Simon Miller
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Policy Brief: Dynamic Pricing of Electricity

Introduction

Traditional electricity pricing charges the same rate for consumption of electricity throughout the day. Some consider this troublesome, as the actual cost of electricity generation varies over time. As a result, some consumers overpay for their consumption of electricity, while other consumers see their consumption subsidized by the former consumers.

The marginal cost of electricity is mostly changed by changing the mix of generating capacity used. There are three sources of electricity used to meet demand: the baseload capacity, which has high construction costs and low marginal costs, the intermediate capacity, which has moderate construction costs and marginal costs, and peaking capacity, which has low construction costs, but faces high marginal costs of power generation. Efforts are focused on balancing supply and demand given a community's available capacity throughout the day, so costs depend on how these sources are used.

If demand were constant, it could be met with simply base capacity, very efficiently. However, demand changes throughout the day, and electricity is expensive to store, so the optimal generation mix changes as well. This changing demand on the power grid is the second source of changing marginal costs. During off-peak hours, such as late at night when few people are using electricity, demand can be met with simple base capacity, resulting in low marginal costs. However, during peak periods, such as just after 5 pm when consumers return home from their day jobs, the generation mix changes, and energy marketers must use peaking capacity to meet demand efficiently. At this point, marginal costs increase. Demand may also shift seasonally, as moderate temperatures result in fewer people using air conditioning, while more extreme temperatures cause people to utilize heat and air conditioning. Hence, more electricity is demanded all at once. Putting different levels of strain on the infrastructure at different times will result in different marginal costs of power generation.

If demand were smoothed out, so it was closer to constant throughout the day, electricity could be provided at a relatively low marginal cost for all consumers. Improving the efficiency with which energy is provided is a major goal of the *dynamic pricing* of electricity, which is the idea that the price consumers are charged for electricity consumption should vary throughout the day to reflect the actual marginal cost of electricity generation. There are several mechanisms that could be used to implement the dynamic pricing of electricity.

This paper aims to compare the merits of each of these pricing schemas, as well the potential risks they introduce, and considers their implementation instead of the popular uniform pricing system in place, in which consumers are charged the same rate for electricity consumption at all times. Since the utility sectors are heavily regulated, this is inherently a policy question, which requires the consideration of economic impacts at both the household level and beyond. Allowing for the deregulation of electricity markets is an inherently risky endeavor due to potential abuse of market power by energy providers and threats to the stability of electricity supply, however possible efficiency gains could offset these risks.

Overview

In "Dynamic Pricing of Electricity," Joskow and Wolfram provide an introduction to the issues associated with uniform pricing schemes and consider incentives of and barriers to adopting a dynamic pricing system in the United States. They begin with a discussion of the time-varying nature of the marginal cost of electricity, as well as the changes to the optimal electricity generation mix overtime, both of which were discussed above. Without dynamic pricing, the authors note that consumption and infrastructure investment decisions are distorted, and electricity is generated by the available infrastructure in a suboptimal manner.

Joskow and Wolfram continue to discuss developments that make dynamic pricing of energy more feasible in the modern era. One major development is progress in the wholesale electricity market, which can quickly reflect changes to the marginal cost of electricity throughout the day. This can deliver consumers and electricity providers with greater information, allowing for more informed consumption decisions and accurate cost estimation. Additionally, the advent of smart meters could send real-time consumption information to electricity providers, again increasing the accuracy of cost estimates of serving consumers, while technological advances also empower the consumer to manage consumption in real-time. Consumers leveraging access to this lower level data could result in better decision making during peak periods, reducing the strain on the grid when prices reflect higher costs. Lastly, there is support for adopting smart metering technology at federal and state levels of government, which could result in replacing deteriorating infrastructure with improved technology. It is also notable that switching generation sources to renewable becomes easier when demand is less peaky as well.

Joskow and Wolfram next address current barriers to the adoption of dynamic pricing schemas. One point of focus was consumers' lack of understanding under a more complex pricing system. They address this risk by stating that consumers opting into studies demonstrate an understanding of dynamic pricing and respond to price incentives appropriately, but warn that selection bias could be a confounding factor when attempting to extend results to the general population. They also discuss that in most simulations, the most informed and price-sensitive consumers experience most of the welfare gains. Policymakers are wary about the adoption of dynamic pricing schemas due to the potential to disproportionately impact low-income households, so the authors advise conducting more research to understand how different types of consumers would be impacted. There are technologies that empower the consumer to make better choices, but it is ultimately the responsibility of the consumer to adopt this technology and respond to price incentives if they hope to avoid paying high prices.

In "A Primer on Electricity and the Economics of Deregulation," Griffin and Puller dedicate some discussion to risks of price volatility and abuse of market power if the deregulation necessary for dynamic pricing were allowed. While some level of price volatility is to be expected when electricity providers are responding to price incentives during peak demand periods. Price volatility increases given the limited stock of generation capacity, as well as some inelastic short-run demand. Short-run demand may become more elastic under a dynamic pricing schema, as the incentive to move pricing out of peak periods is introduced. The authors also discuss incentives to withhold supply which exist under dynamic pricing systems, ultimately causing huge price increases, though the authors discuss means of mitigating risks of this.

Griffin and Puller also consider several issues regarding deregulation. Due to the lack of understanding regarding dynamic pricing, some believe there is a need to allow for adaptations to the scope and specifics of regulation over time. This uncertainty could stymie investment in infrastructure, as the irreversible nature of investment may make investors unwilling to take risks. Previous investors made investment decisions under a different set of conditions, and adopting new rules could be unfair. Utilities may not be open to deregulation if they are unable to recover some costs of these investments. Also, consumers must support the changes, and while they would likely benefit from efficiency gains, they would likely not realize many benefits until the long run. The U.S. balance of power between federal and state governments could also complicate the process of deregulation necessary for dynamic pricing.

Specific Pricing Implementations

When considering the optimal policy decision regarding electricity pricing, there are several implementations that could be evaluated and compared to the standard uniform pricing, which charges the same price throughout the day, regardless of the marginal cost of electricity generation. A common dynamic pricing scheme discussed is real-time pricing (RTP). With this method of pricing, prices are set for hour-long intervals, with prices published the day before, to allow consumers to be aware of prices they should expect to pay, due to expected strain on the power grid. Another system of dynamic pricing focuses on critical-peaks, either offering rebates to consumers for reducing their electricity consumption during critical peaks or increasing prices during these critical peaks. These techniques are referred to as critical peak pricing (CPP). Finally, there is time-of-use (TOU) pricing, which frequently deconstructs the day into 3 periods- off-peak, interim, and peak sections of the day- and charges different prices during each of these periods. While TOU is not technically dynamic pricing, because rates are predetermined and static, it deserves a place in the conversation surrounding dynamic pricing because it is based on similar principles, intending to achieve similar results.

Note there are other implementations of dynamic pricing, but we limit our discussion to the pricing systems above. As a framework, our discussion introduces a pricing system then examines an empirical study of that system.

Under RTP, utilities can charge prices at a very granular level. This allows for an accurate reflection of marginal costs and enables consumers to adjust their demand schedules efficiently. Simply shifting an activity's time by a few hours could provide consumers substantial savings. This type of pricing system could be too difficult for consumers to adopt due to the complexity of considering over 700 prices in a given month.

Alcott estimates a residential consumer demand function under RTP in "Rethinking real-time electricity pricing" using Energy-Smart Pricing Plan data, produced by a pilot program running out of Chicago. As a result of RTP, the author found households were price elastic and identified a reduction in consumption during peak periods, without increased consumption during other periods. Alcott also found that making monitoring of prices easier increases a household's price elasticity. The author found consumers' costs were reduced by $13 per year under RTP and that RTP has the potential to reduce carbon emissions if the generation mix does not move towards more carbon-intensive sources of electricity. Notably, advanced meters are estimated to cost around $150, so the incentive for consumers to switch to a smart meter is not very strong. However, there are opportunities for utilities to reduce the cost of a smart meter for the consumer because the utility could reduce meter monitoring costs and stands to grow more efficient under RTP.

Some argue that CPR and CPP offer benefits similar to RTP but through simpler means. By defining critical peaks before they occur, consumers are given a greater opportunity to modify their consumption decisions. Some implementations of CPP do not define critical peaks before they occur, which result in welfare losses for consumers as it becomes more difficult to respond to price signals. The opportunity to receive rebates under CPR may be particularly enticing for consumers, which could result in increased openness to switching pricing schemes.

In "Residential Customer Response to Real-Time Pricing: The Anaheim Critical-Peak Pricing Experiment," Wolak examines the effects of CPP with rebates on the demand of residential consumers. An experiment was designed to efficiently parse out the treatment effects of being placed on a CPP system. While demand was reduced by customers under CPP, Wolak found that reductions would have occurred without the rebates. This presents issues in efficiently setting rebate rates and reference consumption levels to ensure that customers and providers can both benefit from this system. Wolak also explores how different portions of consumers enrolled in a CPP plan could influence market prices and reduction in peak load, with higher enrollment rates resulting in greater benefits for all. However, this number does not need to be extremely high to be impactful. Also, bid caps for electricity retailers impact the strength of financial incentives to utilize CPP, so regulation aiming for less volatile energy may prevent the benefits the system offers. Since Wolak hypothesizes that bid caps will not increase in the future, the true benefits of CPP could go unrealized.

Under TOU pricing, prices are set over longer intervals, more consistently than RTP. While there is still an incentive to reduce peak load due to high prices, the simpler design of TOU pricing may be more friendly to consumers. Even if it is not the ideal pricing system, it may be a good system to introduce consumers to principles of dynamic pricing. Offering three prices simplifies consumption decisions.

In “The effect of utility time-varying pricing and load control strategies on residential summer peak electricity use: A review,” Newsham and Bowker examine the effects of different time-varying pricing schemes on peak-load reductions. The authors conduct a literature review and find that, while CPP is more efficient at reducing peak-load, TOU pricing could result in a 5% reduction in demand during peaks. They refer to another piece of literature, which shows that this might result in a 50% reduction in electricity spot prices during peaks due to the exceptionally high marginal cost during these periods. This translates to substantial savings for U.S. consumers due to the scale of electricity demand. The authors recognize that under TOU pricing, consumers are faced with incentives to alter their behavior more frequently than with CPP, which makes it less attractive as well.

Considerations

The above discussion introduced the potential benefits of various dynamic pricing schemes and presented empirical evidence of consumer response to each of these types of systems. When evaluating each pricing scheme, we should consider the opportunities for welfare gains, how likely it is to garner consumer and producer support, and how easily it could be integrated with U.S. regulations.

While RTP offers the opportunity to price electricity most accurately, and consumers are shown to be responsive to RTP, but it is likely too complex for all consumers to understand. This alone could make the path from uniform pricing to RTP difficult. Utilities and retailers stand to benefit from this system, as the consumer’s reducing demand during peak periods could enable them to provide electricity much more efficiently in the future. Federal and state regulations could limit feasibility because capping prices would not allow retailers to send an accurate signal to consumers. Allowing for greater instability in energy prices, an uncomfortable idea, could produce efficiency gains. The public’s comfort with this could impact regulation changes.

While Wolak saw demand fall under the Anaheim CPP experiment, there was no evidence that CPP caused this decrease. Hence, CPP may not result in the peak load reduction sought from dynamic pricing. CPP may not be attractive to consumers or retailers due to the risks associated with inaccurately setting rebate rates or calculating reference consumption levels. If these are not accurately determined, one party could stand to lose more money. For example, as discussed by Wolak, it may be more expensive for utilities to meet demand under CPP, while nearly all consumers face lower prices. Conversely, consumers could consistently pay higher prices if rebate rates and reference levels are too low. However, the need to only change consumption habits during a few critical-peak events could be attractive to consumers.

Wolak's discussion of bid caps also indicates that effective integration of CPP with bid caps which the government is comfortable with could be difficult. Greater instability in energy prices could result in net benefits to all, but CPP peak prices might be too high to be considered fair.

TOU pricing could be integrated more easily than RTP and CPP because it communicates clearly what prices are with very favorable time in advance. Thus, TOU may be the most feasible pricing system in providing benefits to all parties involved. It is more modest in the complexity it presents to customers than RTP, and asks consumers to change their habits year-round instead of less frequently like CPP. For this reason, consumers may be less willing to adopt it. Utilities are likely interested in greater peak demand reductions than TOU pricing has been shown to produce, but they could still integrate lower marginal cost sources of generation under TOU pricing. Altering the specifics of price incentives could offer greater peak reductions as well. Allowing peak prices to approach their true level to send the proper signal to consumers appears to be the only barrier when considering legal barriers to TOU.

Conclusion

Given all that we have discussed, I would recommend offering and advertising TOU pricing, with hopes of introducing customers to concepts of time-varying pricing of electricity. After some level of comfort from customers and advances in our ability to offer cheaper smart metering technology, I would begin to offer RTP. A caveat of this recommendation is that federal and state regulations should allow energy prices to reach levels that more accurately send price signals to consumers; otherwise, little will change.

A system in which prices more closely reflect the cost of electricity generation stands to reduce demand during peaks. TOU pricing and RTP could both achieve this. If peak-load reductions are not great enough, a stronger price signal could be used. As result, demand would be smoother throughout the day, resulting in lower total costs of electricity generation. When smart metering technology is cheap enough for most households to adopt it, customers and utilities would then be net benefactors of the system. Additionally, the environment could benefit as more sources of renewable energy become integrated into the grid.

Requesting that customers to change their consumption timeline through load-shifting is a big ask. TOU pricing is a more moderate request than RTP in this regard, so customers are more likely to accept it. When this becomes normalized, they may be ready for RTP, either optionally or by mandate. With more advanced technology, consumers are empowered and there should be heavy investment in explaining this to all income-bands to ensure that nobody is systematically impacted. Utilities stand to gain from even moderate peak load reductions, so allowing them to deviate from uniform pricing will be much less difficult. A key issue would be determining the proper prices to offer before switching to TOU to ensure all parties reap some benefits early.

Legally, the stifling of energy prices could be negatively impacting the reliability of our energy. Under TOU pricing with fewer restrictions than those currently in place, the grid could become more reliable, with less price volatility during peaks than RTP or CPP would cause. Making the step to RTP would require greater levels of comfort with this price volatility. Due to issues regarding equitable access to power, this system may be too drastic. As a result, the more measured TOU pricing could be the solution.

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