pay more when demand is higher; for example, plane tickets cost more on Friday nights and hotel room rates are higher on Friday and Saturday nights. At the same time, price-sensitive consumers can plan trips around low-priced times and save significant amounts of money.

Dynamic pricing is spreading to a huge number of capital-intensive industries, including broadcasting, manufactures, and cruise lines. Even professional sports are moving toward dynamic pricing. Since 2009, tickets for San Francisco Giants baseball games have varied according to the value of the game. According to the Giants' website, "market pricing applies to all tickets.... [R] ates can fluctuate based on factors affecting supply and demand." While sunny weekend games against big rivals cost more than the average game, fans benefit from cheaper prices during other games. Ticket prices fluctuate according to an algorithm that takes into account the interest in the opponent, weather conditions, and other factors. After the Giants introduced dynamic pricing in 2009, the Minnesota Twins and St. Louis Cardinals followed suit, and more teams are considering the new option. Concert tickets work the same way: Ticketmaster recently introduced a new technology to allow artists to change the ticket price based on demand observed during the initial sales.

Consumers are used to paying different amounts during different times of the day in a variety of settings. In large cities, drivers pay more for parking when there is higher demand, such as during the day or during special events. New parking meters have the technology to charge drivers different amounts depending on the time of day. Similarly, toll charges on major bridges such as the Oakland–San Francisco Bay Bridge increase during commuting hours and drivers who can wait to drive across the bridge during off-peak hours will save money. Customers even know that they will pay more for using their cell phone minutes during weekdays rather than nights and weekends.

In each of these settings, higher prices during some times are balanced out by lower prices during other times, giving consumers the opportunity to save money by altering their behavior. Customers are used to this and benefit from it, and for the most part want it — which leads us to the final myth.

Myth #7: Customers don't want dynamic pricing.

Some critics assume that customers are simply happy with the status quo and have no desire to switch to dynamic pricing. Naturally, there is some inertia that makes customers reluctant to actively desire to switch pricing plans. However, among customers who have experienced dynamic pricing in pilots, customer satisfaction is strong.

In Connecticut Light and Power's Plan-it Wise pilot, post-pilot surveys and focus groups were carried out to examine how customers felt about their participation in the pilot. Residential customers who participated in the survey had an overall satisfaction rating of 5.1 out of a possible 6, with 92 percent saying they would participate again. Commercial and industrial customers had an average satisfaction rating of 4.1 out of 6, with 73.5 percent indicating they would participate again. The focus groups revealed that what they liked most about the program was that it saved them money.

Consumers Energy's 2010 Dynamic Pricing Pilot, carried out in Lower Michigan, tested a CPP rate and a PTR. The utility surveyed participants to determine satisfaction with the program. The survey found that 78 percent of customers were extremely satisfied or somewhat satisfied with the program, and that 92 percent were likely to participate in the same program again.

Baltimore Gas and Electric's surveys among customers in its Smart Energy Pricing pilot found that 92 percent of the customers in 2008, 93 percent of the customers in 2009, and 93 percent again in 2010 reported that they were satisfied with the program. Furthermore, 98 percent, 99 percent, and 97 percent, respectively, were interested in returning to a similar pricing structure the following year.

When the California Statewide Pricing Pilot ended two years after its initiation in 2003, participants were offered an opportunity to continue with some form of dynamic pricing rate or return to the standard tariff. Of the customers who were on the CPP rate, 78 percent chose a time-differentiated rate (either CPP or TOU).

Related to the myth that customers do not want dynamic pricing is the idea that customers will have to resort to extreme measures to save money on dynamic rates, such as getting up at 2 a.m. to do the laundry. Unless a rate were designed such that the peak period was in effect during all waking hours, customers have no need to change their sleeping schedules to save money. In a recent survey of customers who participated in the Hydro One TOU pilot, 72 percent of customers wanted to remain on the TOU rates, and only 4 percent found the changes in their daily activities to be inconvenient.

Conclusion

At the national level, an assessment carried out for FERC two years ago showed that the universal application of dynamic pricing in the United States had the potential for quintupling the share of U.S. peak demand that could be lowered through demand response, from 4 percent to 20 percent. Another assessment quantified the value of demand response and showed that even a 5 percent reduction in U.S. peak demand could lower energy costs $3 billion a year.

However, progress on dynamic pricing is stalled due to the negative mythology discussed above. This is true even in California. In the aftermath of the energy crisis in California 10 years ago, a group of economists issued a manifesto calling for the institution of dynamic pricing among other reforms. While California's dynamic pricing experiment concluded in 2004 and meter deployment is rapidly underway, large-scale deployment of dynamic pricing has still to take place. Hot weather and rapid economic growth can precipitate another crisis. Sure, the state has expanded its portfolio of incentive-based reliability-focused programs and rolled out dynamic pricing to large commercial and industrial customers. But by excluding its residential customers from dynamic pricing, it has left a large share of peak demand exposed to higher costs.

Across the Pacific, Japan lies engulfed in a severe power shortage as a result of last March's tsunami that has forced people to drastically rotate their work schedules, often switching weekends with weekdays in an effort to lower peak demand by 20 percent. As noted recently in the *Wall Street Journal,*

> To prevent blackouts [during the summer], the government is legally mandating that Tokyo Electric Power Co.'s large customers, such as factories, cut their usage by 15% from 9 a.m. to 8 p.m. on weekdays. It's asking others, including households, to do the same. Similar steps are being asked of Tohoku Electric Power users. Together, the two utilities supply an area accounting for nearly half of the country's economic output.

An early estimate of value of lost production due to the power crisis has come in at a staggering $60 billion. If a regimen of smart metering and smart prices had been in place, the demand–supply balance would have been restored at much less economic cost.

California and Japan are not the only places where the move to dynamic pricing is stalled. This seems to be a global problem, ranging from the state of Victoria in Australia, which had begun rolling out smart meters with TOU pricing and then ran into opposition from low-income advocates, to the countries of the European Union where smart meters are being rolled out with no dynamic pricing. Just about all the hesitation can be traced to one or more of the seven myths discussed in this paper.

Of course, the myths are just that. Customers do respond to dynamic pricing and the response varies depending on the intensity of the price signal. The response persists over time and improves when enabling technologies are added. Dynamic pricing does not hurt low-income customers; on the contrary, many low-income customers would benefit from dynamic pricing. When appropriately informed, consumers see the value of dynamic pricing.

With the national deployment of smart meters, a major barrier to the mass deployment of dynamic prices has been lifted. As District of Columbia Public Service Commissioner Rick Morgan asked in a widely cited article two years ago, what is the point in having smart meters with dumb rates?

Postscript

Winston Churchill famously averred, "The future, while imminent, is obscure." While several misperceptions have to be dispelled in the regulatory arena before dynamic pricing will be deployed on a large scale, we wish to note that three recent signs have emerged that create some grounds for optimism.

First, at its recent summer meetings, the National Association of Regulatory Commissioners passed a resolution on smart grid investments that calls on state commissions to "consider whether to encourage or require the use of tools and innovations that can help consumers understand their energy usage, empower them to make informed choices, and encourage consumers to shift their usage as appropriate. These tools may include dynamic rate structures, energy usage information and comparisons, in-home devices and web-based portals." Even the inclusion of the words "dynamic rates" would have been unthinkable just a few years ago.

Second, two state public service commissions — in the District of Columbia and Maryland — have approved in principle the full-scale rollout of peak-time rebates to all residential customers. And, third, a survey of more than 100 senior utility executives carried out in the United States and Canada by the consulting firm CapGemini in conjunction with the energy information firm Platts found that dynamic pricing was one of the top five issues on the minds of the respondents as they pondered the future.

Even if there is burgeoning agreement on the end-state, doubts remain about how to make the transition from flat rates to dynamic-pricing rates. One way is to begin informing the public about the benefits of dynamic pricing and to then start rolling out smart prices with smart meters, but under the umbrella of full-bill protection in the first year, i.e., customers would pay the lower of the flat-rate bill and the dynamic pricing bill. The bill protection would then be phased out over a three- to five-year period. R

READINGS

- "Dynamic Pricing of Electricity in the Mid-Atlantic Region: Econometric Results from the Baltimore Gas and Electric Company Experiment," by Ahmad Faruqui and Sanem Sergici. *Journal of Regulatory Economics*, August 2011.
- "Impact Evaluation of CL&P's Plan-it Wise Energy Program," by Ahmad Faruqui and Sanem Sergici. The Brattle Group, November 2, 2009.
- "Overview of Demand Response in the United States," by Dean Wight. *Metering International*, Vol. 2 (2011).
- "Power Measurements," by Lisa Wood and Ahmad Faruqui. *Public Utilities Fortnightly*, Vol. 148, No. 11 (November 2010).
- "Quantifying Customer Response to Dynamic Pricing," by Ahmad Faruqui and Stephen George. *Electricity Journal*, Vol. 18, No. 4 (May 2005).
- "Real Mass Market Customers React to Real Time-Differentiated Rates: What Choices Do They Make and Why?" by Dean Schultz and David Lineweber. 16th National Energy Services Conference (San Diego), February 2006.
- "Rethinking 'Dumb' Rates," by Rick Morgan. *Public Utilities Fortnightly*, March 2009.
- *Revenue Management: Hard-Core Tactics for Market Domination*, by Robert Cross. Crown Business, 1997.
- "The Impact of Dynamic Pricing on Low Income Customers," by Ahmad Faruqui, Sanem Sergici, and Jennifer Palmer. Institute for Electric Efficiency whitepaper, September 2010.
- "The Power of 5 Percent," by Ahmad Faruqui, Ryan Hledik, Sam Newell, and Johannes Pfeifenberger. *Electricity Journal*, Vol. 20, No. 8 (October 2007).