Market Power Mitigation in the Real Time Market Does Not Completely Mitigate IFM Market Power If RT Supply Elasticity is Smaller than IFM Supply Elasticity

Benjamin F. Hobbs, Chair, CAISO Market Surveillance Committee

Schad Professor of Environmental Management, The Johns Hopkins University

bhobbs@jhu.edu

Revised 10/10/2019

Introduction

This memo addresses the following three propositions by solving a simple analytical model of the two settlement (IFM-DA/RT) market where suppliers have market power day ahead, but are mitigated in real time. Virtual bidders play a crucial role. In sum, it is possible for RT market power mitigation to mitigate DA market power completely (under restrictive assumptions concerning symmetry of supply in RT and DA)--but if DA supply elasticity is greater than RT supply elasticity, the mitigation of DA market power is incomplete and some market power is exercised. This memo documents the basic model and some variants, and some simulation results.

Simplifying assumptions are made for purposes of ease of exposition:

1. the RT market is perfectly forecast day-ahead,
2. suppliers in the DA market only optimize against their DA marginal cost curve and don't consider how their DA supply will affect RT marginal costs,
3. DA RUC is disregarded (or, equivalently, RUC decisions don't change supply decisions in the RT market)
4. mitigation is perfect (offers are set equal to marginal cost exactly).
5. all oligopolists are identical (have the same cost functions)

However, the first assumption is not anticipated to change the basic results. Meanwhile the Appendix shows that the basic qualitative results (Proposition 1 and 2) don't change if the second assumption is altered. RUC could significantly change the results if the units that are RUC'd are the optimal units to dispatch if all demand was met at the mitigated price in the day-ahead market. The result is that the RT offer curve would follow the DA marginal costs, and the market outcomes would be the same as Proposition 1 below (all market power mitigated). If mitigation is not perfect, market power could persist if RT mitigated offers are above marginal cost. Finally, assumption 5 is not anticipated to qualitatively change the results (for instance, if there are some smaller fringe suppliers).

The propositions are as follows:

Proposition 1: Under perfect arbitrage (virtual bidding) and a monopoly or oligopolistic suppliers, if the IFM supply (MC) curves are the same as the RT supply demand curves, *then mitigating just the RT market will result in the competitive solution in both markets.* (This assumes that monopolist does not anticipate how its IFM decision will affect the amount of virtual supply – i.e., Cournot.) Demand elasticities don't affect this result.

Proposition 2: Under perfect arbitrage (VB) and a monopoly or oligopolistic suppliers, if the RT supply curve is less elastic than the IFM supply curve, *then mitigating just the RT market will still allow some residual market power to be exercised in the DA market.*

Proposition 3: However, the mark up in the latter case will be less than if either (a) there is no mitigation in either market, or (b) if the monopolist anticipates how arbitrage and RT prices will change if it changes IFM supply. Case (b) is sometimes referred to as a "closed loop monopoly" rather than a Cournot solution.

These propositions are illustrated below for linear supply and demand assumptions. The upshot is that RT mitigation is not enough to prevent market power in the IFM if RT supply is less elastic than IFM supply, but it helps. (Lower elasticity in real time is expected since long start units cannot change their status in the short run/RT.) What happens is that the monopolist or oligopolist restricts supply in the IFM, so that prices are higher in the IFM, enticing some virtual supply to be provided DA. As a result, there is RT production, and the mitigated but less elastic supply curve in the RT sets a higher price than would be the case if the IFM was competitive. Market power in the IFM results in IFM supply restriction and increased (and inefficient) production in the RT market, raising prices in both markets, and lowering consumption.

First, I show these propositions for the case of a single firm (monopoly) in the IFM, then I generalize the model to the oligopoly case.

Example 1: Monopoly in the IFM

Notation:

g_1=Total IFM production by the monopolist

g_2=Total incremental production in RT by the monopolist

vs_1 = virtual supply in IFM (settled as virtual demand in RT)

d_1=quantity demanded in IFM, equal to $g_1 + vs_1$

d_2=incremental quantity demanded in RT, equal to $g_2 - vs_1$

$P_1(d_1) = P_{1o} – B_1*d_1$ = IFM demand curve

$P_2(d_2|d_1) = P_{1o} – B_1*d_1 – B_2*d_2$ = RT demand curve ($B_2>B_1$ if less elastic than in IFM)

$MC_1(g_1) = MC_{1o} + C_1*g_1$ = IFM marginal cost curve

$MC_2(g_2|g_1) = MC_{1o} + C_1*g_1 + C_2*g_2$ = RT marginal cost curve ($C_2>C_1$ if RT supply less elastic than in IFM)

There are 5 unknowns (generation and load in each market, and IFM virtual supply) and 5 equations ((1)-(5)) as follows that give the market equilibrium:

IFM (market 1): served by a monopolist subject to elastic demand and virtual supply (which the monopolist is Cournot against). Monopolist maximizes its DA profit, equal to revenue minus IFM cost: $P_1(d_1)*g_1 – (MC_{1o}*g_1+C_1*g_1^2/2)$, subject to its recognition that load equals its supply plus virtual supply

($d_1 = g_1 + vs_1$). (This is a naïve monopolist who doesn't anticipate how IFM decisions affect its RT costs; see the Appendix for a more general model where the monopolist anticipates that if it supplies more DA, its MC in the RT market will increase. The results are not qualitatively different). The first order condition for profit maximization is:

$$\text{Marginal Revenue} = P_1'(d_1)*g_1 + P_1 = MC_1(g_1) \quad (1)$$

Market clearing in IFM:

$$d_1 = g_1 + vs_1 \quad (2)$$

No arbitrage condition (efficient virtual bidding), implying that IFM and RT prices are equal:

$$P_1(d_1) = P_2(d_2|d_1) \quad (3)$$

RT mitigated market solution results in price = marginal cost:

$$P_2(d_2|d_1) = MC_{1o} + C_1*g_1 + C_2*g_2 \quad (4)$$

Market clearing in RT:

$$d_2 = g_2 – vs_1 \quad (5)$$

We could use algebra to define g_1, g_2, d_1, d_2, and vs_1 as explicit functions of the parameters. One immediate result is that no arbitrage (3) means that $d_2 = 0$, $g_2 = vs_1$, and the demand price elasticity (represented by coefficient B_2) in RT doesn't matter. (With uncertainty of supply or demand in real time, though, this would not be generally true.)

Here's an example. I solve (1)-(5) with the following parameters.

Demand	P_{1o} =	100
	B_1 =	1
	B_2 =	1.3
Supply	MC_{1o} =	10
	C_1 =	1.5
	C_2 =	1.8

So the incremental supply curve in RT is 20% steeper than the IFM supply (marginal cost) curve.

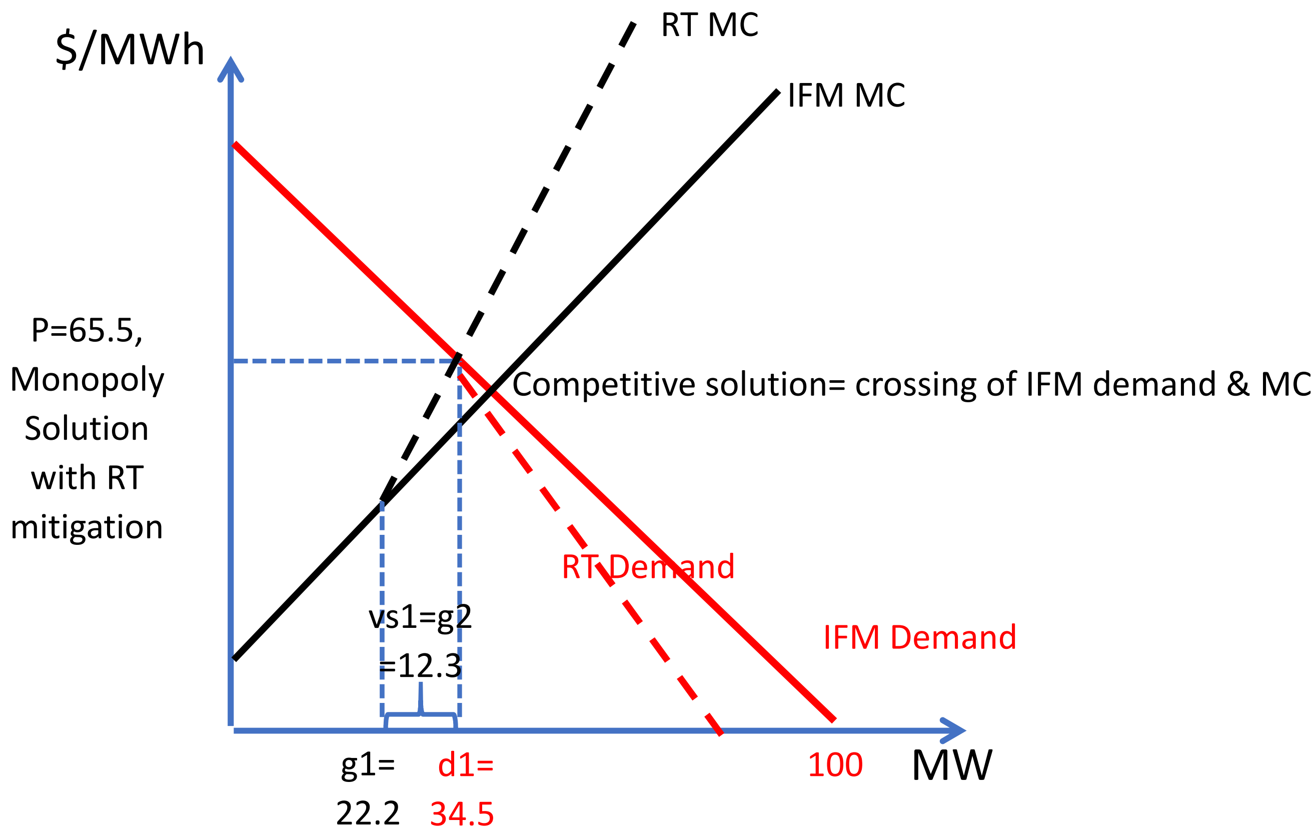
The solution is:

d_1	d_2	g_1	g_2	vs_1
34.52	0.00	22.19	12.33	12.33

With price in both DA and RT equal to \$65.48/MWh. If instead the IFM was perfectly competitive, then the solution would be:

d1	d2	g1	g2	vs1
36	0.00	36	0	0

Which has a lower price (64 \$/MWh) and higher market surplus. This illustrates Proposition 2. These two solutions are shown graphically below.



Note that RT supply starts from the point on the IFM supply curve corresponding to g1. Similarly, RT demand starts from the point on the IFM demand curve corresponding to d1. RT lines are steeper in both cases.

Proposition 1 is illustrated by setting B_1=B_2=1, and C_1=C_2=1.5 (same IFM and RT elasticities). Then the solution is:

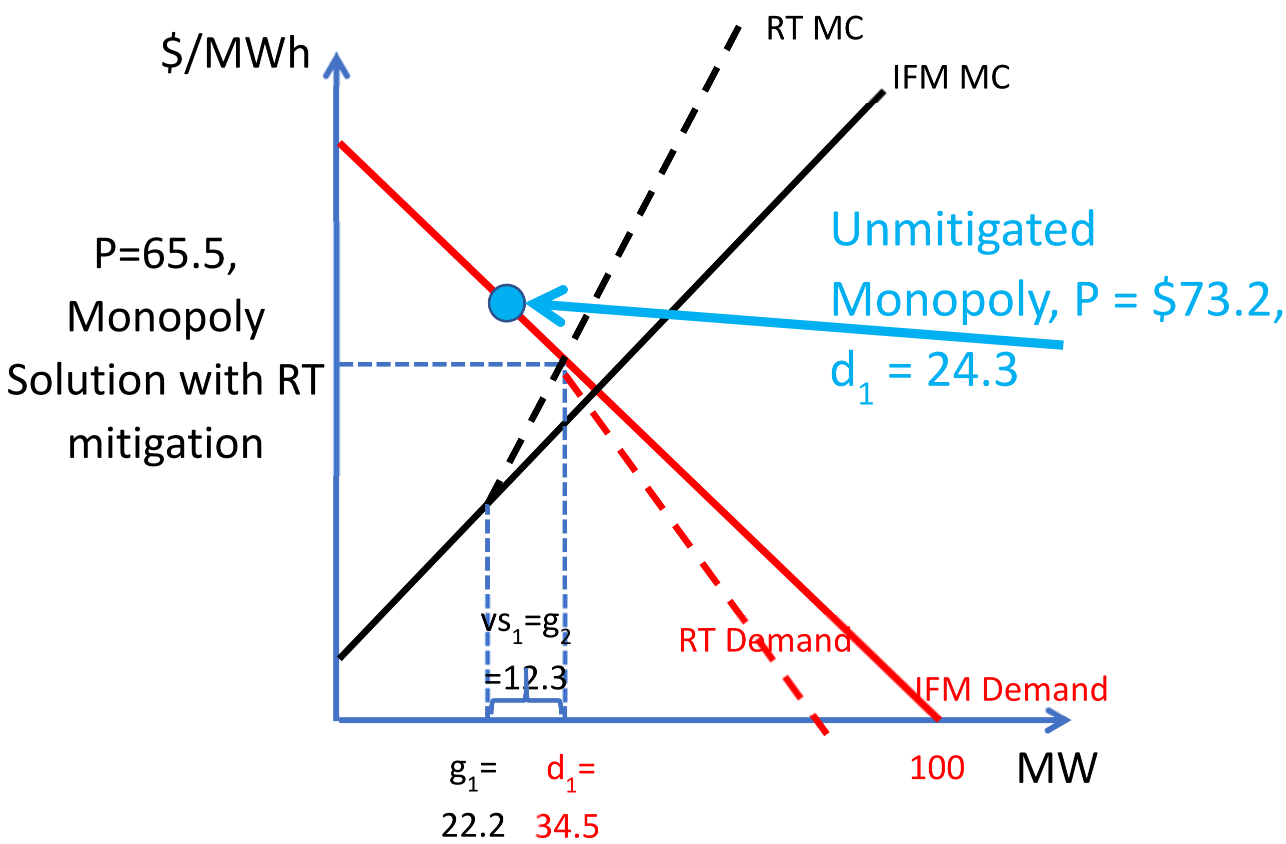
d_1	d_2	g_1	g_2	vs_1
36	0	21.6	14.4	14.4

Which is the same quantity, price ($64), and market surplus as the competitive solution.

Proposition 3 is illustrated by the following profit maximizing (maximal market power) solution in which the monopolist recognizes that it should produce everything in the IFM (which is cheaper than producing in RT) and nothing in the second period. Then:

d_1	d_2	g_1	g_2	vs_1
24.325	0.000	24.324	0.000	0.000

Which yields a price of 73.2 $/MWh, and much less efficiency (see the figure below). So comparing this with the previous solutions, the RT mitigation succeeds in moving the market much closer to the competitive solution (i.e., mitigated in both markets), but there is residual market power.



To the extent that the RT supply elasticity is less than the IFM, the solution will approach the maximal market power solution, and diverge from the competitive solution. For instance, if the RT supply elasticity was one-half the IFM elasticity (increasing C_2 to 3), the equilibrium price increases to 68.7$/MWh (compared to the competitive level of $64 and the maximal market power level of $73.2.)

Example 2: Oligopoly in the IFM

Assume there are n oligopolists. Notation is as follows:

g_1=Total IFM production by oligopolists. g_{1i} is production by oligopolist i

g_2=Total incremental production in RT by oligopolists, and g_{2i} is production by oligopolist i

vs_1 = virtual supply in IFM (settled as virtual demand in RT), as in monopoly model

d_1=quantity demanded in IFM, equal to $\Sigma_i\, g_{1i} + vs_1$

d_2=incremental quantity demanded in RT, equal to $\Sigma_i\, g_{2i} - vs_1$

$P_1(d_1) = P_{1o} - B_1 * d_1$ = IFM demand curve

$P_2(d_2|d_1) = P_{1o} - B_1 * d_1 - B_2 * d_2$ = RT demand curve ($B_2 > B_1$ if less elastic than in IFM)

$MC_1(g_{1i}) = MC_{1o} + n * C_1 * g_{1i}$ = IFM marginal cost curve (assume same all i)

$MC_2(g_{2i}|g_{1i}) = MC_{1o} + n*C_1*g_{1i} + n*C_2*g_{2i}$ = RT marginal cost curve ($C_2>C_1$ if supply less elastic than in IFM) (assume same all i)

There are 5 unknowns and 5 equations ((1')-(5')) as follows that give the market solution. Solving these is made easier if we assume that by symmetry all $g_{1i} = g_1/n$, and $g_{2i} = g_2/n$. The five equations are developed below.

IFM (market 1): served by n Cournot oligopolists subject to elastic demand and the quantities provided by virtual supply and other physical suppliers (both assumed to be fixed by the Cournot oligopolist). The oligopolist chooses its g_{1i} to maximize revenue minus cost $P_1(d_1)*g_{1i} - (MC_{1o}\, g_{1i} + n*C_1*g_{1i}^2/2)$, while recognizing that $d_1 = \Sigma_i\, g_{1i} + vs_1$. The resulting first order condition is:

Marginal Revenue = $P_1'(d_1)*g_{1i} + P_1 = MC_1(g_{1i})$, for all i (1')

Market clearing in IFM:

$d_1 = \Sigma_i\, g_{1i} + vs_1$ (2')

No arbitrage condition (efficient virtual bidding) => IFM and RT prices are equal:

$P_1(d_1) = P_2(d_2|d_1)$ (3')

RT mitigated market solution is price = marginal cost for all i:

$P_2(d_2|d_1) = MC_2(g_{2i}|g_{1i})$, for all i (4')

Market clearing in RT:

$d_2 = \Sigma_i\, g_{2i} - vs_1$ (5')

We could use algebra to define g1i, g2i, d_1, d_2, and vs_1 as explicit functions of the parameters, but it is a bit messy, so just some sample numerical results are shown. One immediate result is that no arbitrage condition (3) means that $d_2 = 0$, g_{2i} = vs1/n, and the demand price elasticity in RT (represented by coefficient B_2) doesn't matter. (With uncertainty, this would not be generally true.)

Here is an example. I solve (1')-(5') with the following parameters.

Demand	P_{1o} =	100
	B_1 =	1
	B_2 =	1.3
Supply	MC_{1o} =	10
	C_1 =	1.5
	C_2 =	1.8
Firms	n =	3

So the incremental supply curve in RT is 20% steeper than the IFM supply curve.

The solution is:

d_1	d_2	g_1	g_2	vs_1
35.337	0.000	29.816	5.521	5.521

With price \$64.66/MWh.

If instead the IFM was perfectly competitive, then the solution would be (as before):

d_1	d_2	g_1	g_2	vs_1
36	0.00	36	0	0

Which has a lower price (64 \$/MWh) and higher market surplus. This illustrates Proposition 2 for the oligopoly case. Note that the oligopoly (n=3) markup is \$0.66, which is about 45% of the monopoly marketup.

Proposition 1 for the oligopoly (n=3) case is illustrated by setting B_1=B_2=1, and C_1=C_2=1.5 (same IFM and RT elasticities). Then the solution is:

d_1	d_2	g_1	g_2	vs_1
36.000	0.000	29.455	6.545	6.545

Which is the same quantity, price (\$64), and market surplus as the competitive solution.

Proposition 3 is illustrated by the following profit maximizing (no mitigation of market power) solution in which the oligopolists recognize that they should produce everything in the IFM (which is cheaper) and nothing in the second period. Then:

d_1	d_2	g_1	g_2	vs_1
31.77	0.000	31.76	0.0	0.0

Which yields a price of 68.2 \$/MWh, and much less efficiency. So in this case, a comparison of this unmitigated solution with the previous RT mitigation solution (immediately above) shows that RT mitigation succeeds in moving the market much closer to the competitive solution (i.e., mitigated in both markets), but there is residual market power.

To the extent that the RT supply elasticity is less than the IFM, the solution will approach the maximal market power solution even if RT mitigation is in place, and diverge from the competitive solution. For instance, if the RT supply elasticity was one-half the IFM elasticity (C_2 = 3), the equilibrium price increases to 66.04\$/MWh (compared to the competitive level of \$64 and the no mitigation market power level of \$68.23.) It turns out that, like the monopoly case, demand elasticities in RT don't affect the solution.

For n=3, the use of RT mitigation reduces the mark-up to 16% of the unmitigated value (for C_2=1.8, 20% reduction in supply elasticity) or 48% (for C_2 = 3, half the supply elasticity). These reductions are almost exactly the same as for the monopoly case (14% and 46% respectively). So the fact that the markets are oligopolistic rather than monopolistic doesn't appreciably change the percentage that market power-driven mark-ups are reduced relatively to unmitigated levels.

APPENDIX: Generators Anticipate Effect of DA Supply Decisions on RT Costs

What if each supplier optimizes over both markets at once, recognizing that producing more in period 1 will increase her cost in period 2?

Choose $\{g_{1i}, g_{2i}\}$ in order to maximize profit over both periods:

$\{P_1(d_1)*g_{1i} – (MC_{1o}\ g_{1i} + n*C_1*g_{1i}{}^2/2)\} + \{P_2*g_{2i} – [(MC_{1o} + n*C_1*g_{1i})g_{2i} + n*C_2*g_{2i}{}^2/2]\}$

Note that P_2 is exogenous in this profit expression, which is equivalent to mitigation of RT prices, because it results in price being set equal to i's marginal cost (the second first order condition below). The first order conditions are:

Marginal Revenue DA = $P_1'(d_1)*g_{1i} + P_1 = MC_1(g_{1i}) + n*C_1*g_{2i}$, all i (1")

$P_2 = P_2(d_2|d_1) = MC_2(g_{2i}|g_{1i})$, all i (4')

So condition (1') has changed to condition (1"); now the producer is equating marginal revenue in the first period with the marginal cost *that would occur* if it supplied all $g_{1i} + g_{2i}$ in the first period, rather than just g_{1i}, not its first period marginal cost of just supplying g_{1i}. If there is a positive second period supply, this implies that the perceived marginal cost of supply in the first period increases, which motivates the firm to sell even less in the first period than it would in the original model, which will ultimately increase the first price further, and, if $C_2>C_1$, increase costs by increasing second period production whose marginal cost is greater than if the same production occurred in period 1. Condition (4) is unchanged (price equals marginal cost in the second period)

Simulations (solving (1"),(2')-(5')) with the same parameters as considered in the body of this memo result in the following comparison with the original model results:

(a) Same results (no market power in DA) if supply elasticity is the same in both RT and DA
(b) More market power in DA if supply elasticity is more in DA

As an illustration, here is the example as before, but solving (1"),(2')-(5') rather than (1')-(5') with the following parameters.

Demand	P_{1o} =	100
	B_1 =	1
	B_2 =	1.3
Supply	MC_{1o} =	10
	C_1 =	1.5
	C_2 =	1.8
	Firms n =	3

So the incremental supply curve in RT is 20% steeper than the IFM supply curve.

The solution is:

d_1	d_2	g_1	g_2	vs_1
33.861	0.000	16.040	17.822	17.822

with price \$66.13/MWh. So the price is higher than the \$64.66 price in the original model in which the supplier doesn't consider impact on second period marginal cost of first period decision, while three times as much virtual supply is being provided in the DA market (so there is three times as much RT generation). Thus, more market power is being exercised under this model.