The Brattle Group

Dynamic Pricing of Electricity and its Discontents

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The free market has often enough been condemned as a snare and a delusion, but if indeed prices have failed to perform their function in the context of modern industrial society, it may be not because the free market will not work, but because it has not been effectively tried.[ii]

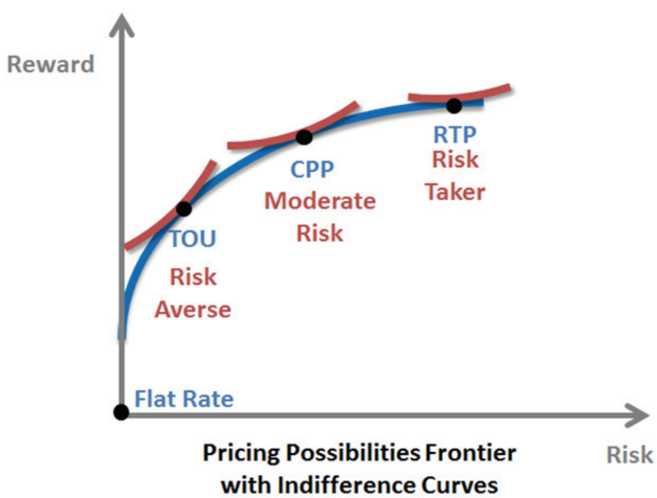
INTRODUCTION

Dynamic pricing incentivizes electricity customers to lower their usage during peak times, especially during the top 100 "critical" hours of the year which may account for between eight and eighteen 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 encompasses many different pricing options from nearly instantaneous, hour-ahead pricing designs (often called real-time pricing or RTP) to simple time-of-use (TOU) pricing designs in which the time periods and prices are often fixed at least a year in advance. In between lies critical peak pricing (CPP), in which the prices during the top 60 to 100 hours are known ahead of time but the time in which they will be called is only known on a day-ahead (and sometimes day-of) basis. A variant on CPP is called critical peak rebates (CPR), in which the standard rate applies but customers can earn a rebate by reducing usage during the critical peak hours. In yet 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, with RTP rates offering potentially the highest reward compared to a flat rate but also the highest risk. Conversely, a TOU rate offers the least potential reward at the lowest risk. Depending on their risk preferences, customers can 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.

Figure 1



Until fairly recently, the lack of smart meters for residential customers posed a technical barrier to the deployment of these rate designs because almost all dynamic pricing designs require the use of smart meters. As of 2009, less than nine percent of customers had smart meters.[iii] A rapid deployment of smart meters is now underway, pulled by the need to update an aging and increasingly unreliable infrastructure and pushed by the federal stimulus of nearly five billion dollars in smart grid grants. According to the Institute of Electric Efficiency, by 2015 approximately half of the nation's 125 million residential customers will have smart meters and by 2020, nearly all customers will be on smart meters.[iv] Thus, a major technical barrier to dynamic pricing should be lifted in the next five to ten 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. In regulatory hearings, critics routinely 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.[v]

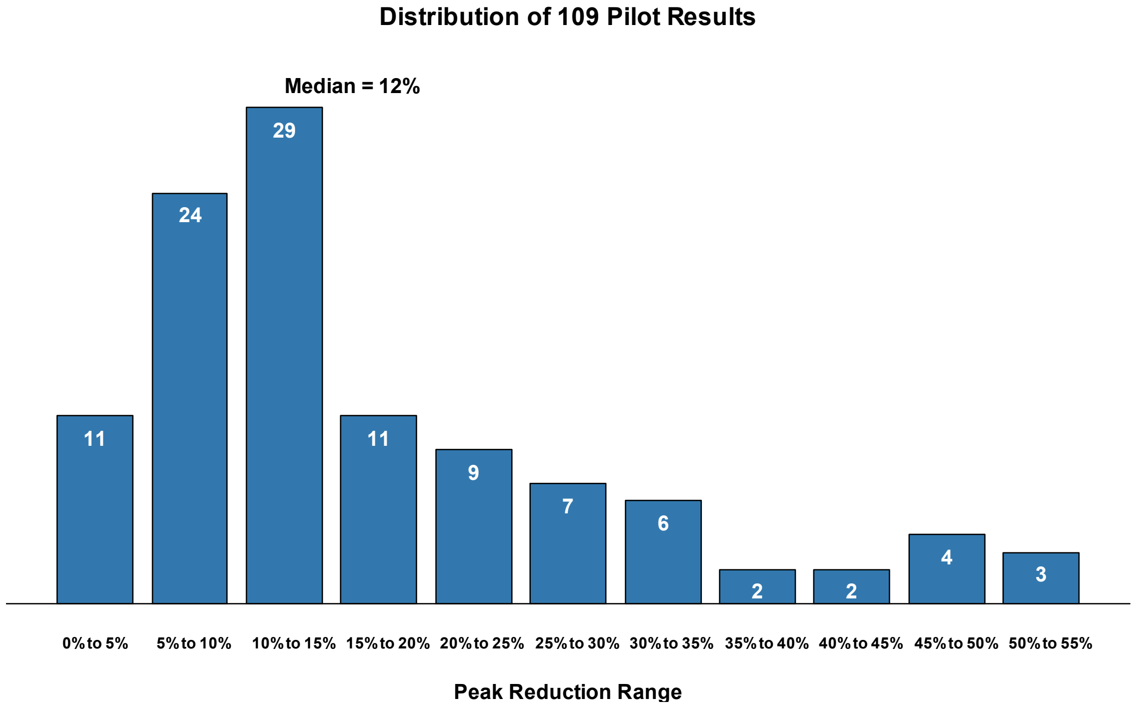
In the acrimonious atmosphere within which such hearings are often held, a negative mythology has taken root. This negativism has prevented dynamic pricing from germinating. Only 4 of 1,755 respondents to a 2010 survey commissioned by the Federal Energy Regulatory Commission (FERC) indicated they had non-experimental dynamic pricing programs in place for residential customers.[vi] Traditional TOU pricing was more widespread, but even that rate design had only garnered a million residential customers, or less than one percent of the national population.

In this article, we assess the top seven myths about residential dynamic pricing by accessing an international database of dynamic rate experiments that has been compiled by *The Brattle Group*, *D-Rex*, which 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 DO NOT 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 (Figure 2.)[vii] Almost thirty results fell in the range of 10 to15 percent, and many more exhibited larger responses. In other words, the demand for electricity does respond to price, just like the demand for other products and services that customers buy. The contention that electricity is a necessity with zero price elasticity, and thus is not subject to the normal rules by which a market economy functions, is based on opinion and not fact.

Figure 2

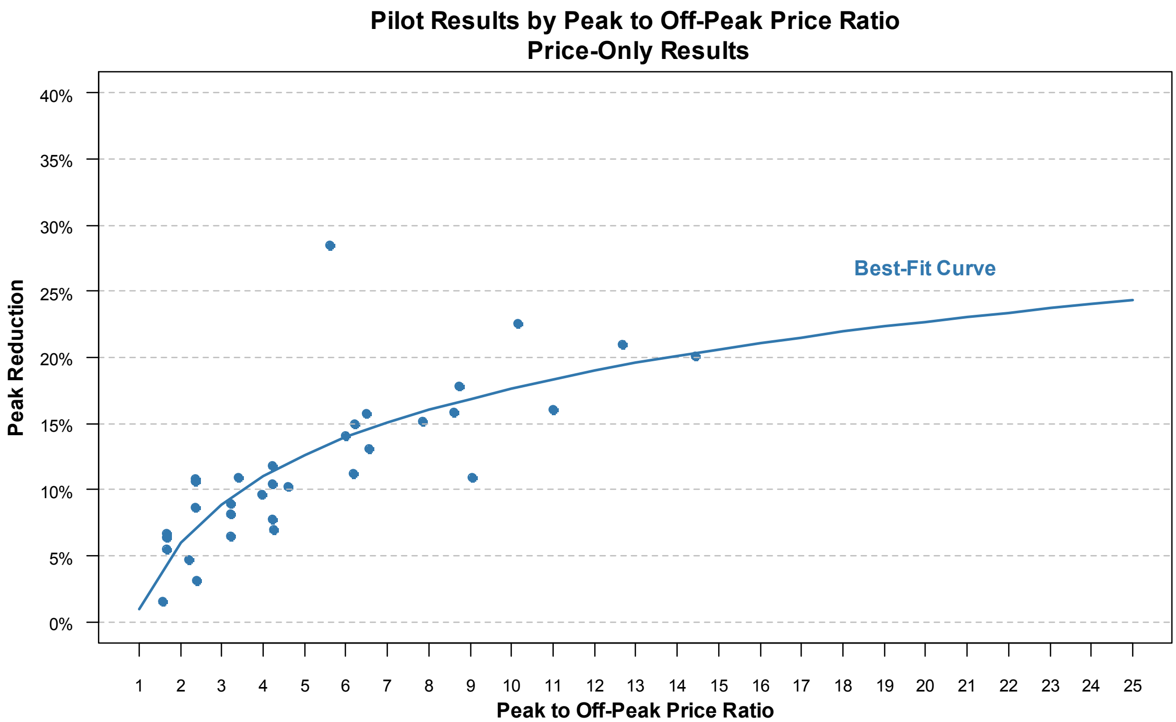


MYTH #2: CUSTOMER RESPONSE DOES NOT VARY WITH DYNAMIC PRICING

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 (BGE) pilot results revealed substitution elasticity between peak and off-peak hours of -0.096 and -0.120 in 2008 and 2009, respectively.[viii] Connecticut Light & Power's (CLP) 2009 pilot showed substitution elasticities of -0.080 for the CPP rates and -0.052 for the peak time rebate (PTR) rates.[ix] Customers placed on the CPP rate in the California Statewide Pricing Program (SPP) pilot exhibited a substitution elasticity of -0.076, and customers in the Consumers Energy pilot showed -0.107 as their substitution elasticity.[x] 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, 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. The curve is not a simulation of expected results from a particular peak-to-off-peak ratio; rather, it is the best-fit curve of actual pilot results.

Figure 3



MYTH #3: ENABLING TECHNOLOGIES DO NOT BOOST DEMAND RESPONSE

During the past few years, a variety of new technologies have been introduced to help customers understand their usage patterns (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). Critics contend that such hardware is unnecessary and not cost-effective. Once again, this is contrary to empirical evidence.

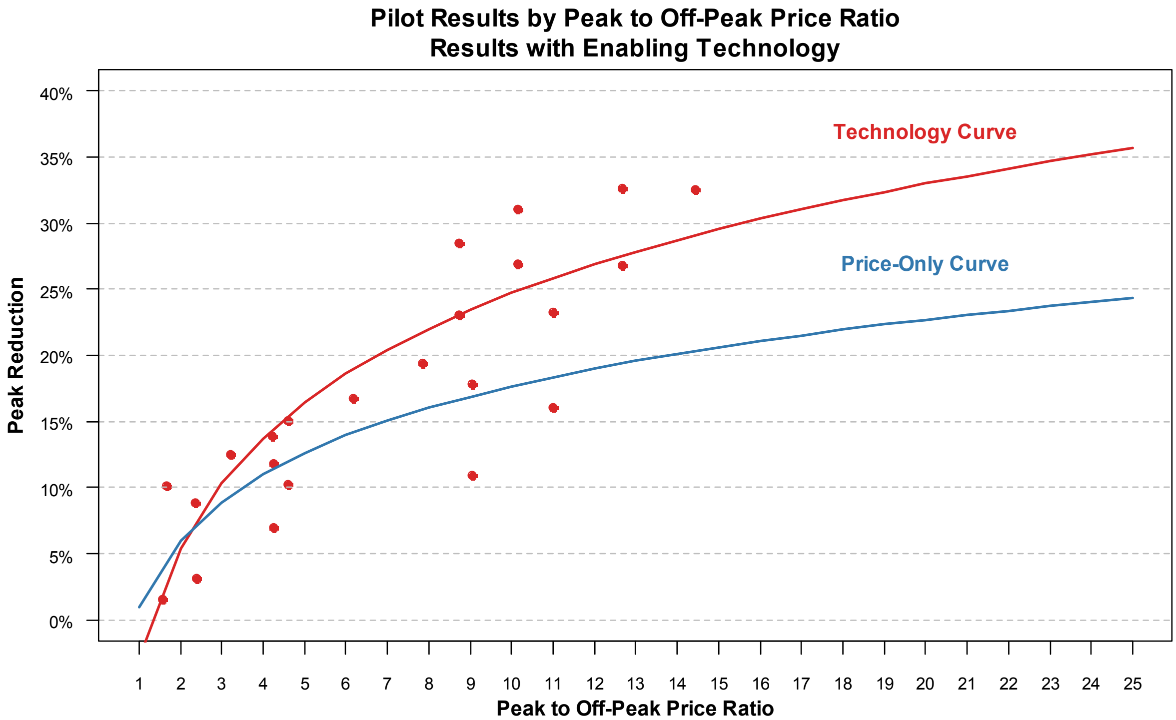
For example, BGE, through its Smart Energy Plan (SEP) pilot, tested a variety of dynamic pricing rates with and without enabling technologies in 2008 and 2009. The technologies included an "energy orb" that changed color depending on the price, as well as a switch for cycling central air conditioners. 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, energy orb, and the air conditioner switch combined, was even greater. For example, in 2008, the peak reduction with the high ratio of the PTR was estimated to be 21 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 percent.[xi]

Similarly, CLP's Plan-It Wise Energy Program, conducted in the summer of 2009, tested multiple rates with the following technologies: smart thermostats, air conditioner (A/C) 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 the peak time pricing (PTP), PTR, and TOU rates, the presence of an A/C 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 A/C 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.[xii]

These results are consistent with pilot results outside the United States. In Ontario, Canada, 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 was also affected when IHDs were provided, increasing from 3.3 to 8.5 percent. While that magnitude of conservation result is atypical, the marginal impact of the enabling technology is not. Over half (63 percent) of pilot participants surveyed afterwards stated that they found the real time in home display monitors useful for conserving energy.[xiii]

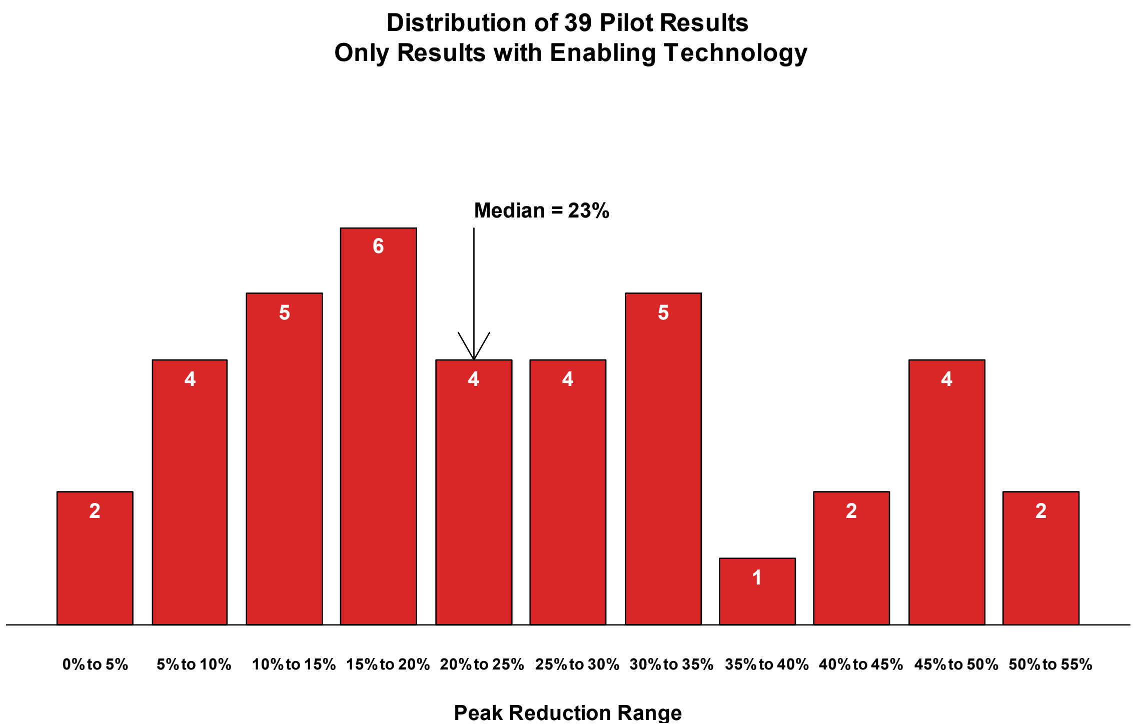
Recall from Myth 2 that the peak impact and the peak to off-peak price ratio were found to be positively correlated across a series of 33 tests. These results were obtained in the absence of an enabling technology. We also have a total of 26 test results with enabling technology that was offered in conjunction 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 (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.

Figure 4



Looking across all 39 pilot results with enabling technologies, the median peak reduction is 23 percent, nine percentage points higher than the median across all 109 results (Figure 5.)

Figure 5



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 the demand pattern that might be experienced during a heat wave. They also argue that customer response is something that may not last across multiple years.

Persistence in demand response across multiple years has been demonstrated in pilots in California and Maryland. California's SPP 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 – one with a fixed critical peak period (CPP-F) and one with a variable length peak period (CPP-V). 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 roughly the same as customers in the first summer.[xiv]

In the Baltimore Gas and Electric example discussed earlier, which was carried out in Maryland, about one thousand 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 become *more* price responsive in the second summer.[xv] 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 used an energy orb, with or without an enabling technology, also showed stronger results in the second summer. Not only did customers maintain their price responsiveness, they increased it, suggesting that these customers actually learned 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 California's SPP, Pacific Gas & Electric (PG&E) began to offer a critical peak pricing program called *SmartRate* to residential customers as part of a full-scale rollout. By the end of 2008 more than 10,000 customers were enrolled in the program and 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.[xvi]

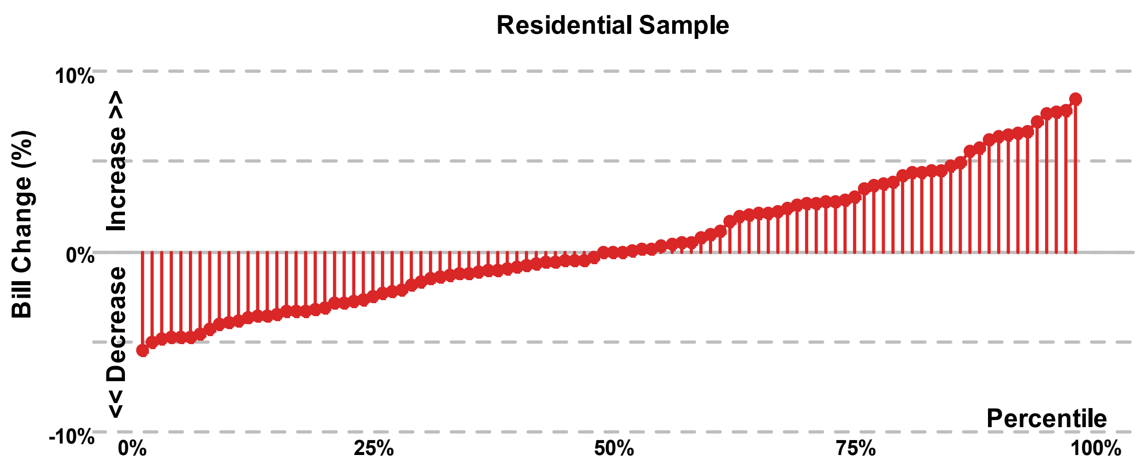
MYTH #5: DYNAMIC PRICING WILL HURT LOW-INCOME CUSTOMERS

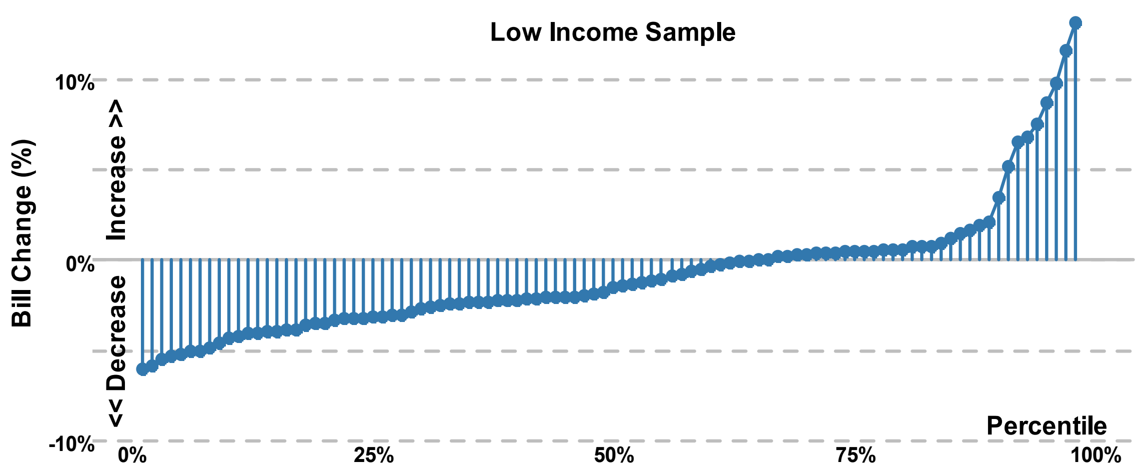
Even when people agree that dynamic pricing works and is beneficial overall, there is disagreement about the impact of dynamic pricing on low-income customers. Some people speculate that because low-income customers typically use less power, they have little discretion in their power usage and are thus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

However, empirical evaluation of this speculation has indicated that most low-income customers would immediately save money on their electricity bills from dynamic pricing.[xvii] 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 immediately 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 both average income residential and low-income residential customers from a large urban utility, we simulated the electricity bills for 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 benefit from 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.

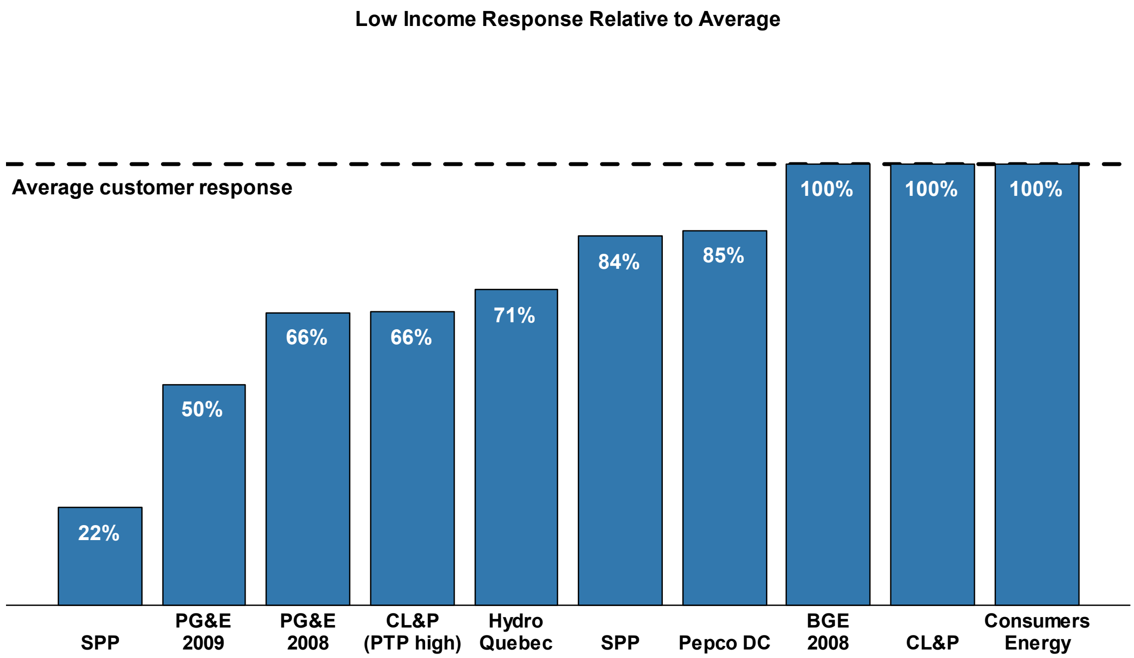
Figure 6





Furthermore, results from nine studies show that low-income customers do reduce peak load in response to dynamic rates.[xviii] Our review of these ten 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 CL&P, BGE, 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 ten pilots.

Figure 7



MYTH #6: CUSTOMERS HAVE NEVER ENCOUNTERED DYNAMIC PRICING

Customers experience dynamic pricing in a wide variety of everyday purchases. In his classic book on revenue management that was published in the late nineties, Robert Cross highlighted the trend toward setting prices dynamically to maximize profit.[xix] 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 companies, and railroads. Customers 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, customers also understand the benefit: price-sensitive customers 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, manufacturing, and cruise lines. Even professional sports are moving towards 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… rates 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 a number of factors including the interest in the opponents and weather conditions. After the Giants introduced dynamic pricing in 2009, the Minnesota Twins and St. Louis Cardinals followed suit, and more teams are considering this 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.[xx]

Consumers are used to paying different amounts during different times of 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 adjust to charge different amounts depending on the time of day. Similarly, toll charges on major bridges increase during commuting hours, and drivers who can wait to drive across the bridge during off-peak hours will save money. Customers even acknowledge 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 next myth.

MYTH #7: CUSTOMERS DO NOT 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 CL&P's 2009 Plan-It-Wise pilot, carried out in Connecticut, post-pilot surveys and focus groups were carried out to determine 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 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.[xxi]

Consumers Energy's 2010 Dynamic Pricing Pilot, carried out in Lower Michigan, tested a critical peak pricing rate and a critical peak rebate. 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.[xxii]

BGE's surveys among customers in the Smart Energy Pricing pilot found that 92 percent of the customers in 2008, 93 percent of the customers in both 2009 and 2010 reported that they were satisfied with the program. Furthermore, 98 percent, 99 percent, and 97 percent in the three years, respectively, were overwhelmingly interested in returning to a similar pricing structure the following year.[xxiii]

When the California SPP pilot ended two years after its initiation in 2003, participants were offered the 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).[xxiv]

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 in the morning to run the laundry. Unless a rate were designed such that the peak period was 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 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 the FERC two years ago showed that the universal application of dynamic pricing in the U.S. had the potential for quintupling the share of U.S. peak demand that could be lowered through demand response, from four percent to twenty percent.[xxv] Another assessment quantified the value of demand response and showed that even a five percent reduction in U.S. peak demand could lower energy costs $3 billion a year.[xxvi]

However, progress on dynamic pricing is stalled due to the negative mythology discussed in this article. In the aftermath of the energy crisis in California ten 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 yet to take place. Hot weather and rapid economic growth can surely precipitate another crisis. It is true that the state has expanded its portfolio of incentive-based reliability-focused programs and rolled out dynamic pricing to large commercial and industrial customers. However, 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 that has forced people to drastically rotate their work schedules, often switching weekends with weekdays in an effort to lower peak demands 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.*[xxvii]

An early estimate of the value of lost production due to the power crisis in Japan is a staggering $60 billion.[xxviii] 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. Almost all the hesitation can be traced to one or more of the seven myths discussed in this article.

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, customers 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 Commissioner Rick Morgan of the District of Columbia asked in a widely cited article two years ago, there is no longer any reason for deploying dumb rates with smart meters?[xxix]

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 which 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."[xxx] Even the inclusion of the words "dynamic rates" would have been unthinkable just a few years ago.

Second, two state commissions, one in the District of Columbia and one in 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 U.S. and Canada by the consulting firm Cap-Gemini, in conjunction with Platts, found that dynamic pricing was one of the top five issues on the minds of the respondents as they pondered the future.[xxxi]

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 possible way is to begin informing the public about the benefits of dynamic pricing and then start rolling out smart prices with smart meters but under the umbrella of full bill protection in the first year. That is, 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.

ENDNOTES

[i] The authors, Ahmad Faruqui and Jenny Palmer, are a Principal and a Research Analyst, respectively, with *The Brattle Group*. We have benefited from numerous discussions with our colleagues Lamine Akaba, Ryan Hledik, Doug Mitarotonda, and Sanem Sergici. However, the views expressed in this paper are entirely those of the authors and not necessarily those of *The Brattle Group*.

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[iv] Institute for Electric Efficiency, "Utility Scale Smart Meter Deployments, Plans, & Proposals," September, 2010. www.edisonfoundation.net/IEE

[v] Consumer advocates often agree that demand response should be pursued but contend that the best solution is not dynamic pricing, because it is "punitive." Instead, they argue for pursuing traditional programs such as direct load control of central air conditioners which incentivize customers through monthly rebates. For an exposition, see the viewpoint of Mark Toney, executive director of TURN. http://www.vimeo.com/20206833.

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