Reliability and Competitive Electricity Markets
Supplementary material: Procurement by the ISO

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This material examines the effects of two types of behavior by an ISO that empirical analysis has suggested may distort prices and investment (Patton 2002). The first involves inefficient or "out-of-merit" dispatch of resources procured by the ISO. Such dispatch in the short run depresses off-peak prices and in the long term leads to an inefficient substitution of base load units by peakers. The second involves the recovery of the costs of resources acquired by the ISO through an uplift charge spread over prices in all demand states or else in only peak demand states. Whether the uplift is socialized (spread over demand states) or not, large ISO purchases discourage the build up of baseload capacity and depresses the peak price. For small purchases, off-peak capacity decreases under a socialized uplift, and peak capacity decreases under an uplift that applies solely to peak energy consumption.

As described by Patton, Van Schaik and Sinclair (2004, page 44) in their recent evaluation of the New England ISO's real time wholesale energy market,

> "Out-of-merit dispatching occurs in real time when energy is produced from a unit whose incremental energy bid is greater than the LMP [locational marginal price] at its location. In a very simple example, assume

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> the two resources closest to the margin are a $60 per MWh resource and a $65 per MWh resource, with a market clearing price set at $65. When a $100 per MWh resource is dispatched out-of-merit, it will be treated by the [dispatch] software as a resource with a $0 [per MWh] offer. Assuming the energy produced by the $100 resource displaces all of the energy produced by the $65 resource, the [locational marginal] price will decrease to $60 per MWh."

Accordingly, the marginal cost of the most expensive resource dispatched is greater than the market clearing price and the associated marginal value placed on incremental supplies by consumers at its location. Note as well that in this example, the ISO effectively pays two prices for energy. It pays one price for energy dispatched through the market and a second higher price for the resource dispatched out-of-merit, while treating the latter in the dispatch stack as if it had a bid (marginal cost) of zero. Out-of-merit dispatch is typically rationalized as being necessary to deal with reliability constraints or dynamic factors related to minimum run-times or ramping constraints that are not fully reflected in the "products" and associated prices available to the ISO in its organized public markets.

Uplift refers to a situation in which the ISO makes a payment to a generator in excess of the revenues the generator would receive by making sales through the ISO's organized wholesale markets. These additional payments are then recovered by the ISO by placing a surcharge on wholesale energy transactions based on some administrative cost allocation formula. The costs of out-of-merit dispatch, the costs of voltage support in the absence of a complete set of reactive power markets, out-of-market payments made by the ISO to ensure that specific generating units are available during peak demand periods, and out-of-market payments made by the ISO to certain customers to allow the ISO to curtail their demands on short notice may be recovered through uplift charges. In what follows, however, we treat the effects of out-of-merit dispatch and recovery through uplift charges separately. Different sources of uplift costs may be recovered with different allocation procedures (Patton, VanSchaick and Sinclair, page 51.)

1 Out-of-merit dispatching

In this subsection, we assume that the ISO contracts for peak production plants and dispatches them at the bottom of the merit order (at price 0), without regards to a price-cost test. Assume that there are two states: State 1 is off-peak, state 2 peak. K_1 is baseload capacity (investment cost I_1, marginal cost c_1), K_2 is peak capacity, used only during peak (investment cost $I_2 < I_1$, marginal cost $c_2 > c_1$). Consumers react to the real-time price. A fraction f_1 (resp. f_2) of periods is off peak, with demand $D_1(p)$ (resp. on peak, with demand $D_2(p) > D_1(p)$).

Competitive equilibrium (indexed by a "star"):

Free entry conditions:

$$I_1 = f_1(p_1^* - c_1) + f_2(p_2^* - c_1)$$

$$I_2 = f_2(p_2^* - c_2)$$

Supply = demand:

$$D_1(p_1^*) = K_1^*$$

$$D_2(p_2^*) = K_1^* + K_2^* = K^*$$

The competitive equilibrium is depicted in figure 1.

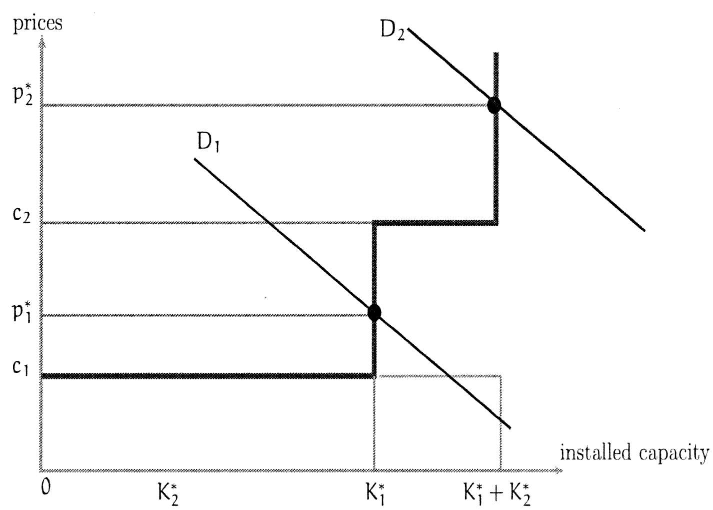

Figure 1

ISO procurement behavior

Suppose that the ISO contracts for $K_2^0 \leq K_2^*$ units of capacity and dispatches them at price 0 even off peak. This sounds strange, but more generally, as long as ISO purchases are financed externally, perverse effects arising from ISO dispatch decisions arise only if the dispatch is not economically efficient as long as $K_2^0 \leq K_2^*$. Note also that one could imagine that state 1 is an intermediate state of demand. There would then be an off-peak state 0 with frequency f_0. As long as the off-peak price p_0^* is unaffected, one can easily generalize the analysis below.

In order to clearly separate the effect studied here from that analyzed in the next subsection, assume that ISO losses (to be computed later) are financed externally (in practice, there would be injection / withdrawal taxes, that would shift the curves. Let us thus abstract from such complications).

Short-term impact. We analyze the short-term impact assuming a fixed capacity K_2^*. One may have in mind that K_2^0 of the K_2^* units of peaking capacity are purchased by the ISO. For given investments K_1^* and K_2^*, the short-term impact of the ISO policy is depicted in figure 2, which assumes $K_2^0 = K_2^*$:

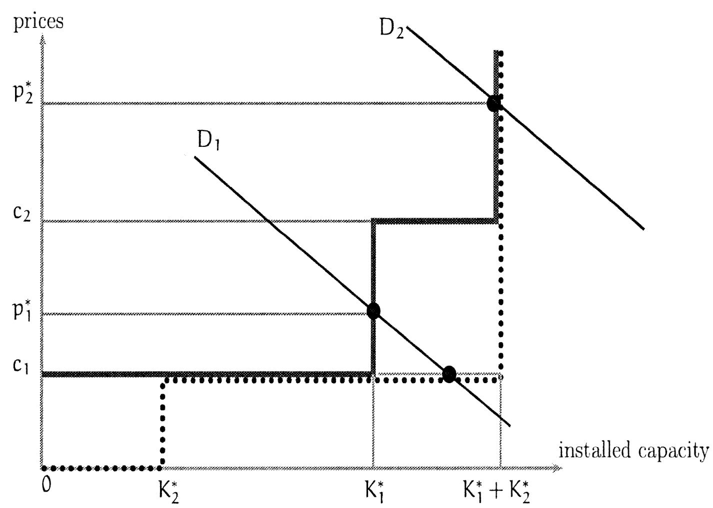

Figure 2

- the peak price remains unchanged (p_2^*),

- the off-peak price falls to $\max\left\{c_1, D_1^{-1}(K_1^* + K_2^*)\right\} = p_1^{ST}$,
- there is overproduction off-peak,
- the ISO loses

$$f_1 K_2^* \left(c_2 - p_1^{ST}\right).$$

Long-term effects. Suppose that the ISO buys a quantity $K_2^0 \leq K_2^*$ of peak-period units that it dispatches at zero price. It is easily seen that prices and capacities adjust in the following way:

- $p_2^{LT} = p_2^*$
- $p_1^{LT} = p_1^*$
- Peak units substitute partly for off-peak units (production inefficiency): $K_1^* - K_1^{LT} = K_2^0$ (or else $K_1^{LT} = 0$ if $K_2^0 \geq K_1^*$).

Proposition 1. *Suppose that ISO purchases $K_2^0 \leq K_2^*$ are financed externally (i.e., not through an uplift) and are dispatched out-of-merit.*

(i) The short-term incidence of a purchase is entirely on off-peak price and quantity: p_1 decreases, q_1 increases.

(ii) The long-term incidence of a purchase $K_2^0 \leq K_1^*$ is a substitution of off-peak units by peakers; on- and off-peak prices are unaffected.

Proof: To prove part (ii), note first that $p_2 > p_2^*$ is inconsistent with the free-entry condition. Next if $p_2 < p_2^*$, then $K = K_1 + K_2^0 > K^*$, and so if $K_2^0 \leq K_2^*$, $p_1 < p_1^*$; but then $K_1 = 0$, a contradiction. Hence $p_2 = p_2^*$. Next either $K_1 = 0$ or $K_1 > 0$. In the latter case, $p_1 = p_1^*$ by the free entry condition. To get this price, one must have $K_2^0 + K_1^{LT} = K_1^*$ (see figures 1 and 2). ■

Remark: The analysis in this section assumes that the ISO purchases no more than K_2^* units of peaking capacity and finances any revenue shortfalls externally. In this case inefficiencies come solely from inefficient dispatching. That is, there is no inefficiency as long as energy is dispatched only when the market price exceeds marginal cost. Moreover, peak period prices are unaffected even if dispatch is inefficient. However, if the ISO were to purchase more than K_2^* units of peaking capacity it could affect the peak period price even if the dispatch were efficient. Specifically if the ISO made additional purchases of peaking capacity to increase its ownership to more than K_2^* units and dispatched it efficiently only to meet peak period demand, the peak period price would fall in the short run. If it purchased a large enough quantity of additional peaking capacity and bid it into the market at its marginal cost c_2 it could drive the peak period price down to c_2. Clearly, such an ISO investment strategy would be inefficient. Moreover, such a strategy would have significant adverse long run effects on private investment incentives. Private investment in peaking capacity would be unprofitable and the incentives to invest in base load capacity would also be reduced. In the long run this would lead to a substitution of peaking capacity for base load capacity and could potentially lead to a situation where the ISO had to purchase a large fraction of the capacity required to balance supply and demand.

2 Recovery through an uplift

In practice, ISO purchases are not financed through lump-sum taxation. Rather some or all of the associated costs are often at least partially recovered through an uplift. There is no general rule on how uplifts are recovered. They can be recovered monthly (often) or annually. They are typically spread across all kWh, but they can also be allocated to groups of hours (for example peak hours). In this section, we will work with the polar case assumption that none of the associated costs of ISO purchases are recovered from market revenues, but we recognize that some of these costs may be recovered from market revenues rather than uplift charges. There are several reasons for why some of the costs of ISO purchases in practice are not fully recovered from selling the energy in the market and so an uplift is needed: existence of a price cap; absence of a locational price allowing recovery at an expensive node;

and usage of reserves outside the market place.

a) Let us analyze the implications of a (perfectly anticipated) uplift, starting with the *case in which the cost recovery is spread over peak and off-peak periods* (the cost is "socialized" through the uplift).

Suppose that the system operator purchases K_2^0 units of peaking energy forward, and dispatches the corresponding units only on peak (so that the inefficiency studied in subsection ?? does not arise). Total capacity to meet peak demand is then K_1+K_2, where

$$K_2 = K_2^0 \quad \text{if} \quad f_2(p_2 - c_2) < I_2$$

$$K_2 \geq K_2^0 \quad \text{if} \quad f_2(p_2 - c_2) = I_2.$$

The uplift t is given by

$$t\left[f_1 D_1(p_1+t) + f_2 D_2(p_2+t)\right] = K_2^0 I_2$$

Off-peak capacity, K_1, and prices are given by:

$$D_1(p_1+t) = K_1$$

$$f_1(p_1 - c_1) + f_2(p_2 - c_1) = I_1$$

$$\Longrightarrow E(p) = E(p^*).$$

Peak capacity satisfies:

$$D_2(p_2+t) = K_1 + K_2.$$

And so

$$t\left[K_1 + f_2 K_2\right] = K_2^0 I_2.$$

Figure 3 depicts the equilibrium outcome for linear demands ($D_i(p) = a_i - p$). For small purchases K_2^0, production prices (p_1, p_2) don't move with the size of procurement. This is because the private sector still offers peaking capacity beyond K_2^0 and so peak and off-peak prices must remain consistent with the free-entry conditions. Investment in off-peak capacity is negatively affected by the uplift, while total peaking capacity does not move (the latter property hinges on the linearity of demand functions and is not robust). At some point, the private sector finds it uneconomical to invest in peakers; the only available peaking capacity is then that procured by the ISO. The peak price falls and the (before tax) off-peak price grows with the size of purchases.

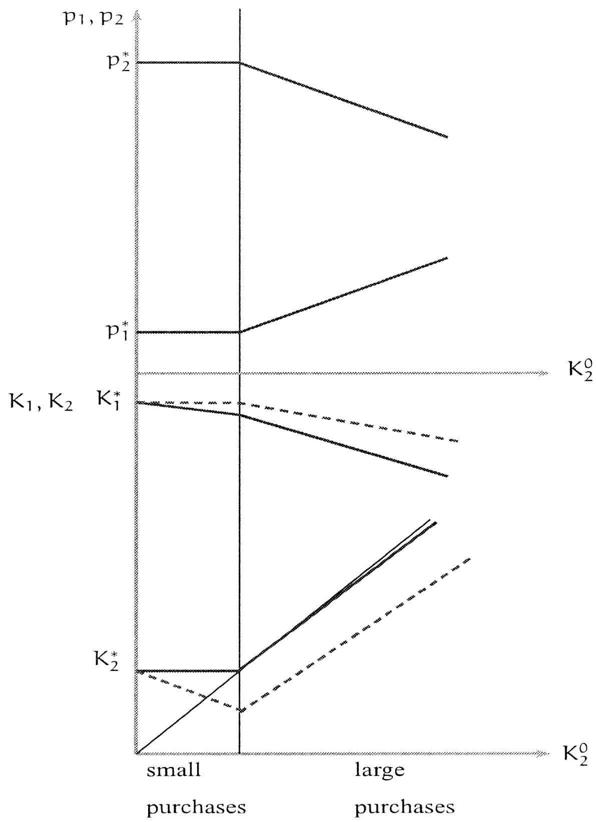

Figure 3: **Plain line: Socialized uplift; dotted line: uplift levied solely on peak consumption**

The results generalize to demand functions such that

$$D_2'(p_2) \leq D_1'(p_1) \text{ whenever } p_2 \geq p_1$$

(this condition is much stronger than needed, though).

b) Last, let us consider the impact of an *uplift levied solely in peak periods* . The uplift, when levied on peak consumption only, is given by:

$$f_2 t D_2(p_2 + t) = K_2^0 I_2 \Longleftrightarrow f_2 t (K_1 + K_2) = K_2^0 I_2.$$

The *off-peak* conditions are

$$D_1(p_1) = K_1$$

and

$$f_1(p_1 - c_1) + f_2(p_2 - c_1) = I_1,$$

or, equivalently

$$E[p] = E[p^*].$$

The *peak* conditions are, as earlier:

$$K_2 = K_2^0 \quad \text{if} \quad f_2(p_2 - c_2) < I_2$$

$$K_2 \geq K_2^0 \quad \text{if} \quad f_2(p_2 - c_2) = I_2,$$

and

$$D_2(p_2 + t) = K_1 + K_2.$$

Hence:

$$D_2\left(p_2 + \frac{K_2^0 I_2}{f_2(K_1 + K_2)}\right) = K_1 + K_2. \tag{1}$$

We assume that the equation in K (for an arbitrary p_2)

$$D_2\left(p_2 + \frac{K_2^0 I_2}{f_2 K}\right) = K$$

admits a single solution K and that this solution is decreasing in K_2^0.[1]

For *small purchases*, as in the case of a socialized uplift, a small purchase K_2^0 is complemented by private sector offering $(K_2 > K_2^0)$ and so $p_2 = p_2^*$. Given that the average price must be the same as for the free entry equilibrium, p_1 is then equal to p_1^*.

Hence, for K_2^0 small,

[1] One has

$$\left[1 + D_2' \frac{K_2^0 I_2}{f_2 K^2}\right] dK = \frac{D_2' I_2}{f_2 K} dK_2^0.$$

Because, in this range, $I_2 = f_2(p_2 - c_2)$, a sufficient condition for this is that the peak elasticity of demand $-D_2' p_2 / D_2$ be equal to or less than one.

$$p_1 = p_1^* \quad \text{and} \quad p_2 = p_2^*$$

$$K_1 = K_1^*.$$

K_2 decreases as K_2^0 increases : There is *more than full crowding out of private investment in peakers by ISO purchases.*

For *larger purchases* at some point $K_2 = K_2^0$ and private investment in peakers disappears $(f_2(p_2 - c_2) \leq I_2)$. But (1) still holds. Suppose that when K_2^0 increases, p_2 increases; then p_1 decreases (as the average price must remain constant) and so K_1 increases (and so does K). For a given K, the left-hand side of (1) decreases as p_2 and K_2^0 increase. So to restore equality in (1), K must decrease, a contradiction. Hence p_2 decreases.

Proposition 2. *Suppose that an uplift is levied in order to finance ISO purchases, and that the latter are dispatched in merit.*

(i) If the uplift is socialized, off-peak capacity is reduced, peak capacity may increase or decrease, and prices are unaffected for small purchases. For larger purchases, the off-peak price increases while the off-peak capacity decreases; the peak price decreases while the peaking capacity increases with the size of the purchases. As ISO purchases increase, private investment in peakers becomes unprofitable at some point and the only available peaking capacity is procured by the ISO.

(ii) If the uplift applies solely to peak energy consumption, only peak capacity is affected (downward) for small purchases. For larger purchases, the characterization is the same as for a socialized uplift. There is more than full crowding out of peakers by ISO purchases and as ISO purchases increase a point is reached were private investment in peakers disappears.

References

[1] Patton, D. (2002) "Summer 2002 Review of the New York Electricity Market," presentation to the New York ISO Board of Directors and Management Committee (October 15).

[2] Patton, D., VanSchaick, P. L., and R. A. Sinclair (2004) "Six Month Review of the SMD Markets in New England," *Potomac Economics for the New England ISO*, February.