Congestion Cost Examples
Societal Cost Approach vs. Load Payments Approach

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Overview

An ongoing debate is taking place about the preferred approach to measuring the congestion costs associated with transmission constraints. Two estimation methods have risen to the top. They are:

1. *Societal Cost Approach*. This is also known as the Bid Production Cost approach. It makes the assumption that generator bids equal the marginal cost of production. It estimates congestion costs to equal the reduction in total production costs that would occur if the existing transmission system and its constraints were replaced by an unlimited transmission system that had no constraints. In essence, it is a measure of the production cost savings that could be had if all the low-cost power in the low-cost parts of the system could be transported to displace higher cost power in the high-cost parts of the system.

2. *Load Payments Approach*. This method measures the total payments by load (spot price times quantity, by location), under the current, congested system, and estimates how these total load payments would change if an unlimited transmission system that eliminated all constraints were to exist.

The purpose of this exercise is to use a small number of numerical examples to demonstrate some of the properties of these two approaches. The examples use a simple system in which there are two locations: a low-cost location and a high-cost location. The low-cost part of the electric system faces a transmission constraint between it and the high-cost part of the electric system. This constrained system is then compared to an unconstrained system and quantifications of congestion costs are performed using the two approaches.

Example 1

Example 1 is based on Figure 1.

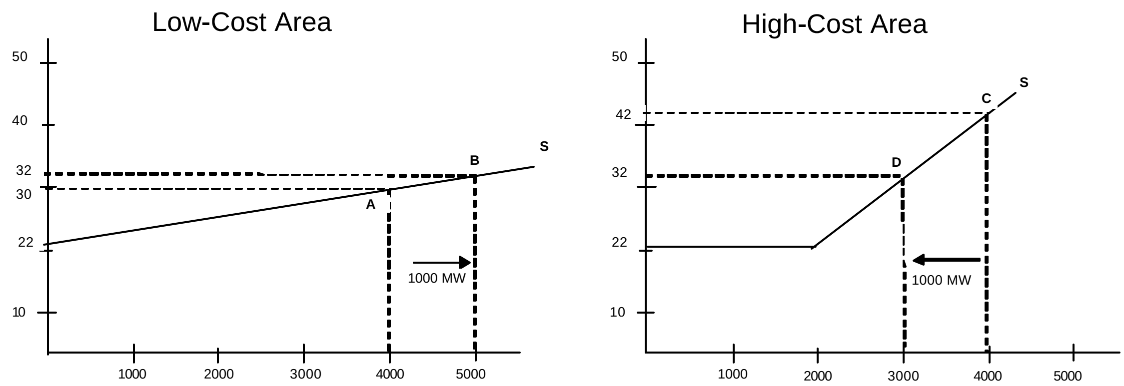

Figure 1: Congestion Cost Example 1

The low-cost area starts at point A, at which the area's 4,000 MW of load is served by the area's own relatively low-cost generation. At the starting point, which is the constrained system, a transmission constraint permits no power to flow to the high-cost area. As the constraint is removed, the dispatch of generation in the low-cost area slides up its supply curve from point A to point B. The reverse occurs in the high-cost area. Its starting point constrained system starts at point C where all of its load is served by its own relatively high-cost generation; then, as the constraint is removed, its production is reduced, sliding down its supply curve from point C to point D. In the unconstrained case, the system equilibrates where the marginal cost in the low-cost area equals the marginal cost in the high-cost area (line losses are ignored, for simplicity). This occurs at a marginal cost of $32/MWh in Example 1, at points B and D. A thousand megawatts of power moves from the low-cost area to supply load in the high-cost area.

Example 1 has a relatively shallow supply curve in the low-cost area; this means that the extra 1,000 MW of generation in the low-cost area will cause only a modest rise in the low-cost area's LBMP (from $30/MWh to $32/MWh). The high-cost area's supply curve is relatively steep; this yields a substantial drop in the high-cost area's LBMP (from $42/MWh to $32/MWh) as it backs down 1,000 MW of its generation to accommodate the inflow of the cheaper low-cost area's generation. This difference in the steepness of the supply curves of the two areas is one of the driving factors in the calculation of congestion costs using the Load Payments Approach. It is a much less important factor in the congestion calculation using the Societal Cost Approach.

Congestion, Societal Cost Approach (Example 1): This calculation is quite simple in the example. One compares the constrained case to the unconstrained case and measures the saved bid production costs that occur. This equals the difference between the cost of the generators that are backed down in the high-cost area and the cost of the generators that are ramped up in the low-cost area. In Example 1, 1,000 MW of generation in the high-cost area, with an average cost of $37, is backed down and is replaced by 1,000 MW of generation in the low-cost area with an average cost of $31. The result is a congestion cost that equals $6,000. (Calculations are shown in Appendix A.)

Congestion, Load Payment Approach (Example 1): The load payment approach calls for a comparison of the amount paid by load in the constrained system to the amount paid by load in the unconstrained system. The beginning and ending point LBMPs are key here. A move to an unconstrained system will always tend to lower the market price in the receiving area and raise the market price in the sending area. The net result of the Load Payment Approach's calculation of congestion hinges on the relative sizes of the lowered payments of loads in the receiving area and the increased payments of loads in the sending area.

The result for Example 1 is a value of congestion that equals $32,000. This is the net effect of a $40,000 improvement in bills in the high-cost area and an $8,000 worsening of bills in the low-cost area that occurs upon the elimination of congestion. A look back at the supply curves in Figure 1 shows that the receiving area's supply curve is steeper than the sending area's supply curve over the relevant portion of the curves associated with the re-dispatch caused by the constraint. It is this steepness difference that causes the bill reduction of the receiving area's load to outweigh the bill increase of the sending area's load, yielding a positive value of congestion cost.

Example 2

Example 2 is based on Figure 2.

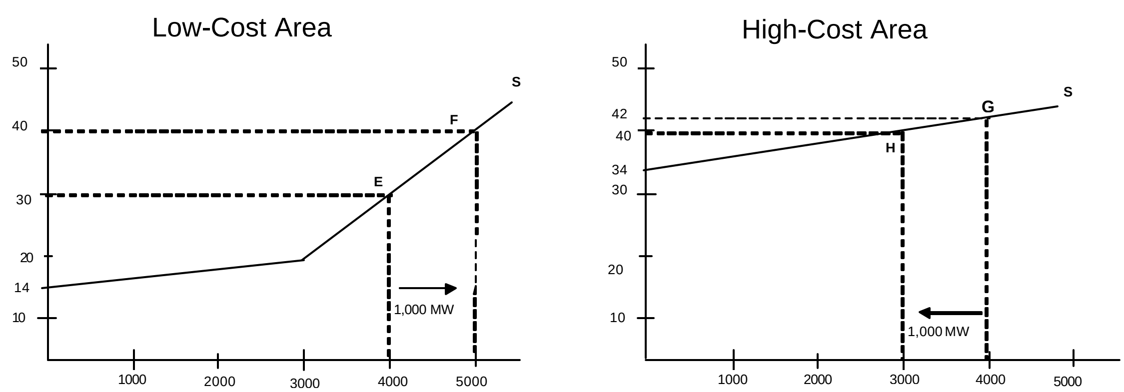

Figure 2: Congestion Cost Example 2

This is set up much the same as Example 1, except this time the low-cost area has the steep supply curve, and the high-cost area has the shallow one.

<u>Congestion, Societal Cost Approach (Example 2)</u>: The savings in bid production costs are found by comparing the cost savings from backing down the high-cost area's marginal generation (1,000 MW at an average cost of $41) to the costs incurred in ramping up the low-cost area's marginal generation (1,000 MW at an average cost of $35). The result is a bid production cost savings from eliminating the constraint of $6,000. This is the Societal Cost Approach's congestion cost estimate.

Congestion, Load Payment Approach (Example 2): According to the Load Payment Approach, congestion is defined as the difference between load payments in the congested system and load payments in the uncongested system. In this example, the price reduction in the receiving area is quite small ($2), whereas the price rise in the sending area is large ($10). This causes the receiving area's bill reductions to be swamped by the effect of the sending area's increased bills. The net result is a congestion cost of -$32,000.

The result is a confounding one; it says that congestion cost is negative. In other words, the method appears to tell one that the transmission constraint is beneficial. As with Example 1, this result is driven by the relative steepness of the supply curves in the two areas.

Example 3

Example 3 is based on Figure 3.

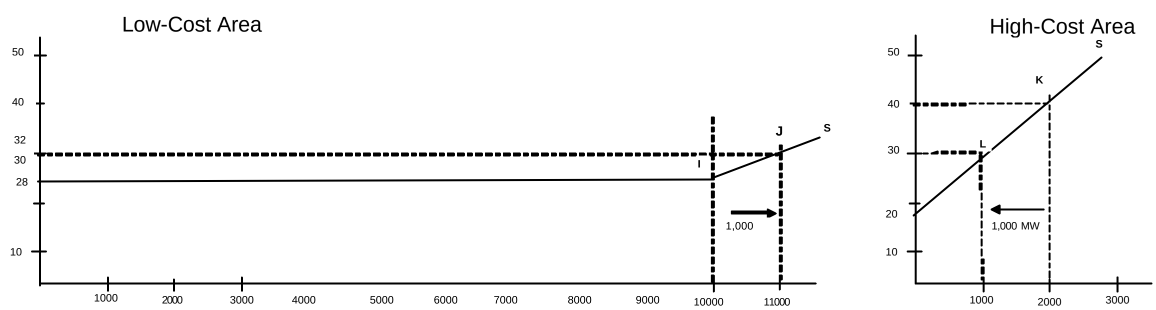

Figure 3: Congestion Cost Example 3

Figure 3 depicts two areas, one low cost and one high cost. The high-cost area can be thought of as a small load pocket (2,000 MW of load) alongside a much larger, lower cost, system (10,000 MW of load). At the starting point, no transmission connects the small load pocket to the larger system. The 2,000 MW of load in the load pocket is met entirely by the pocket's internal generation, yielding a market price of $40/MWh (at point K). This is substantially higher than the $28/MWh market price at which the larger market serves its 10,000 MW of load (at point I). The elimination of the transmission constraint enables the larger system's cheaper power to flow into the small load pocket, reaching an equilibrium at which 1,000 MW moves into the pocket, and the market clearing price in both areas is $30/MWh.

Congestion, Societal Cost Approach (Example 3): The average cost of the marginal generation backed down in the small load pocket is $35/MWh. The average cost of the marginal generation ramped up in the large system is $29. With 1,000 MW moving from the latter to the former, the total savings from eliminating the transmission constraint is $6,000. This is the Societal Cost Approach's estimate of the congestion cost caused by the constraint.

Congestion, Load Payment Approach (Example 3): The elimination of the transmission constraint provides a benefit to the loads inside the pocket via a price drop from $40 (point K) to $30 (point L). At the same time, prices in the larger system are pushed up from $28 (point I) to $30 (point J). According to the Load Payment Approach, the quantitative measure of congestion depends on the net effect of the fall in load payments in the small pocket and the rise in load payments in the larger system. When one does the math for this example, one gets a congestion cost estimate of zero.

This is an unusual result. Even though the transmission constraint prevents the flow of cheap power into a small pocket where it could displace more expensive power, the Load Payment Approach says that the cost of this congestion is $0. This result occurs in Example 3 because, even though the price reduction in the small pocket (a $10 reduction) is much more significant than the price increase in the large system (a $2 increase), the latter applies to a much bigger base (a load of 10,000 MW compared to 2,000 MW). The Load Payment Approach, therefore, yields a computation in which the decreased payments by loads in the small pocket are exactly offset by the increased payments by loads in the large system. Thus, a $0 value occurs despite the apparent cost savings to the system that takes place when the constraint is eliminated and the more expensive small pocket generators can be backed down in deference to the cheaper power that can now enter the load pocket to serve the load.

<u>Where Did the $6,000 Savings Go (Example 3)?</u>

To shed a little more light on this example, it is instructive to look at how eliminating the constraint affects generators. Generators' revenues in Example 3 don't change upon elimination of the constraint, but their profits go up by $6,000, as a group, due to the $6,000 of production cost savings that are realized from running the low-cost units more and the high-cost units less. Thus, in Example 3, the elimination of the constraint yields a societal gain of $6,000, and all of it takes the form of an increase in the profits of generators.

One could go back to Examples 1 and 2 and calculate the effect of the constraint on generators, but for the sake of brevity, this is not done here. A conclusion that can be drawn, however, is that while the Societal Cost Approach is solely driven by the societal costs of congestion, the Load Payment Approach depends heavily on how those societal costs are distributed between generators and load.

Conclusion

The results of the three Examples are shown in the table below.

	Amount of Low-Cost Power That Can Be Moved Into High-Cost Area Upon Removal of the Constraint	Congestion, Based on the Societal Cost Approach	Congestion, Based on the Load Payment Approach
Example 1	1,000 MW	$6,000	$32,000
Example 2	1,000 MW	$6,000	-$32,000
Example 3	1,000 MW	$6,000	$0

In all three examples, Congestion is eliminated by the assumption of unlimited transmission. In all three examples, 1,000 MW of low-cost power is initially prevented from flowing into the high-cost area, but is then allowed to flow by the elimination of the constraint. The numerical estimates of the cost of congestion are computed by comparing the transmission constrained system to the unconstrained system. The Societal Cost Approach yields results that consistently show a positive value for congestion. The Load Payment Approach, however, yields a confusing set of results, including a result that purports to show that congestion costs are negative (Example 2). One property of the Load Payment Approach is that it is unstable; its results depend on the relative sizes of the load payment decrease in the receiving area and the load payment increase in the sending area. These, in turn, depend on factors like the steepness of the supply curves and the size of the loads in the two markets.

As a final note, it should be stressed that each of these approaches are short-run measures, meaning that they look at changes in the short-run operation of the system for a given set of generators, rather than taking the further step of evaluating how a reduction/elimination of a transmission constraint might, over the longer run, affect the set of generators themselves, either through retirement of existing units, or entry into the market by new units. Considerations of long-run adjustments, and how they affect measures of congestion are left for another exercise.

Appendix A – Congestion Cost Calculations

Subscript "O" represents the starting point constrained system.

Subscript "1" is the ending point unconstrained system.

Superscripts "L" and "H" represent the low-cost and high-cost areas, respectively.

Example 1 – Societal Cost Approach

Congestion = Total Bid Production Cost Savings from Eliminating Constraint
= Cost Reduction^{H} – Cost Increase^{L}
= (1,000)(37) – (1,000)(31)
= 37,000 – 31,000
= $6,000

Example 1 – Load Payment Approach

Congestion = Load Payments w/Congestion – Load Payments w/o Congestion
= Change in Load Payments Caused by Congestion
= [Change in Low-Cost Area's Load Payments] + [Change in High-Cost Area's Load Payments]
= [Bills^{L}_{O} - Bills^{L}_{1}] + [Bills^{H}_{O} - Bills^{H}_{1}]
= [(4,000)(30) - (4,000)(32)] + [(4,000)(42) - (4,000)(32)]
= [120,000 – 128,000] + [168,000 – 128,000]
= -8,000 + 40,000
= $32,000

Example 2 – Societal Cost Approach

Congestion = Total Bid Production Cost Savings from Eliminating Constraint
= Cost Reduction^{H} – Cost Increase^{L}
= (1,000)(41) – (1,000)(35)
= 41,000 – 35,000
= $6,000

Example 2 – Load Payment Approach

Congestion = Load Payments w/Congestion – Load Payments w/o Congestion
= Change in Load Payments Caused by Congestion
= [Change in Low-Cost Area's Load Payments] + [Change in High-Cost Area's Load Payments]
= [Bills^{L}_{O} - Bills^{L}_{1}] + [Bills^{H}_{O} - Bills^{H}_{1}]
= [(4,000)(30) - (4,000)(40)] + [(4,000)(42) - (4,000)(40)]
= [120,000 – 160,000] + [168,000 – 160,000]
= -40,000 + 8,000
= -$32,000

Example 3 - Societal Cost Approach

Congestion = Total Bid Production Cost Savings from Eliminating Constraint
$= \text{Cost Reduction}^H - \text{Cost Increase}^L$
= (1,000)(35) – (1,000)(29)
= 35,000 – 29,000
= $6,000

Example 3 – Load Payment Approach

Congestion = Load Payments w/Congestion – Load Payments w/o Congestion
= Change in Load Payments Caused by Congestion
= [Change in Low-Cost Area's Load Payments] + [Change in High-Cost Area's Load Payments]
$= [\text{Bills}^L_O - \text{Bills}^L_1] + [\text{Bills}^H_O - \text{Bills}^H_1]$
= [(10,000)(28) - (10,000)(30)] + [(2,000)(40) - (2,000)(30)]
= [280,000 – 300,000] + [80,000 – 60,000]
= -20,000 + 20,000
= $0