Energy Economics 40 (2013) 1–7

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneco

A new approach to congestion pricing in electricity markets: Improving user pays pricing incentives☆

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ARTICLE INFO

Article history:
Received 11 January 2011
Received in revised form 29 August 2012
Accepted 7 June 2013
Available online 21 June 2013

JEL classification:
D40
D61
Q48

Keywords:
Electricity pricing
Time-of-use pricing
Congestion pricing

ABSTRACT

Electricity pricing has traditionally been based on average cost pricing where consumers pay a 'flat' tariff based upon the average cost of production and transportation of electricity. The introduction of new 'smart' meters allows electricity providers to differentiate tariffs on the basis of time. Utilising congestion pricing theory, the energy industry has embraced 'time-of-use' (ToU) tariffs with a view to more efficiently pricing electricity. This paper demonstrates that pricing as a function of demand variability (reflecting capacity utilisation) is a more appropriate alternative to existing ToU tariffs for more efficiently allocating costs to end users. We call this new alternative pricing model 'first derivative ratio' FDR pricing. This new approach to congestion pricing could be applied to markets other than electricity, such as road transportation.

1. Introduction

Electricity is relatively unique among goods and services as it cannot be stored economically. As it is produced, it must be consumed. Inventory management cannot be used to allow for smooth production schedules to meet variable demand. Electricity markets are also characterised by significant demand variability as a result of changes in weather. Space heating and cooling requirements can result in rapid increases in demand for small periods on the coolest and hottest days respectively. These characteristics manifest themselves in a low utilisation rate for installed capital. For example, in the Australian National Electricity Market (NEM), total capacity is currently 49,000 MW but annual output is only 205,000 MWh (ESAA (2010)). This represents an effective utilisation rate of around 47%. Very few industries with market based pricing have such low utilisation rates of installed capital.

Historically, retail electricity prices around the world have been based upon the total costs of supplying customers averaged across the total energy consumed. Where demand is not variable across time, this 'flat tariff' or 'average cost' approach appropriately allocates costs to users assuming that the cost of providing an additional unit of demand capacity is a linear function. However, this approach breaks down when demand varies according to the time of day. This is because the distribution and transmission network capital costs associated with installing peak levels of capacity ($/MW) translate into significantly higher unit energy costs (in $/MWh) as the costs are spread across a lower level of consumption. Furthermore, the cost of energy from a peaking power station (e.g. OCGT[1]) is often double that of a baseload power station (e.g. coal) (ACIL Tasman, 2009). A 'flat tariff' approach apportions these underutilised peak capacity costs to all users regardless of whether they actually contribute to the peak demand.

New forms of electricity pricing have been considered as technologies have been developed which allow for more differentiated forms of pricing. In particular, remotely read smart-metering technologies allow energy companies to determine when a user has consumed electricity and differentiate tariffs as a function of time. 'Time of use' (ToU) pricing has been widely documented as a form of congestion pricing in both electricity and transportation markets. While much of the focus in developing new forms of ToU congestion pricing has been on the time point at which congestion occurs, there has been little focus on the other time periods where large amounts of capacity

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[1] Open-cycle gas turbine.

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http://dx.doi.org/10.1016/j.eneco.2013.06.005

sit idle. The purpose of this paper is to challenge whether tariffs set as a function of time are the most appropriate way of pricing electricity and ensuring that end-users receive the most appropriate pricing signals. We propose that tariffs as a function of both time and individual demand variability (based upon a measure of first derivative rate of change) may be better suited to pricing electricity effectively.

It is timely for discussion to occur about the best way to price electricity. Historically, electricity pricing has not necessarily been a high profile public policy issue. However, many countries around the world are now grappling with much higher electricity prices as a result of two main factors: peak demand growth and lower rates of utilisation of energy infrastructure; and the move towards new sources of fuel (in particular gas and renewables). Peak demand growth is being driven by wealthier communities installing space heating and cooling devices which are used for short periods of time. The capital costs associated with installing higher levels of peak demand capacity are recovered as charges based on actual energy consumed rather than capacity. This focus on energy rather than capacity forms the basis for electricity pricing. The switch to new sources of fuel with higher costs is largely driven by government policy aimed at improving energy security and/or reducing anthropogenic greenhouse gas emissions.

In the Australian context, Simshauser et al. (2011) demonstrated that electricity prices at the household level are likely to double between FY08 and FY15. Importantly, the study concluded that price increases are likely to be driven by higher capital costs, higher fuel costs and significantly greater levels of expenditure on electricity networks as peak demand increases materially. In fact, peak demand in some jurisdictions within Australia is currently growing at double the rate of underlying energy demand resulting in a further deterioration in the capital utilisation rate (AEMO: Australian Energy Market Operator, 2009).

Section 2 of this paper outlines the current approaches to electricity pricing based upon flat tariffs, inclining/declining block tariffs and ToU pricing and proposes a set of assessment criteria by which to compare tariff structure designs. Section 3 presents a simple two-user electricity market and demonstrates that flat tariff and ToU pricing regimes do not adequately allocate costs of building capacity to end users based upon their use of electricity. The macroeconomic costs associated with ToU pricing customer cross-subsidisation are explored in Section 4. Alternative models to ToU and flat tariffs are discussed in Section 5. Specifically, new models of pricing based upon demand variability are proposed. Importantly, simple approximations of our new models of pricing could be implemented with or without smart metering technology. Section 6 contains an assessment of various tariff structures against the nominated criteria, concluding that “first derivative ratio” (FDR) pricing best meets these requirements. Section 7 outlines policy recommendations based upon our findings and provides concluding remarks.

2. Current approach to pricing and criteria for assessment

Electricity supply chains are essentially composed of three components: wholesale markets (generation of electricity); transmission and distribution (the use of poles and wires); and retailing (billing and customer service). In Australia, the National Electricity Market (NEM) provides a wholesale market for generators and retailers to sell and buy electricity. The NEM uses a uniform, first-price, energy-only gross pool auction design. Accordingly, wholesale electricity prices are effectively ToU prices. The pricing of distribution and transmission is generally based upon flat average cost tariffs regulated by the Australian Energy Regulator (AER). However, some jurisdictions use a combination of fixed (capacity) and variable (usage) charges. Energex (2010) is an example of such an approach where fixed charges are levied on capacity ($/kW/month) and variable charges are levied on energy ($/MWh). Retail tariffs are set in different ways based upon the regulatory regime of the particular jurisdiction, the technology available (i.e. smart meters) and the economic strategy of the individual retailer. The distribution and transmission component of the end retail tariff is generally a ‘pass-through’ cost which is not varied by the retailer. The wholesale component and retail margin are essentially the points of difference between individual retailer offerings to consumers.

There are generally three types of end-user pricing: average flat tariffs (including peak/off peak differentiated tariffs); inclining/declining block tariffs; and ToU pricing. These are described in greater detail below:

- Flat tariffs: Flat tariffs are based on the average cost incurred to supply a customer with generation from the wholesale market. Flat tariffs developed in electricity markets where smart metering technology did not exist and pricing as a function of time was therefore impracticable. An early form of ToU pricing based upon ‘peak’ and ‘off-peak’ consumption utilising two separate simple accumulation meters is in place in many jurisdictions. As outlined above, some flat tariffs pass-through network tariffs which have both a fixed capacity and variable usage charge.
- Inclining/declining block tariffs: An inclining block tariff system is based upon ‘blocks’ of energy (not capacity — this is an important distinction) consumption having different tariffs. For example, a consumer might pay $200/MWh for the first 7 MWh of consumption and then $300/MWh for any MWh consumed over and above 7 MWh. The purpose of these tariffs is to discourage (inclining) or encourage (declining) electricity use by utilising a form of second-degree price discrimination.
- ToU tariffs: As the name suggests, ToU pricing is based upon pricing which varies between individual time periods, whereby electricity is more expensive at peak times, and less expensive during periods of lower demand. The advent of smart metering technologies where electricity consumption can be recorded digitally every few minutes has been a necessary development for the adoption of ToU pricing.

ToU pricing has its origins in congestion pricing theory. As far back as 1920, economists such as Pigou (1920, p.194) suggested that taxation may be required to optimise transportation economics. Lindsey (2006) demonstrates that the history of congestion pricing has focused on alleviation of congestion in transport. There is an important distinction between the economic literature associated with ToU pricing in electricity and transport. While congestion is often an issue in transport (i.e. commuter travelling times at peak periods are significantly slower than average), electricity markets are characterised more by continuous building of capacity with low utilisation rates.[2]

In this context, it is worth noting that much of the discussion around the need for ToU pricing is based upon macroeconomic objectives such as lowering peak demand and thereby avoiding capital expenditure on networks which are significantly underutilised. For example, the recent studies by Faruqui et al. (2009a) and Faruqui et al. (2009b) have observed that interval meters, time-of-use tariffs, and smart appliances have achieved sustained peak load reductions of between 6% and 15% by electricity utilities in the U.S. and in Australia. However, there is little discussion in these studies in relation to alternatives to tariffs as a function of time which achieves the same objectives: pricing which reflects underutilised capital.

To analyse these existing end-user tariffs (comprised of wholesale, retail and network components aggregated together) and the new alternative forms of electricity pricing proposed in this paper, we propose the following assessment criteria for comparing the efficiency and efficacy of tariff structures:

[2] In fact, if transport markets responded to congestion in the same way as electricity, motorways or freeways would be continuously expanded with many of the new lanes utilised for only small proportions of the year.