Comments on the London Economics Methodology for Assessing the Benefits of Transmission Expansions

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Summary

These comments assess the extent to which the London Economics (LE) transmission upgrade evaluation methodology provides credible estimates of the benefits to expanding the California ISO network. Locational differences in electricity prices are the major determinant of the benefits of transmission upgrades. In the vertically integrated monopoly regime locational electricity price differences are driven by differences in the cost to the monopolist of producing or procuring electricity at each location in the transmission network. In the wholesale market regime, differences in production costs also determine locational price differences, but often the more important determinant of locational price differences is the amount of competition each seller of wholesale electricity faces at each location in the network. For this reason, the validity of any methodology for estimating the benefits of transmission upgrades in a wholesale market regime depends crucially on its ability to capture the impacts of generator market power in a potentially constrained transmission network on locational price differences. Capturing such impacts of strategic behavior in the context of a realistic model of the California ISO transmission network presents an enormous technical challenge.

The LE methodology attempts to estimate expected benefits considering multiple objectives, uncertainty in fuels, demands, and hydro conditions, and simulations of market power. These are critical goals for a transmission methodology, and if successful, would represent an important advance in the state-of-the-art. But we believe that the LE methodology has not been successful in several crucial ways. In particular, the methodology fails to recognize and adequately account for the technical challenges associated with quantifying the expected benefits of transmission upgrades. These shortcomings undermine the ability of the LE methodology to produce defensible estimates of the benefits of transmission upgrades to California ISO transmission network. Hence, we cannot endorse the adoption of the current LE methodology for the valuation of potential transmission expansions. Nevertheless, we would like to emphasize that the development of models to evaluate the value of transmission expansions in the wholesale electricity market regime is an evolutionary process that is still in its very early stages and the LE methodology is a useful contribution to this process. We also believe that it is too early in the process for the ISO to rely on a single tool or model for evaluating such a complex set of issues and decisions. Instead, we recommend using a variety of methods, each of which has different strengths and weaknesses. This approach should minimize the likelihood of significant errors in assessing the benefits of a proposed transmission upgrade.

The remainder of this memo summarizes the logic underlying our recommendations. To provide the appropriate context for conveying our logic, the next section characterizes the ideal methodology for evaluating transmission upgrades in a wholesale market regime and why it is not feasible to implement given the current state of knowledge in power systems engineering and economic theory. This is followed by a discussion of the key determinants of the benefits of transmission upgrades in a wholesale market regime. This section closes with a discussion of potential directions for simplifying the ideal methodology so that it captures these key determinants of the benefits of upgrades and is technologically feasible to implement. The third section summarizes the major shortcomings of the LE methodology. We also discuss why several of these shortcomings can introduce large enough errors in the estimated benefits of a transmission upgrade that we do not recommend the ISO adopt the LE methodology. The memo closes with suggested for analyses that would provide valuable input to the process of developing the methodology that the ISO would ultimately adopt.

Transmission Upgrade Evaluation Methodology for Wholesale Market Regime

The theoretically ideal methodology for evaluating transmission upgrades is an equilibrium model that can represent multiple strategic generation owners bidding for the right to supply electricity each hour of the day through a transmission network model that reflects the physical realities of the California market rules and grid. Solving such a model is currently beyond the research frontier in economics and power systems engineering. Neither the economic nor the power flow models are, by themselves, beyond the capability of either discipline. The currently insurmountable complexity of this problem arises from the combination of strategic behavior by firms owning multiple generation units with the requirement that power flows respect the capacity constraints and the physical realities of a looped transmission network.

Consequently, to make any progress on quantifying the benefits of transmission expansions, it is necessary to make simplifying assumptions, many of which may be very unrealistic. For this reason, any framework for assessing the benefits of transmission upgrades must take account of the potential consequences of those assumptions. Simplifying assumptions made to obtain computational tractability can create logical inconsistencies between different components of an economic model of generator behavior, or between the economic model and the engineering model governing operation of the transmission network. We feel that the methodology proposed by LE and its associated simplifying assumptions falls prey to these problems. We also believe that it fails to account for important dimensions of the benefits of transmission upgrades.

Transmission Capacity Adequacy in a Wholesale Market Regime

Existing transmission networks throughout the United States were designed to be operated by vertically-integrated geographic monopolies. The key feature of these networks is that they take advantage of the fact that the same entity—the geographic monopoly—owned and operated the transmission and distribution network, as well as the vast majority of generating units needed to meet the monopolist's load obligations. Moreover, these transmission networks were primarily constructed to guarantee the engineering reliability of each control area. In general, these networks were not designed to facilitate substantial across-region or within-control-area trade of electricity. They were built to ensure a pre-specified level of reliability in the monopolist's control area by allowing resources from neighboring regions to be used when there is inadequate local generation available to meet local demand.

Particularly for large population centers and geographically remote areas, the vertically integrated monopolist used a mix of local generation and transmission capacity (bringing distant generation) to meet the area's annual electricity needs. Typically, the geographic monopolist supplied the region's base load energy needs from distant inexpensive units using high-voltage transmission lines. The monopolist used expensive generating units located near the load center to meet local demand peaks. Under the vertically integrated monopoly regime, the firm had a legal obligation to serve all demand at the regulated retail price. For this reason, the vertically integrated monopoly utilities had no incentive to withhold output from low-cost generation units in any part of its network.

In contrast, under the wholesale market regime, the owner of local generating units is financially independent of the operator of the transmission network. These firms can earn higher profits by bidding or scheduling their generation units to raise prices in the wholesale market. Their ability to raise prices depends on the scheduling and bidding behavior of other firms, the configuration of the transmission network, the level and geographic distribution of demand, and the amount of capacity the firm owns. In most large population centers, the limits of the transmission network convey tremendous market power to the owners of generation located within these regions. Specifically, when the amount transmission capacity available to bring distant generation into a local area is less than the level of demand in that area, if a single firm owns all of the local generation units in this area, this firm can bid whatever the market will bear for the energy it must supply from its units.

Key Determinants of the Value of Transmission Capacity in Wholesale Market Regime

This logic suggests several important determinants of the benefits of transmission upgrades in a wholesale market regime that extend beyond the benefits provided by transmission under regulation. Transmission networks provide an important role in supporting competition as well as maintaining reliability. Further, the presence of a restructured wholesale market changes the definition of what constitutes a reliable transmission network. The ability to exercise market power gives the firm an incentive to reduce output, thereby likely increasing congestion and limiting reliability. However, the threat that any reduced output would simply be replaced by other firms significantly limits the incentives a firm has to try and reduce output in the first place. Transmission capacity into a region provides that competitive threat. We define an economically reliable transmission network as one with sufficient capacity so that each location in the network faces sufficient competition from distant generation to cause local unit owners to compete with distant generation unit owners rather than withhold output to cause congestion and create a local monopoly market.

The value of increasing the transmission capacity between two points still depends in part on the extent to which this expansion allows substitution of "cheap" generation in one area for "expensive" generation in the other area. However, in a restructured wholesale market, the differences between "cheap" and "expensive" generation can be orders of magnitude larger than under regulation. This is because the high price of expensive generation will reflect both production cost considerations and market power. In circumstances where market power is severe, the vast majority of difference between prices in different locations is driven by market power rather than production costs. For example, during early 2000, when the price cap on the California ISO real-time market was $750/MWh, congestion between the SP15 and NP15 zones led to price differences between the two zones equal to as much $700/MWh, despite the fact that the difference in the variable costs of the highest cost units operating in the two zones was less than $20/MWh.

By increasing competition at locations in the ISO's control area, the addition of new transmission capacity can make the "cheap" power "cheaper." This is because in the wholesale market regime even low-cost generation units may offer to sell at prices well above their variable cost. However, in the face of substantial potential competition resulting from significant transmission capacity relative to local demand at each location in the transmission network, generation unit owners would be unable to raise their offer prices substantially above its variable costs and still expect to sell electricity. For this reason, increasing transmission capacity can in fact lower prices in *all* locations, not just in those suffering the most congestion.

The above discussion highlights the crucial difference between valuing transmission under a vertically-integrated regulated-monopoly regime and a wholesale market regime: Transmission capacity limits the ability of generation unit owners to exercise market power. For any methodology to quantify accurately the benefits of transmission expansions in a wholesale market regime, it must accurately account for the strategic behavior of generation unit owners operating within a potentially constrained network.

Increased Reliability Risk in a Market Environment

In the vertically integrated monopoly regime, one rationale for upgrades of the monopolist's network was to manage the reliability risk associated with generation or transmission line outages. For example, an upgrade could be justified by the logic that if certain generating units became unavailable, the supply shortfall could be temporarily served with distant, but more expensive, generating units. The reliability justification for such upgrades was that the cost of upgrade was less than the economic value created by the distant generation that could be consumed because of the transmission upgrade.

Under the competitive market regime, generation unit owners have an additional incentive to declare a unit unavailable, besides the fact that it is physically unable to operate. They may find it profitable to create an artificial scarcity of generating capacity in a geographic area in order to increase the wholesale price they receive for the energy they do sell. As discussed above, this incentive to withhold generating capacity did not exist in the regulated monopoly regime. However, in the wholesale market regime, if a firm is able to raise the price it receives for its energy by 100% by withholding less than 10% of its capacity, it will find this behavior unilaterally profitable.

Consequently, in the wholesale market regime, the reliability risk has an additional dimension because of the incentive generation unit owners have to declare generation capacity unavailable in order to raise prices if they do not face sufficient competition. For example, few, if any, market observers would have predicted that the California ISO would have a daily average of approximately 10,000 MW of generating units in the California ISO control area unavailable during the seven-month period November 2000 to May 2001. Additional transmission capacity can render physical withholding strategies, which may lead to load curtailments, less profitable and therefore less likely to occur.

The above discussion suggests that any methodology for evaluating transmission upgrades in a wholesale market regime must account for the strategic behavior of generation unit owners bidding to supply electricity each hour of the day through a transmission network model that reflects the physical realities of the California system. With this methodology, market outcomes could be simulated with and without the proposed transmission upgrade. These market outcomes would reflect the impact of transmission upgrades on the profitability of generators withholding capacity from the market by either bidding in excess of their operating costs or by simply declaring capacity unavailable. Given the enormous potential across-location wholesale price risk associated with the exercise of market power, any credible methodology must realistically model the market power reducing implications of transmission upgrades.

If we would like to solve for the equilibrium strategies of all firms selling in the various markets operated by the California ISO accounting for the portfolio of generation units the firm owns and the potential opportunities to sell energy and ancillary services at various time horizons before delivery, then the computational complexity increases to the point of being impossible to solve in a reasonable period of time. This conclusion remains valid even if we do not attempt to account for the configuration of the ISO transmission network. Because the goal of this modeling effort is to assess the benefits of transmission upgrades, adding a realistic network model of the California ISO control area is essential. Moreover, we also expect market outcomes to be very sensitive to the details of the assumed transmission network model. Unfortunately, modeling strategic firms competing through a realistic representation of the California ISO transmission network with finite capacity yields a model that is currently impossible to solve in finite time.

In order to make progress on this question some modeling compromises must be made. However, we believe that a number of the modeling compromises made by LE fail to recognize and adequately account for the additional economic and reliability dimensions of the benefits of transmission upgrades in a wholesale market regime.

Areas of Concern with the London Economics Methodology

We identify five areas of concern with the August 2002 version of the LE methodology that we feel limit its ability to produce accurate estimates of the benefits of transmission upgrades for the California market. These are: (1) the method used to model the exercise of market power by generation unit owners, (2) the relatively simplistic model of the California ISO transmission network, (3) the limited range of market outcome scenarios selected, (4) the approach used to model of new generation unit investment, and (5) the use of linear interpolation techniques to estimate total producer and consumer benefits for market outcome scenarios not explicitly modeled.

Our first area of concern is the way the LE methodology models the exercise of market power by generation unit owners. We have two specific criticisms here. The first relates to the unintended consequences of simplifying assumptions. Specifically, we are not convinced that the approach used by LE to compute a “converged strategy” for each generation unit owner satisfies the standard properties of an economic equilibrium. If LE cannot establish that its simulated market outcome constitutes an economic equilibrium, this market outcome is no more valid a representation of actual market outcomes than any other technologically feasible market outcome. This leads to our second criticism of the LE market-power modeling process: It is unable to replicate important qualitative features of actual market outcomes. Specifically, when LE applied their methodology to market data from the summer of 2000, their analysis produced bid curves and market outcomes that reflected far less market power than that indicated by studies performed by the MSC, the ISO’s Department of Market Analysis, and a number of independent academic studies. While we would not expect such a model to reproduce market prices with a high level of accuracy, we would feel much more comfortable with a model that can reproduce the general pattern and severity of the market power reflected in actual market outcomes over the first four years of market operations. Because a significant source of the benefits of transmission upgrades in a wholesale market regime is the potential to limit the market power that any generation unit owner can exercise, it is essential that the ISO's transmission evaluation methodology at least be able to reproduce qualitatively the market power actually exercised in the California market.

Our second source of concern with the LE methodology is its relatively simplistic representation of the California transmission network. Although this may be adequate to obtain a rough estimate of the benefits for the Path 26 upgrade, it is not likely to suffice in general. At the very least, there needs to be more analysis of the impact of the level of detail in the network model on the expected benefit estimates. This shortcoming of the LE methodology is even more problematic if the ISO adopts locational marginal pricing (LMP), as it proposes to do as part of the Market Design 2002.

A third area of concern with the methodology is its approach to market outcome scenario development and selection. In essence, we are concerned that there is an over-representation of the most likely market outcome scenarios at the expense of potential extreme scenarios under which the benefits of transmission will be most heavily realized. Transmission expansion represents an important option for limiting the harm to consumers caused by extreme system conditions. In this sense, transmission investments can be seen as physical insurance against either economic or reliability-based “worst-case” outcomes. Selection of scenarios that under represent extreme market outcomes will underestimate the expected benefits of a proposed transmission expansion.

There are also shortcomings with how LE determines the likelihood of the various market outcome scenarios. Rather than make subjective assessments about the joint density of these scenarios and compute the resulting probability distribution of benefits associated with a given transmission upgrade, LE treats each scenario in the case study as equally likely. As noted above, the number of "extreme" scenarios is also limited. The methodology does not allow the model user to vary the assumed joint probability distribution of market outcome scenarios, which significantly limits the methodology's usefulness. Because the joint distribution future market outcomes is unknown, it is imperative that the methodology allows users to analyze the implications of alternative joint distributions constructed by either changing the probabilities of a given set of scenarios or by simulating additional market outcomes. For a given set of market outcome scenarios, finding the set of joint distributions of market outcomes where the expected benefits of the upgrade exceed the cost of the upgrade would provide very useful input to the decision-making process.

A fourth area of concern is with the modeling of generation investment and retirement. For the most part, LE currently limits consideration of entry to the representation of three different entry scenarios. Intuitively, the amount of generation investment will be influenced by the level of transmission investment. However, a fully strategic model of generator entry and bidding behavior is presently out of the realm of computational feasibility.

For this reason we recommend considering a wide range of plausible scenarios for these issues, rather than assume a simple *ad hoc* rule for how much new investment might take place, as appears to be the case with the LE methodology. Our preferred approach is to model entry as a function of expectations of future prices and other market conditions, because we believe that actual entry depends on expectations about the future profitability of new generation capacity.

A final concern we have with the LE approach is the use of linear interpolation techniques to estimate the total benefits for a baseline or counterfactual market outcome scenario. We feel that this can introduce significant bias in LE's estimates of the benefits of transmission upgrades. To economize on the number of scenarios it had to run, LE simulated a subset of the potential upgrade scenarios for each set of market conditions and then estimated a linear regression model relating the total benefits for each scenario to market conditions and the choice of transmission upgrade. The total benefits for scenarios that were not explicitly simulated were estimated by the predicted value from this linear regression evaluated at the appropriate values for system conditions and Path15 and Path26 upgrade indicator variables.

This methodology introduces significant bias in the estimated benefits of transmission upgrades for the following reason. The true relationship between the level of benefits and system conditions and the values of the Path15 upgrade and Path26 upgrade indicator variables is an unknown nonlinear function of these system conditions. Consequently, the linear regression model LE estimates is a misspecified version of the true nonlinear function. For this reason, the estimated linear regression coefficients associated with the Path15 and Path26 indicator variables are likely to be substantially biased estimates of the true marginal increase in benefits to these upgrades. Using biased estimates of total benefits under either the no-upgrade or upgrade scenario implies biased estimates of the expected benefits of the upgrade taken over all system condition scenarios.

This source of bias can be eliminated by estimating a complete set of transmission upgrade scenarios (including the no-upgrade scenario) for each set of assumed system conditions. With a complete set of market outcomes for each possible upgrade scenario under the same set of system conditions, there is no need to use linear interpolation techniques to estimate total benefits for any upgrade scenario.

Desirable Elements of a Comprehensive Methodology

We want to stress that the development of models that capture all of the important elements of a transmission expansion decision in wholesale market regime is in its infancy. Our concerns with the LE methodology suggest several recommendations for moving this process forward. First is the appropriate measure of the benefits of transmission upgrades. The second issue is how to account for two competing goals: to have a realistic model of the California transmission network and market rules, and the desire to model strategic behavior by generation unit owners. The final issue is how to deal with the many degrees of uncertainty about future system conditions and market participant behavior.

Two sources of the benefits of transmission upgrades are the reduction in system-wide production costs and the increase in system-wide consumer surplus that result from this expansion. Giving market power profits the same weight as increases in consumer surplus or reductions in production costs cast transmission upgrades in the most unfavorable light. This is because transfers of market power-derived profits from producers to consumers will net to zero if market power profits are given the same weight as consumer benefits. Valuing market power profits the same as production cost reductions in the total benefits process ignores the fact that monopoly profits are often used by firms in a socially wasteful manner, specifically to protect and perpetuate these monopoly profits. It also ignores the potential dynamic efficiency benefits of more intense competition, in the form of greater incentives for technical and product innovation that do not exist under conditions of extreme market power. For these reasons, purely from a social welfare perspective, monopoly profits should be given less weight than production cost reductions and consumer surplus increases in the expected benefits calculation.

For the same reason that the highways and roads are built to facilitate competitive markets for goods and services delivered along these roads and not to enhance the market power of certain firms, transmission capacity should be built to facilitate competitive electricity markets. A measure of benefits that primarily weights total production costs reductions and consumer surplus increases guarantees that transmission will be built for this purpose.

Turning to the competing goals of physical and strategic realism, because of the extreme difficulty associated with constructing a realistic model of strategic behavior among a small number of large generators in a transmission network similar to the one in California, *any* single simulation model approach is unlikely to yield completely satisfactory measures of the benefits of transmission upgrades.[1] A model that can be solved in finite time is not likely to have realistic

[1] We would like to emphasize that we believe that simulation models can give valuable insights as to the ways in which market power can be exercised and its extent and effects. However, because of the different modeling compromises and assumptions that alternative modeling methods make, the resulting quantitative price and benefit

representations of the transmission network, the actual strategy space available to generation unit owners, and the actual price-setting process. Practical models must make compromises; different compromises and assumptions will yield different estimates of the extent and effect of market power. This suggests an alternative strategy for developing a methodology for assessing transmission upgrades. Instead of attempting to solve for an economic equilibrium with strategic players, one could develop a model that allows the user to input any possible joint distribution of modeling inputs and market conditions in order to compute the resulting distribution of market outcomes. In this way, the model could allow any user to input their subjective beliefs about system conditions and firm-level behavior that are extremely difficult, if not impossible, to predict accurately. In this way, the model user could turn the question of assessing the benefits of a transmission upgrade into one about the joint density of market primitives necessary to make this transmission upgrade financially viable.

The result of this approach would be a tool that policymakers and regulators could use to input their own assumptions about future market conditions in order to assess the desirability of a given transmission upgrade. These assumptions could be based on expert judgment, or could be informed by models such as LE's or other strategic modeling methods. Given the enormous uncertainty about the parameters that enter any benefit assessment process, this approach seems far more defensible than one that would require the production of a specific number or range of numbers. Instead, this approach would demonstrate the sorts of probabilities that would need to be assigned to certain market conditions in order for a given transmission upgrade to be viable. Policymakers could then make the decision as to whether the risk of these conditions is sufficiently great to justify the proposed upgrade.

If the experience of the California ISO with the current Path15 upgrade is any indication, the process of assessing the benefits of a given transmission upgrade is an interactive and iterative process precisely because of the enormous uncertainty associated with future system conditions. To the extent that the ISO has a realistic model of the California transmission network and price-setting process that can be easily solved a large number of times for a large number of potential scenarios (which include different assumptions about generation unit owner bidding behavior), the ISO can quickly respond to inquiries about the benefits of any scenario that a stakeholder or regulator might want to consider. In this way, the ISO's transmission assessment methodology will not fall prey to complaints by stakeholders and regulators that it contains unrealistic or implausible assumptions about future market conditions. The methodology can be easily adjusted to deal with any set of conditions a stakeholder might be interested in assessing.

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estimates can differ greatly. For instance, the precise functional form assumed for bid curves can result in large differences in equilibrium outcomes for models that simulate bid-based competition among generation unit owners to supply electricity. Therefore, no single model for predicting market outcomes should be relied upon; instead, more than one strategic modeling approach should be applied to assess the extent to which benefit estimates are sensitive to modeling assumptions.