Multiple Market-Clearing Prices,
Electricity Market Design and Price Manipulation

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March 31, 2012

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Integration of physical transactions and financial contracts is central to successful electricity market design. Virtually every energy transaction has some impact on prices. The mere fact that a physical transaction can affect prices to some degree, and thereby influence the prices of related financial contracts, cannot be a *per se* definition of price manipulation. A principled policy for characterizing price manipulation in organized electricity markets includes a stand-alone profitability test. Multiple market-clearing prices arise from degenerate pricing conditions that can occur in electricity markets under economic dispatch. In some instances, small changes in bilateral schedules can produce large changes in prices. These prices affect the value of associated financial transmission rights. A stand-alone profitability test distinguishes transactions that are consistent with workably competitive markets from transactions that serve no economic purpose other than to manipulate prices and profit from other financial contracts. Generalizing this standard to the degenerate conditions that give rise to multiple market-clearing prices provides a principled solution without undermining the market-design foundations that integrate economic dispatch, locational prices and financial transmission rights.

Introduction

The purpose of this paper is to describe interactions between electricity market-clearing prices, financial transmission rights and price manipulation. The emphasis is on the close connection in the market design, and the application when there is ambiguity in the determination of market-clearing prices. The motivation is to outline policy for defining and identifying price manipulation in special conditions such as those encountered by the California Independent System Operator (CAISO). The problem of dealing with multiple market-clearing prices is important in itself, and it implicates broader questions of electricity market design. The review supports a discussion of the principles to separate efficient market transactions from cases of price manipulation. The distinctions are important, even critical, in preserving the integrity and functionality of efficient electricity market design.

Electricity Market Design

Successful market design for organized electricity markets utilizes a coordinated spot market under an independent system operator. Organized electricity markets follow the market design built on the principles of bid-based security-constrained economic dispatch with locational prices. The prices arise naturally as part of an economic dispatch. The complicated details of networks and strong interactions across locations appear in the economic dispatch, but the resulting prices and quantities have the usual interpretation of clearing the market. Given these market-clearing prices, all economic bids or offers would be included in the economic dispatch.

The design integrates the treatment of physical and certain financial transactions. Locational market-clearing prices apply for energy imbalances or purchases and sales in the spot market. The differences between locational prices capture the marginal cost of transmission. A financial transmission right provides a contract that hedges the price differences between locations and serves as the replacement for unworkable physical transmission rights (Hogan, 2010).

The design arose in part to address an intractable problem confronting restructured electricity markets based on the principles of open access and non-discrimination. The short version of a long story is that the strong interactions in electric networks precluded definition and use of any workable system of physical transmission rights. And without some replacement for the unavailable physical rights, efficient electricity markets would be impossible. The solution was to utilize the spot market prices and create financial transmission rights that could serve many purposes, including allowing users of the transmission system to match their physical transactions and provide firm delivered prices under forward contracts (Hogan, 1992). After many false starts and dead ends, all the organized markets in the United States have moved to incorporate the basic elements of this market design.

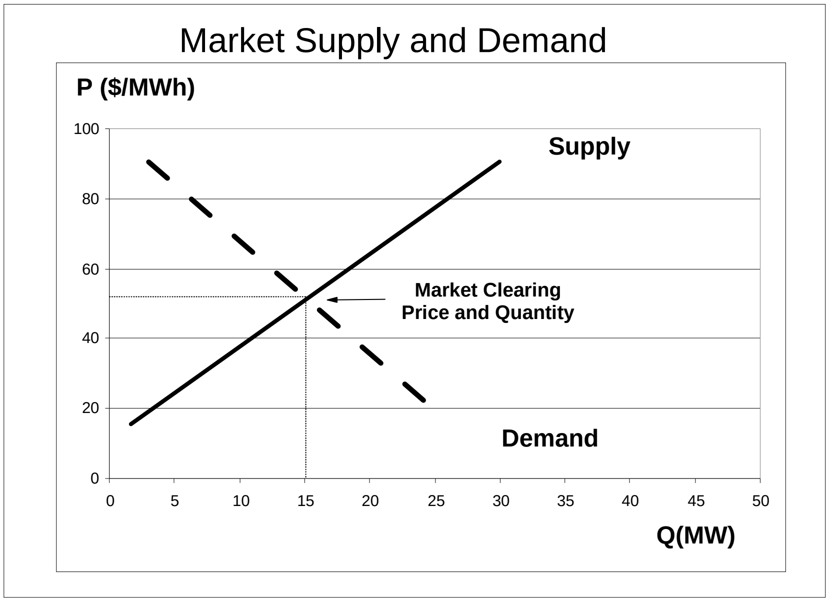
The usual emphasis in discussions of locational market-clearing prices focuses on the sometimes counterintuitive nature of network interactions. However, there are other features of bid-based markets that can create counterintuitive results for market prices even without the impact of network interactions. An illustration, but not the only case, is the so-called “degenerate” pricing conditions that can arise with bids and offers expressed as step functions, as is common in electricity markets.

Market-Clearing Prices

The CAISO describes locational marginal prices that arise from an economic dispatch (CAISO, 2011). The details are important but are not the focus here, which is to elaborate on the implications of ambiguity in determining the market-clearing prices. The CAISO tariff does not explicitly address the issues when describing the relevant price calculations (CAISO 2011, §27). A review of the conventional theory without any ambiguity, where market-clearing prices are unique, provides the background for the subsequent analysis that makes explicit some of the challenges in the more general case.

As shown in Figure 1, the economic dispatch--that maximizes the benefits defined by demand bids minus the costs defined by supply offers--coincides with the intersection of supply and demand that defines the usual market equilibrium. This textbook example provides the standard characterization of equilibrium prices as supporting the dispatch in the sense that it is profit maximizing for price-takers contributing to the supply curve to produce up to the dispatch amount, but above this amount it would not be profitable to operate. A similar interpretation applies for demand. This is also the efficient solution in that it maximizes the surplus of the demand bids over the supply offers. The solution satisfies the no arbitrage condition that there are no remaining profitable trades.

Figure 1

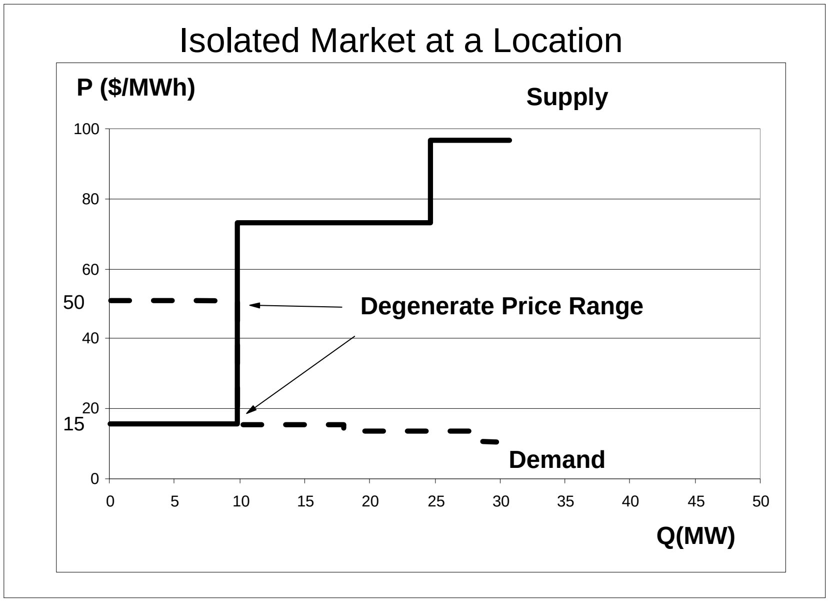


Implicit in this description is an assumption that all opportunities have been characterized in the demand bids and supply offers. However, a foundation of electricity market design has been to allow the flexibility for bilateral schedules that operate in conjunction with the bids and offers of the economic dispatch. At a single location a bilateral schedule could include either a scheduled supply, demand or both. Any imbalance in the schedule would affect the market price, and the imbalance would be priced and settled at the market price. In the textbook case in Figure 1, there is a single price that would apply to all spot transactions, including any imbalances for bilateral schedules. Importantly, for a small change in bilateral schedules, there would be a small change in the single market-clearing price.

Step Functions and Clearing Prices

The assumed supply and demand functions of Figure 1 are linear, or at least smooth curves. For most applications this is a reasonable approximation, and the properties of the market-clearing solution apply. However, actual implementation of electricity markets allows for, or in some cases requires, representation of supply offers and demand bids that aggregate into distinct steps as illustrated in Figure 2.

Figure 2



The demand bids appear in a series of declining steps and the supply offers appear as a sequence of increasing steps. In most cases, the resulting demand and supply "curves" intersect on one of the horizontal segments in the steps. In this circumstance, there is a unique market-clearing price and the textbook example interpretation carries over to the case of bid and offer functions that are not smooth at the edges of the steps.

Another possibility, as constructed in Figure 2, is that a vertical segment of the aggregate demand curve intersects with a vertical segment of the aggregate supply curve. In this case, the market-clearing-quantity is unique, as shown at 10 MW in Figure 2. However, there is an inherent ambiguity in setting the price. In this illustration, the market-clearing price could be set anywhere between $15/MWh and $50/MWh. Taking terminology from the underlying optimization formulation of economic dispatch, this is a case with a "degenerate" solution in the prices. (Hogan, Read, & Ring, 1996) The concern is not that there is no market-clearing price; rather, the situation is that there are many market-clearing prices. For these supply and demand conditions, any price in the degenerate range would suffice. Selecting any price in the range would support the economic dispatch solution. At any such price, there would be no incentive for a price taker to produce more or less than the economic dispatch. The price would satisfy the no-arbitrage condition. And any price in this range would have a claim to be an efficient price because it supports this surplus maximizing outcome.

This interpretation of the degenerate solution as efficient importantly exploits the implicit assumption that all supply and demand information is embedded in the offers and bids. However, the impact of bilateral schedules has a somewhat different interpretation. If the range of the degenerate prices is small, then the standard interpretation of the efficiency of the market-clearing price is approximately correct. However, in the case shown in Figure 2, the wide range for the degenerate prices has an important implication. The market-clearing price can send the wrong signal for even efficient bilateral schedules that could be introduced to this market.

In Figure 1, it is efficient to offer supply that costs less than the market price, or to add demand that is worth more than the single market-clearing price. This is no longer true in the case of Figure 2. Only an incremental demand schedule that is above the highest price in the range, $50/MWh, would be efficient and would change the dispatch solution. Only an incremental supply schedule that is below the lowest price in the range, $15/MWh, would be efficient and would change the dispatch. Clearly, if there is a bilateral schedule to arrange that is not included in the spot market bids and offers, then a market-clearing price in the range would be either too low for demand or too high for supply, or both.

If the incremental uneconomic offer were to be added to the spot market optimization, say for generation, there would be no change in the dispatch, only a change in the price. For example, suppose in Figure 2 the market price is set at $30/MWh. In the next hour, with everything else the same, a $25/MWh offer is added to the supply curve. The new economic dispatch would not choose the incremental offer, and the dispatch would stay the same. However, the incremental supply offer would change the range of possible market-clearing prices, replacing the previous maximum of $50/MWh with the new offer of $25/MWh.

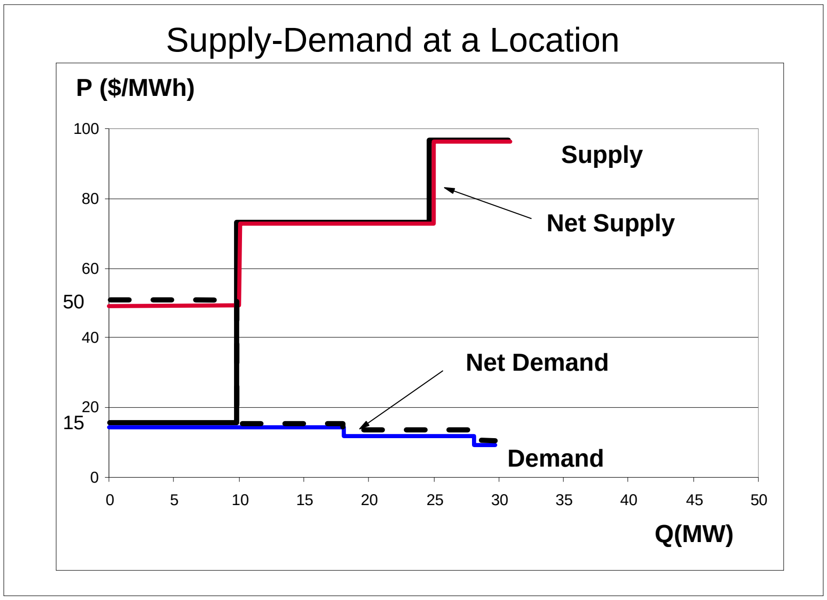
Note that the outcome would be different if the new $25/MWh supply increment was added as an unpriced schedule rather than included as a supply offer. In this case it would shift the supply and the revised supply curve would intersect the demand curve at the now revised single market-clearing price of $15/MWh. The bilateral schedule would lose money after the fact, even though the transaction would have been profitable at the announced market-clearing price of $30/MWh.

In either case, the large range of possible market-clearing prices creates a knife-edge result. Any shift in supply or demand would eliminate the degeneracy, and even a small change in quantity could produce a large change in the market-clearing price. Furthermore, whatever the price selected in the degenerate range, it would be efficient only if the spot market bids and offers included all the possible supply and demand conditions. If the some other supply or demand could be included, signaled by the reported price, the result could be large change in the price and a small or no change in the dispatch.

Locational Prices

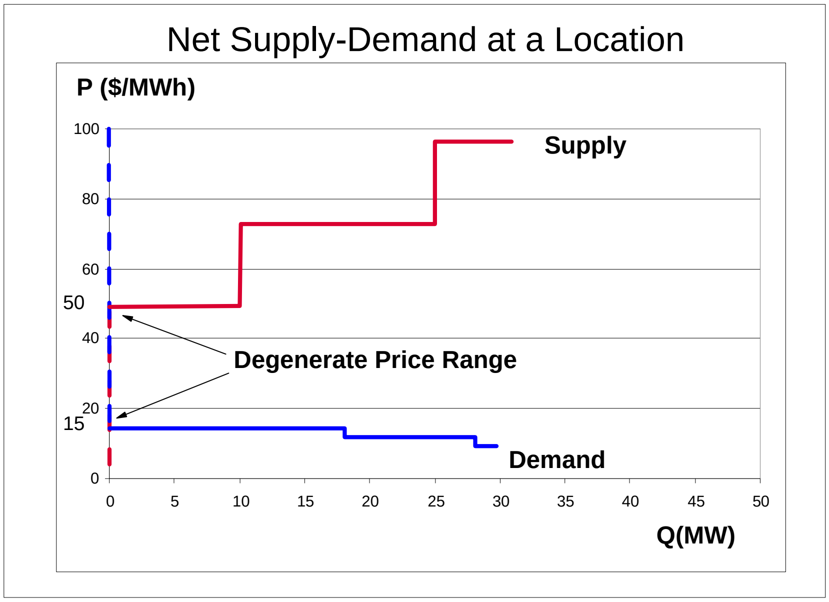
The example illustration in Figure 2 applies to an isolated market. Similar analysis and conclusions apply to operations in a transmission network. The easiest extension would be to include another region connected through a radial line. To extend the example, consider that the analysis in Figure 2 represents the net effect of a region.

Figure 3



To simplify the analysis of a radial transmission line, recast the supply and demand in this region into a representation of the net of supply minus demand. When this net difference is positive, we can call this net supply. When the difference is negative, we call the difference net demand.

Figure 4

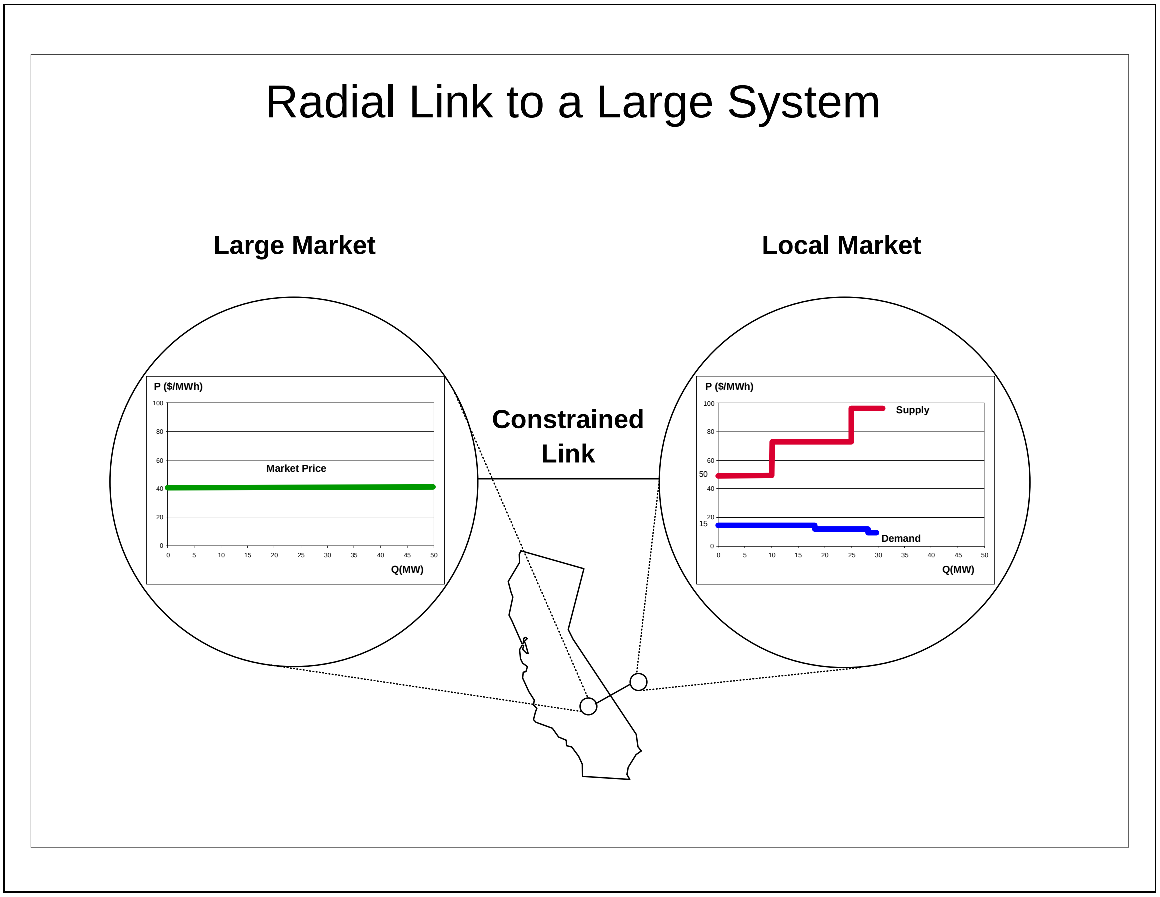


For example, if prices rise above $50/MWh, then demand would decrease and be added to the remaining supply to yield the net supply curve in Figure 3. Similarly, if price falls below $15/MWh, supply would decrease and we obtain the net demand.

The region could then be recast as having net supply and demand offers as shown in Figure 4. The degenerate price range remains between \$15 and \$50/MWh, but at the quantity zero for local supply minus local demand.

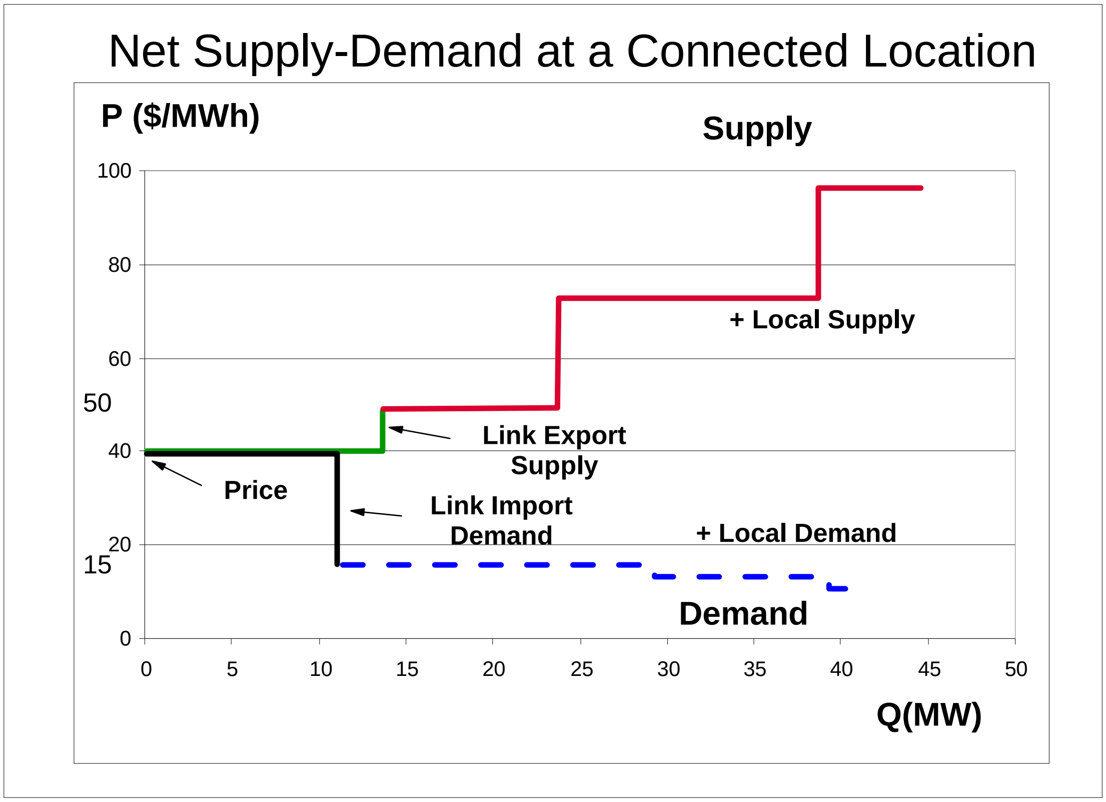
This reduced model represents one region. For the other region we assume that there is a large market with an otherwise unconstrained price at \$40/MWh. This region connects via a radial link which has constraints on imports and exports from and to the local market. A schematic summary of the setup appears in Figure 5. Different characterizations of the transmission limits would give rise to different market equilibrium conditions.

Figure 5



In a first illustration, suppose that there is a different limit on imports and exports. Imports into the larger region on the left appear as increased demand in the local market on the right. Exports from the larger region appear as increased supply in the local market. In Figure 6 the assumed limit on imports is 11 MW and the limit on exports is 13 MW. The export supply and import demand shift the local market supply and demand curves.

Figure 6

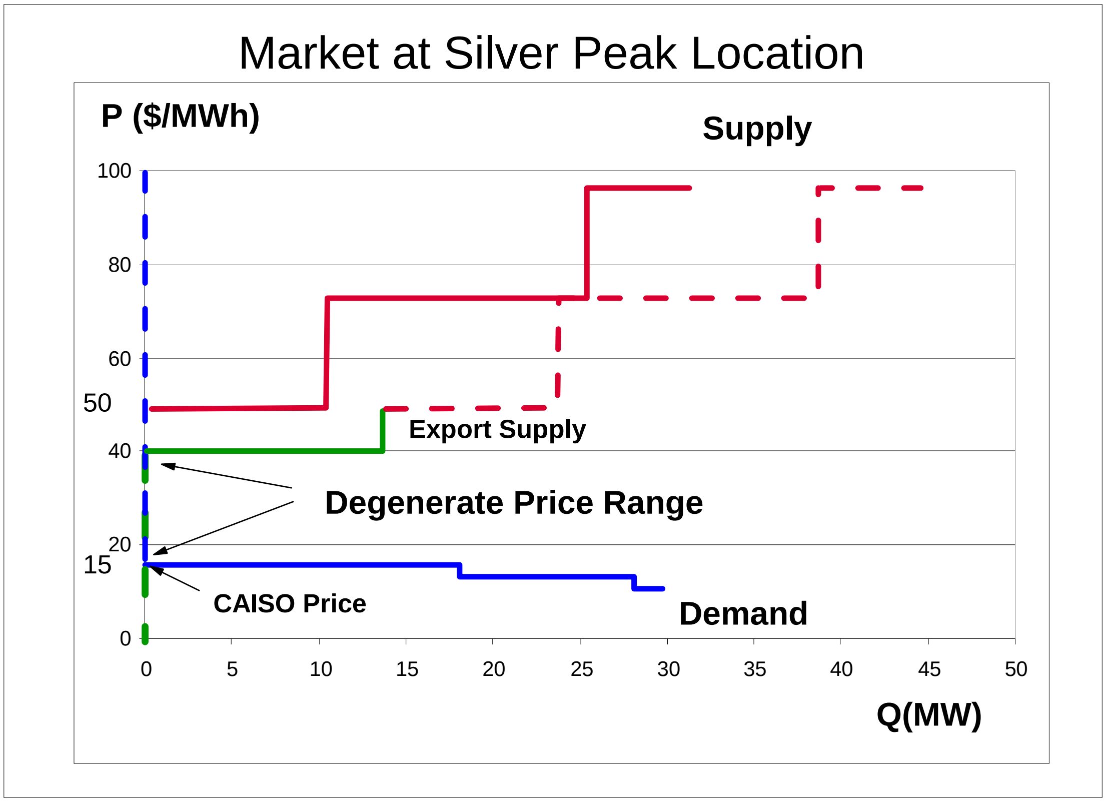


The result in this case is to eliminate the price degeneracy. The market-clearing price in the local market would be $40/MWh, the same as in the larger market. The actual quantity imported and exported would net to zero, and there would be no congestion on the transmission link. It is clear from Figure 6 that this outcome would apply in this case to any solution where the transmission limits are greater than zero. The resulting price would be efficient and would send the right signal to both supply and demand. A small shift in the supply or demand curve would not change the market price.

This leads to the conditions identified by the CAISO as applying at locations like Silver Peak in early 2010. This is an example of an Inter-tie modeled as a radial connection to the CAISO system as adapted from (Wells, 2010). A different outcome would apply in the case that one of the transmission limits on the radial link is zero. In this case the bids and offers of the net supply and demand curves can be interpreted as for the rest of the western system interacting at the Silver Peak location. The large market at the assumed $40/MWh price is the connected location for the rest of the CAISO region for the hour of interest.

The graphic in Figure 7 represents the conditions according to a conventional supply and demand representation at the Silver Peak node. The import offers are interpreted as local supply to Silver Peak, and export capacity from CAISO defines an implicit supply curve at the assumed clearing price inside CAISO. Similarly, local export bids are interpreted as demand at Silver Peak.

Figure 7



The implicit export offers from CAISO are subject to a limit on transmission exports of 13 MW. Given these exports, the two supply curves add horizontally to define the total Silver Peak supply curve.

In this case, the constraint on imports into CAISO is zero. Hence, there is no addition to the local Silver Peak demand. As shown in Figure 7, the implied aggregate supply and demand curves intersect at zero quantity. As examined before in Figure 2 and Figure 4, the result is a degenerate case defined by an overlap of vertical segments on the supply and demand curves. This yields a degenerate price range. With imports limited to zero in Figure 7, the price range is between $15 and $40/MWh. Anything above the lower end of $15 sends the wrong signal to incremental local suppliers who were not offering into the dispatch. Anything below the upper end of $40 sends the wrong signal to incremental local loads who had not already bid into the dispatch. But any price within the range of $15 to $40/MWh would be market-clearing for the indicated supply and demand curves.

Price degeneracy in Figure 7 arises because of vertical segment overlap of supply and demand, as in Figure 2, which produces the gap between the net supply and demand curves like those in Figure 4. In this case, in order to preserve this gap in the case of connection through a radial transmission link, it is necessary that either the export or import link be constrained to zero. If the export link is limited to zero, then the degenerate price range would be from $40 to $50/MWh. In Figure 7, with the import link constrained to zero, the degenerate price range is from $15 to $40/MWh.

The presumed example deals with a realistic case with a radial line, and illustrates the elements and some of the consequences of degeneracy in determining a market-clearing price. Although the analysis of a realistic network with loop flows and more complicated interactions across locations cannot be summarized in such a simple supply-demand graphic, the basic conclusion generalize to the broader case. In general, the locational shadow price for net input to the grid defines a support to the economic dispatch solution. The total benefit function may include a "corner" at this solution, where the slope in one direction is different than the slope in the other direction. This characterizes multiple solutions for the prices and the knife-edge property of these solution in the presence of step function offers and bids (Geoffrion, 1971). They are many circumstances that could give rise to a degenerate solution with the associated ambiguity and discontinuity in market-clearing prices. This degeneracy could occur whenever a new constraint becomes binding in the economic dispatch. Since there are many possible constraints and combinations of constraints, there are many conditions where price degeneracy would appear.

Any degenerate price solution is a support for the economic dispatch solution as defined by the available bids and offers. But as for signaling for other schedules not represented in the bids and offers, in the degenerate price case there is no good answer. Any price in the range is an efficient price that supports the solution. But as a signal to the market, any single price selected is wrong as the signal for someone external to the bids and offers considered in the dispatch.

One alternative available to market participants would be to provide incremental bids and offers that might affect the price but not the dispatch. This too would require a principle to distinguish efficient offers from uneconomic offers. This is an important topic related to the treatment of bilateral schedules, which are the focus here.

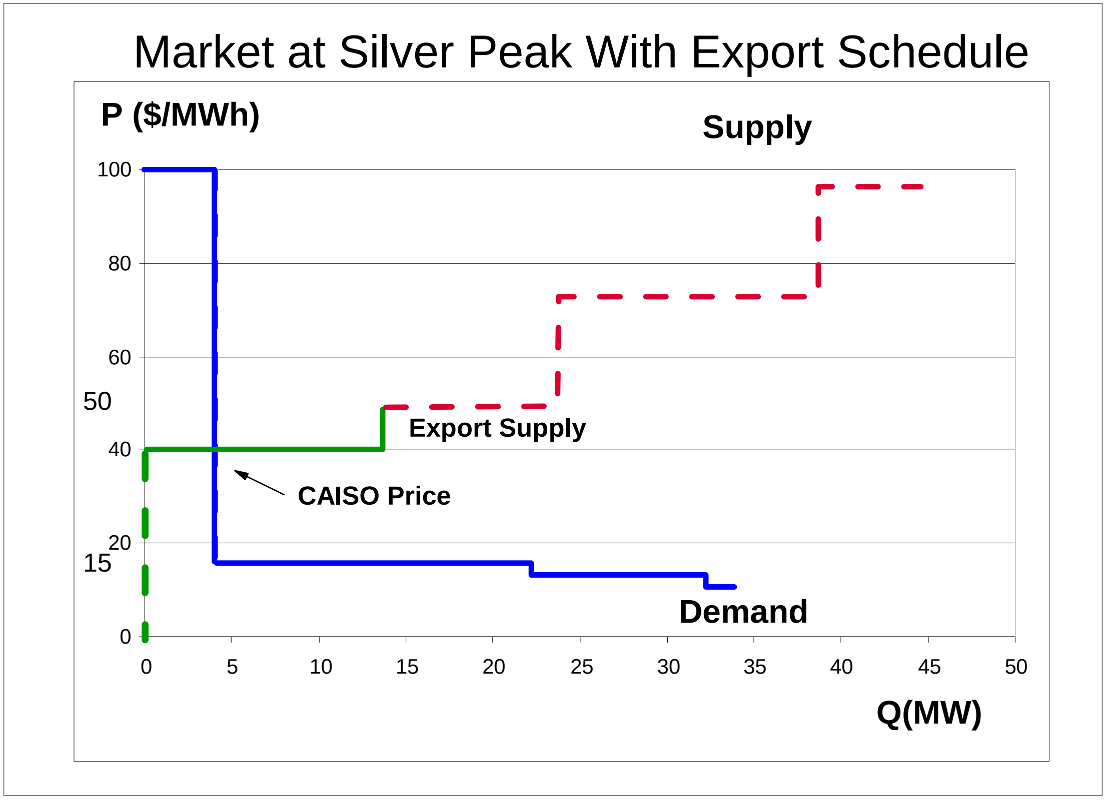
If the degenerate price range is small, then the occasional wrong signal for bitaleral schedules may not be a serious policy problem. But when the price gap is material, as in the illustrative CAISO example, there is no market-clearing price that provides the right information for bilateral schedules.

In the event of the particular case in Figure 7, the CAISO dispatch apparently would select the lower end of this range as the CAISO price at Silver Peak (Wells, 2010). This locational price determined for Silver Peak, coupled with the market-clearing price at \$40/MWh for the CAISO connection, would yield a price difference of \$25/MWh between the two locations. This meant that the implied transmission cost from Silver Peak to CAISO was \$25/WMh. This would apply to no flows because there was no import capacity. Similarly, the implied transmission cost between CAISO and Silver Peak would be -\$25/MWh. This too would apply to no export flows in the economic dispatch.

This choice of price for Silver Peak has important implications. If all the supply and demand were included, then this market-clearing price supported the economic dispatch. Any price in the degenerate range would not change the optimality of the dispatch solution.

However, this implicit assumption that all possible bids and offers are included is important. As described above, the CAISO price would signal that any demand valued above \$15/MWh would be economic and should be supplied. However, supplying any demand valued less than \$40/MWh would not be efficient. This would be apparent if a market participant submitted a small bilateral schedule for exports from the CAISO. The result, illustrated in Figure 8 would be to shift the implied demand curve, remove the price degeneracy and change the market-clearing price to \$40/MWh. If the export was actually worth less than \$40/MWh, it would be inefficient, despite the putative market-clearing price signal of \$15/MWh. Because of the knife edge condition of the price degeneracy, this would occur for even the smallest possible export schedule.

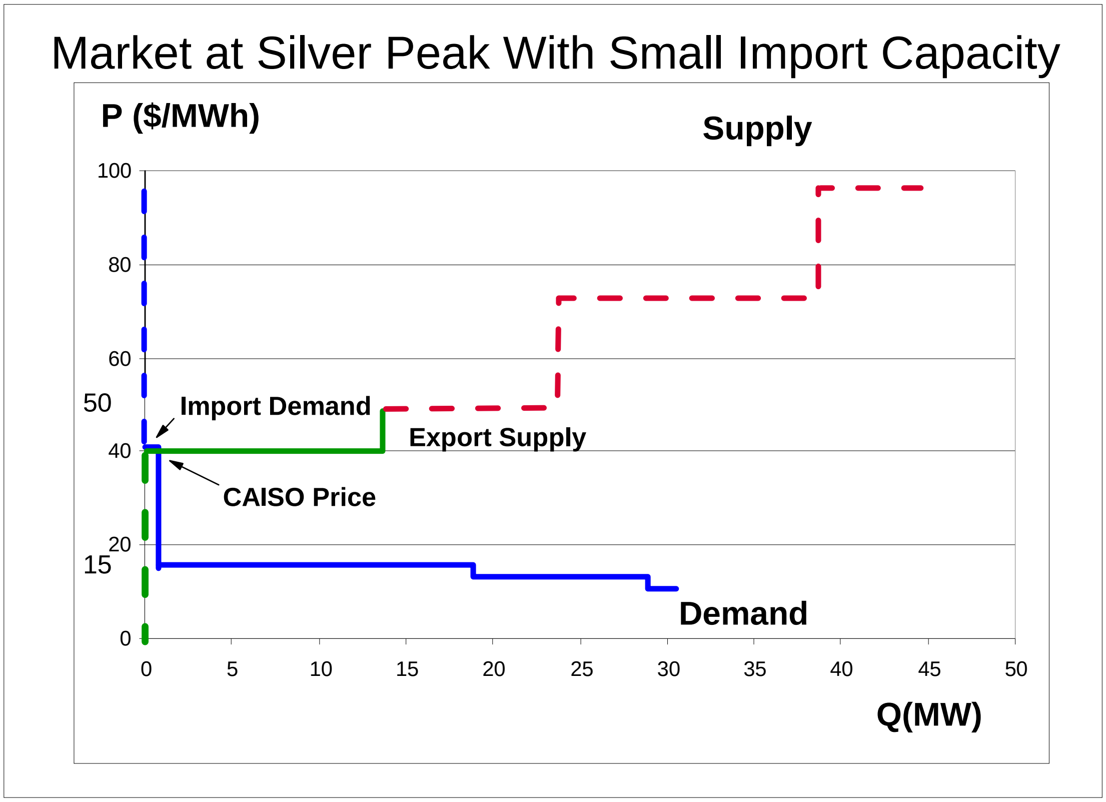
Figure 8



The CASIO example extends to consider a schedule of 4 MW of exports. This case in Figure 8 does not have a degenerate price range. The price at Silver Peak would be the same as the CAISO internal price of \$40/MWh.

The importance of even a small import capacity appears in Figure 9. This creates a small implicit demand block at the CAISO internal price, and shifts the net demand curve at Silver Peak. With the small import capacity, the vertical step of the implied demand curve would not overlap with the supply offers. The result would eliminate the range of price degeneracy and would produce a market-clearing price of \$40/MWh. There would be no congestion implied between Silver Peak and CAISO.

Figure 9



The comparison of examples in Figure 7 and Figure 9 illustrates the knife-edge characteristic of prices in the degenerate case. A small change in the supply and demand conditions can have a large change in the market-clearing price. The conditions in the example emphasize a particular case, with the overlap of supply offers and demand bids on a radial connection. But the problem of degenerate pricing solutions appears in other circumstances, such as when a new transmission constraint is just binding and system congestion produces a jump in locational prices.

These circumstances may not appear too often, and may not always be important when they do occur. However, the potential is always there and the network interactions can make the conditions difficult to anticipate and even harder to subject to an ad hoc fix. The existence of degenerate pricing in optimization problems like economic dispatch is “a feature, not a bug.”

The challenge is to apply market policies that recognize the impact of degenerate prices and treat the consequences accordingly.

Financial Transmission Rights

Financial transmission rights are special contractual instruments administered by system operators. For the sake of this exposition, ignore the effects of marginal losses and focus on the costs of system congestion. For bid-based, security-constrained economic dispatch, the associated locational marginal prices capture the marginal cost of increments in load and generation. Importantly, the difference in the locational prices captures the marginal cost of an increment of transmission between the locations. If bilateral schedules between locations are charged for the difference in the locational prices, and net supply and demand imbalances at each location are settled at the locational prices, then we have an internally consistent and efficient market-based design for a competitive electricity market.

The financial transmission right is to collect (or pay) the difference in the locational prices. From the perspective of a generator, the cost of delivering to a load is the cost of generation plus the cost of transmission charged at the difference in the locational prices. This spot market delivered price can be highly volatile, which would seem to prohibit long-term contracts at a fixed price to the load. However, with the financial transmission right, the holder recoups the spot-market locational difference in prices and the cost of delivery is the cost of generation plus the cost of acquiring the financial transmission right.

This same economic solution would be achieved if there were a way to define and guarantee the generator a physical right to transmit the power to the load. And for those unfamiliar with the inherent characteristics of electrical networks, there is often an implicit or explicit assumption that such physical rights could be defined and enforced in a way that would ensure that the market would find an efficient solution. However, as has been established by theory and reinforced by harsh experience, there is no such workable system of physical transmission rights (Hogan, 2002).

Hence, the existence of financial transmission rights solves a central problem in electricity market design. These are special financial contracts. The purpose was closely connected to the idea of point-to-point transmission capacity rights, with the alternatives of financial payment or scheduling a power flow (Harvey, Hogan, & Pope, 1997). In defining financial transmission rights, the choice was explicit: "A transmission capacity right is defined as the right to put power in one bus and take out the same amount of power at another bus in the network. We assume that the simultaneous use of all the allocated rights is feasible. However, in the contract network, we amend the definition of a capacity right to allow for either specific performance or receipt of an equivalent rental payment. … In effect, the holders of long-term transmission rights are deemed to have acquired the right to use the system and ex post pay only the short-run cost of losses or to receive a rental payment for use of their rights by others." (Hogan, 1992, p. 234)

One important feature is that the system operator can utilize the fact that the net revenues from the spot market will be sufficient to fund the collection of financial transmission rights as long as the rights themselves are simultaneously feasible for the existing grid. Furthermore, the simultaneous feasibility condition provides a natural mechanism for increasing or decreasing the availability of the financial contracts when the grid changes through investment or retirement.

Although they are financial contracts, these financial transmission rights have unusual and intimate connections to the physical market. The allocation of financial transmission rights need not change with the physical dispatch, but the aggregate set of rights is limited by the aggregate capacity of the grid and the simultaneous feasibility condition.

Furthermore, a fundamental purpose of the financial transmission rights is to allow them to be matched with physical transactions for those market participants that want long term contacts that fix the price of delivered power. As with any financial instruments, there are myriad other uses of financial transmission rights as hedges or speculative transactions in a broader portfolio. However, the special characteristics of financial transmission rights in the electricity market make them unusual, or even unique. Anything that upsets these key properties would create an existential threat to efficient electricity markets.

Market Response, Degenerate Prices and Price Manipulation

The conventional analysis of the idealized market in Figure 1 highlights the efficiency of market-clearing prices in supporting the economic dispatch. Price-taking market participants would have no incentive to deviate from the economic dispatch. The price-taking assumption is an idealized case of the perfectly competitive market. In reality, every transaction can have some effect on market-clearing prices. The realistic goal, therefore, is to have a workably competitive market where market participants act as though they are approximately price-takers.

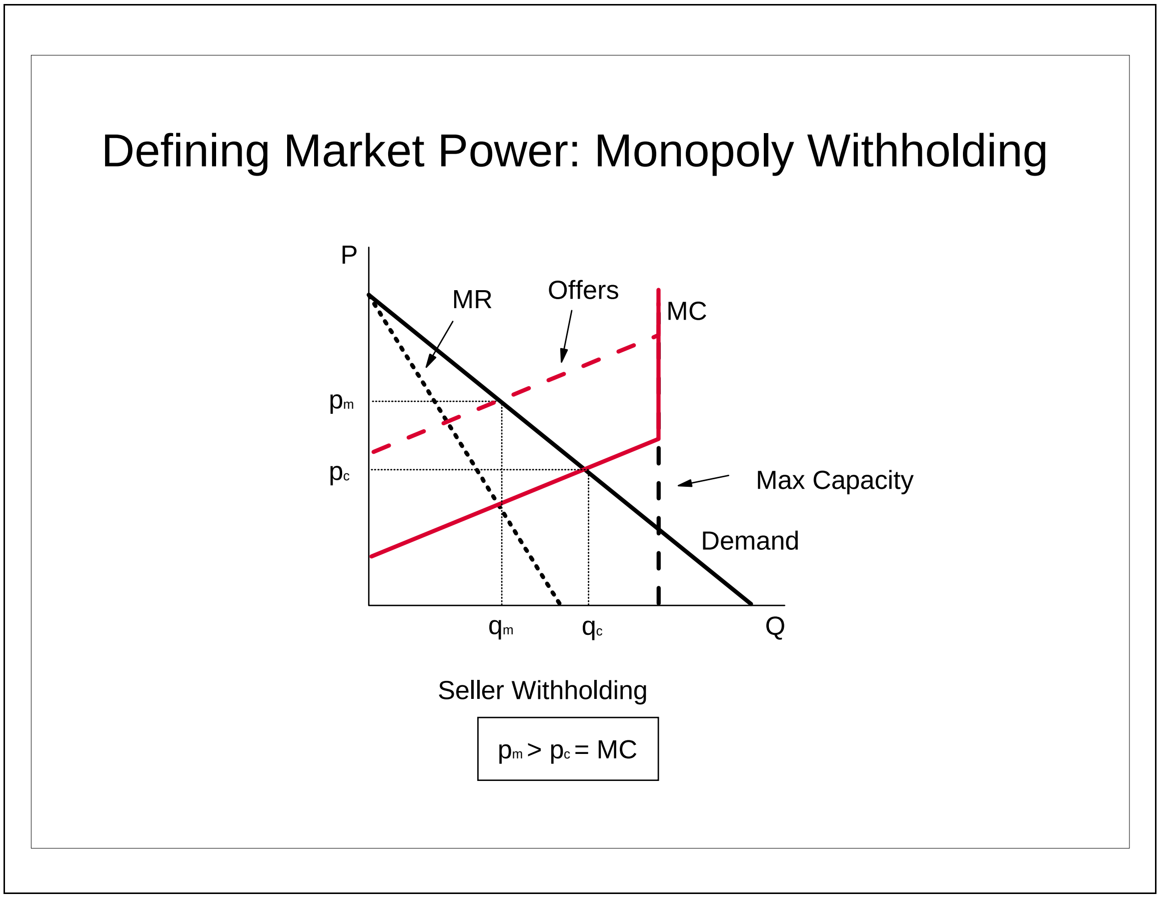
In many circumstance, the workably competitive market appellation is acceptable because market participants with relatively small individual transactions have relatively small impacts on market-clearing prices. Any deviation from the price-taking assumption is minimal and has such a small effect on the market that it does not rise to the level of a policy problem.

Another indication of a workably competitive market would apply whenever predicting the magnitude of a change in prices is so difficult that market participants cannot consistently profit from exploiting behavior that deviates from the price-taking assumption. This too would not rise to the level of a policy problem.

A defining characteristic of both interpretations of a workably competitive market is found in the evaluation of an efficient transaction at the market-clearing price. The standard is that the transaction should be profitable, or at least not loss making, on a stand-alone basis at the market-clearing price. Practical application would require some judgment about the size of the incremental transaction, how to treat fixed overhead costs, how to account for any risk premium, and so on. But the stand-alone profitability test for an incremental transaction is a natural benchmark. Transactions which are uneconomic on a stand-alone basis are not efficient but might be used to affect prices and earn greater profits on other transactions. This is the case of price manipulation. But transactions which are not loss making are efficient, and the impacts on market-clearing prices are consistent with an efficient market outcome.

The most common example of the theory of price manipulation serves to illustrate application of the stand-alone profitability test. The problem arises in the case of a generator that both has and exercises market power. The stylized example in Figure 10 includes a market demand curve and the marginal cost (MC) curve for the generator. If the generator is a price taker, then the equilibrium solution that clears the market is at price p_c and at quantity q_c. This is the competitive equilibrium.

Figure 10



The generator with market power recognizes that by making offers above its marginal cost the market price will be raised to p_m and the quantity reduced to q_m, the monopoly solution. This is an example of economic withholding. Given the monopoly price, the generator is losing money on the quantity $q_c - q_m$ that is withheld from the market. The higher price for the quantity actually supplied raises price and adds to profits on the monopoly sales more than the losses on the quantity withheld. But the withheld supply fails the stand-alone profitability test. If prices were taken as given at p_m it would be profitable to produce up to the full capacity limit. Exercising generator market power by withholding supply is an example of price manipulation.

Similarly, if market price was p_c and the generator did produce at q_c, then there would be no withholding. Taking the price as p_c, the maximum profitable production quantity is q_c. Given the price p_c, generator production at q_c would pass the stand-alone profitability test. There are many variants of this analysis, to include the application to buyer withholding which can be subject to a symmetric analysis (Hogan, 2011). A common feature is that market transactions that are economically efficient pass the stand-alone profitability test. Such a transaction does not implicate price manipulation even if the transaction has an impact on prices.

This “stand alone” standard of not making losses at market-clearing prices is clear in principle, as long as there is a unique market-clearing price. In the case of degenerate prices a complication arises in defining and determining the associated market-clearing prices, and in distinguishing economic transactions from price manipulation.

In the real dispatch, one of the requirements for a degenerate pricing solution would be to know about bids and offers which were “close” to the solution but not part of the economic dispatch. While the system operator may have this information, this requirement presents a substantial informational hurdle for a market participant. The complexity of the problem of recognizing and predicting the behavior of degenerate prices may itself make the market workably competitive.

Market participants will anticipate and react to market prices expected absent their transactions. If the market participant is acting as a price-taker, then the transaction should meet the stand-alone non-negative profitability test. Of course, in the degenerate case, implementation of the transaction could materially affect the market-clearing price. The stand-alone transaction might be profitable at one degenerate price (ex ante) and unprofitable at another equally degenerate price (ex post).

A claim of price manipulation inherently entails a claim that the ex post price with the transaction differs materially from the ex ante price without the transaction. The analysis and treatment of the different prices over the degenerate range presents a central difficulty in defining and interpreting price manipulation.

In practice, the only price immediately observed is the ex post price, which in the degenerate case is not easy to forecast in advance. Determining the but-for ex-ante price requires a calculation by the system operator, the only entity with the necessary information about the dispatch and other offers. Given the informational burden for market participants, a plausible principle would be to place the burden of proof on the system operator and market monitor making any claim of price manipulation. A workable principle that falls out of the analysis here would be to require violation of the stand-alone test for all prices in the degenerate range in order to conclude that the transaction was not economic. In other words, if there is any price in the degenerate range for which the transaction would meet the stand alone test of non-negative profits at that price, then the presumption would apply that the transaction was efficient and not incurred solely because of the effect on prices. Transactions which failed this test would be considered for further analysis of evidence of prohibited price manipulation.

This would extend the stand-alone test in the case of unique prices to the more ambiguous case of degenerate prices. The burden of recalculation of but-for prices would fall on the system operator, who has the necessary information, and not on the market participant, who does not have the necessary information.

This test for the full range of degenerate prices has an important property. It is the only stand-alone pricing test that would avoid another unintended complication. If there is any degenerate price for which the transaction would be economic, at this price failing to enter into the transaction would require the market participant to withhold, appearing to lose money, in order to manipulate prices. In application, therefore, any other stand-alone profitability rule in the degenerate case would appear to prescribe behavior which is prohibited.

By symmetry, the same full range of degenerate price tests should apply for evaluating transactions which were not undertaken. In other words, a necessary condition for judging a transaction that did not occur as possibly economic withholding would be that the transaction would appear profitable on a stand-alone basis for all prices in the degenerate price range. Call this the generalized stand-alone test. In short, whenever the economics of the transaction would be ambiguous over the degenerate price range, the benefit of the doubt would rest with the market participant.

An added advantage of this generalized stand-alone test is that it does not create any further complications in the consideration of the interactions with other contracts, such as with financial transmission rights. To see the problem, consider again the example in Figure 7 and Figure 8. In Figure 7, the congestion component is $25/MWh in the import direction. Any export schedule with a net cost less than $25/MWh would appear profitable. This would be true independent of any holdings of financial transmission rights. If the market participant also held 4MW of financial transmission rights in the export direction, the aggregate profitability would be reduced, but the transaction would still be profitable. However, the market participant would be able to hedge a 4 MW physical transaction. If the transaction did not change the market-clearing price, it would still be profitable. And if the transaction changed the market-clearing price for congestion, reducing it to zero in Figure 8, the price change on the transaction would be exactly offset by the price change in the hedging financial transmission right. There would be no change in the overall profitability of the stand-alone transaction coupled with the matching financial transmission right.

Since a purpose of the financial transmission right is to substitute for the unavailable physical transmission rights and provide just such hedges, this would not be price manipulation. Hence, using any test for the degenerate price case other than the generalized stand-alone test described here would appear to require distinguishing and incorporating the impacts on financial transmission rights or other less perfect financial hedges. But with the requirement of the generalized stand-alone test to apply the analysis to all the degenerate price cases, it is not necessary to entangle the price manipulation test with the inclusion of some financial contracts and exclusion of others.

Most importantly for the broader market, the generalized stand-alone profitability test would not create the perverse incentive to avoid using financial transmission rights as hedges. Otherwise, if ownership of financial transmission rights created a price manipulation exposure merely because decisions in the physical market always have some impacts on prices that affect financial transmission rights, the fundamental design of electricity markets would unravel.

The generalized stand-alone profitability test is clearest if we ignore the interaction with other financial contracts. However, in practice, if there is matching and perfectly complementary financial hedge, then the stand-alone transaction is profitable at some price in the degenerate range only if the combined transaction and complementary hedge would not be net loss making, compared to no transaction, for any price in the range. The condition applies in the example case of financial transmission rights and radial lines. Across the range of degenerate prices the change in the physical price is matched perfectly with the opposite change in the value of the financial transmission right. The profitability of the combined transaction would be the same over the full range of degenerate prices. Hence, the change in profitability of the combined transaction would be zero over the whole range of degenerate prices.

Principled Policy

Any principled policy for characterizing price manipulation in organized electricity markets must include a stand-alone profitability test. The mere fact that a physical transaction can affect prices to some degree, and thereby influence the prices of related financial contracts, cannot be a *per se* definition of price manipulation. Virtually every physical transaction has some impact on prices. And successful electricity market design requires an integration of financial contracts to hedge volatile electricity prices. If holding a financial contract that benefits from the price impact of a physical transaction were to be deemed all that is required to establish price manipulation, then the entire foundation of efficient electricity market design would be destroyed with one stroke.

This cannot be the intent or consequence of a rational policy to support efficient market design and deal with the problem of price manipulation. The solution is, has been, and should be an application of a stand-alone profitability test. For example, in the DC Energy versus HQ Energy case the Federal Energy Regulatory Commission found that:

> "…HQ Energy did not use a combination of market power and trading activity to act against its economic interest in one market in order to benefit its position in another market by artificially moving the market price. There is no evidence that HQ Energy acted against its economic interest in any market. Rather, the facts of this case show that HQ Energy made price-taker bids and used [Transmission Congestion Contracts] to hedge congestion risk in a manner explicitly contemplated by the Commission." [1]

If the transaction is economic on a stand-alone basis, then it is consistent with a workably competitive market and there is no need to consider the impact on other financial contracts, large or small.

The outline of a principled policy extends the conventional stand-alone non-negative profitably test, with a unique market-clearing price, to the ambiguous case of degenerate prices. The generalized stand-alone profitability test would require demonstration of stand-alone losses for the transaction at all the possible prices in the degenerate price range in order to deem the action as "against economic interest." This would be a necessary but not sufficient test of price manipulation, requiring additional evidence of profits on other transactions as a result of the changes in market-clearing prices, persistence in the behavior and evidence of intent and ability to manipulate the complicated market in a sustained and profitable fashion. The generalized test would not require any consideration of other transactions or financial contracts. The generalized test would not require market participants to withhold otherwise apparently profitable transactions in order to maintain prices. The generalized test leaves the burden of

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[1] *DC Energy, LLC v. H.Q. Energy Servs. (U.S.), Inc.*, 124 FERC ¶ 61,295 at 22 (2008) [footnote in original omitted]. Transmission Congestion Contract is another term for Financial Transmission Right.

calculating alternative prices with the system operator who is the only entity with all the relevant information. The generalized test would not create any new unintended consequences from incentives to avoid financial transmission rights that serve such an essential purpose for efficient electricity markets.

Conclusion

Multiple market-clearing prices arise from degenerate pricing conditions that can occur in electricity markets under economic dispatch. In some instances, small changes in bilateral schedules can produce large changes in prices. These prices affect the value of associated financial transmission rights. A market-monitoring policy requires distinguishing transactions that are consistent with workably competitive markets from transactions that serve no economic purpose other than to manipulate prices and profit from other financial contracts. A natural test is stand-alone profitability of the transaction. Generalizing this standard to the degenerate conditions that give rise to multiple market-clearing prices provides a principled solution that is consistent with the market design without undermining the market-design foundations that integrate economic dispatch, locational prices and financial transmission rights.

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Endnote

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