Congestion Example
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Introduction

This example uses some very simple supply curves for exporting ("West") and importing ("East") markets to demonstrate some possible outcomes for several measures that have been used to estimate congestion. The purpose is to gain a deeper understanding of how the parts of these congestion measures behave in yielding estimation results.

Three methods are examined. They are:

1. **Simple Congestion Costs.** This is the value one obtains by simply multiplying the congestion component of each zone's hourly LMBP (spot price) by its hourly load, and summing across all zones. This approach uses data from the starting point congested system only. It does not evaluate a hypothetical changed system in which congestion is eliminated.
2. **Societal Congestion Costs.** This approach estimates the added production costs incurred by the electric system to serve load in a congested system compared to a hypothetical congestion-free system.
3. **Load Payments Congestion Cost.** This approach estimates the added payments made by load (i.e., buyers) in a congested system compared to the payments made by load in a hypothetical uncongested system.

One possible set of results for these three methods is:

Method	Result
Simple	Large positive congestion cost
Societal	Small positive congestion cost
Load Payments	Negative congestion cost

The negative estimate of congestion costs using the load payments method means that the payments made by load in the congested system are smaller than the payments made by load in an uncongested system. In other words, the elimination of congestion causes the total payments by load to go up. The specific example used in this analysis will show that the above seemingly contradictory set of results, including the negative value for congestion cost, can occur for a hypothetical electric system that is in no way unusual or distorted.

The Starting Point System

The attached figures show the hypothetical system. The West has excess cheap power. The East has mostly high-cost power. At the starting point, the East's load of 90 MW is supplied in part by importing as much from the West as the system's transmission can handle. In the figure, 26 MW is imported. This, combined with 64 MW of East's own generation, satisfied East's 90 MW of load. The West produces 26 more MW power than it consumes, 106 MW vs. 80 MW. (Line losses are ignored for simplicity.)

The starting point price in the East is $50, as seen at point A. The West price is $40, as seen at point C. Congestion per MWh is, therefore, $10 ($50 minus $40).

The Simple Congestion Cost Estimate

The Simple Congestion Cost approach can be applied to this system to get its estimate of congestion. In the East, it is simply the $10/MWh congestion value multiplied by the 90 MWh/hour load, which equals $900. Using the Simple Congestion Cost approach, there is no congestion cost in the west, since the West is assumed to be the geographic location where the reference bus resides, and since there is no difference between the West's LBMP and the reference bus's LBMP, there is no congestion in the West, according to the method. Thus, $900 is the estimate of congestion for the Simple Congestion Cost method.

The other two estimation methods require knowledge about the characteristics of the system that would prevail if it were to have unlimited transmission that eliminated all congestion. This is what we now turn to.

The Unlimited Transmission Scenario

Points B in the East and D in the West represent the outcome for the system if it were to have unlimited transmission. Compared to the starting point scenario, unlimited transmission allows more of the West's cheap power to be used to serve the East's load. The equilibrium between the two markets occurs when the West has slid up its supply curve to D, the East has slid down its supply curve to B, and the marginal cost on the two curves equal each other, which occurs at a market price of $45 in the example. All congestion is eliminated. The West produces 120 MW of power, 80 MW of which it uses for itself and 40 MW that it ships to the East. The East provides for its 90 MW of load by generating 50 MW of its own power and buying 40 MW from the West.

The Societal Congestion Cost Estimate

In the figure, the societal benefit of eliminating congestion is simply the production costs saved by being able to ramp up 14 more MW of cheap West generation (moving from point C to point D) and using it to back down 14 MW of relatively expensive East generation (moving from point A to point B). This benefit is worth \$5/MWh, and totals \$70 (\$5/MWh times 14 MWh per hour). Thus, the estimate of the Societal Congestion Cost is \$70. This is dramatically lower than the \$900 estimate obtained using the Simple Congestion Cost approach.

The Load Payment Congestion Cost Estimate

The Load Payment approach is the most difficult to estimate, although it is really not all that hard. The difficulty arises from the need to examine the payments that Loads receive from Transmission Congestion Contracts (TCCs), and the need to account for the way these payments are affected by the elimination of congestion.

In the example, it is assumed that the East buyers (or their regulated transmission companies) own the transmission that initially connects the two markets. They therefore receive the benefit of payments made related to TCCs. At the starting point, these TCC revenues equal \$260 (26 MWh times \$10 per MWh). They vanish, however, upon the elimination of the constraint.

There are three pools of money that constitute the load payments:

1. East load payments at the East LBMP,
2. West load payments at the West LBMP, and
3. TCC payments received by East loads.

In moving from the constrained to the unconstrained case, the increase in the West LBMP rise causes West load payments to rise; the decrease in the East LBMP causes the East load payments to fall; and the TCC payments to East loads are eliminated (this loss of revenues equates to an increase in the East load payments).

It is the net of the above three effects that determine whether the elimination of a constraint causes the total system load payments to rise or fall. In the example, an interesting outcome occurs; the elimination of the constraint yields an increase in the total system load payments of $210. (Calculations are attached.) Thus, the Load Payments Congestion Cost is -$210, i.e., congestion actually is beneficial to load, according to this approach. In terms of West vs. East, a reduction in load payments by the East of $190 is more than offset by an increase in the load payments by the West of $400.

A second, perhaps easier, way of understanding how the elimination of the constraint can raise total payments is to dismiss the TCC concept and just think of the starting point of 26 MW of transmission that links West to East as being owned by East and as giving 26 MW of East load physical access to West. With this physical access, 26 MW of East load can buy power at the West LBMP. At this starting point, therefore, 26 MW of East load is bought at the West's LBMP of $40. Combined with the 80 MW of West load that is bought at the same $40 West price, there is a total of 106 MW of load whose purchases are priced at the West LBMP. East load, therefore, buys just 64 MW of its needs from East generators at the East's $50 price.

In total, there is more of the system's load that buys at the West's price than the East's price, 106 MW vs. 64 MW. It is easy to see that a change that raises the

West price while lowering the East price will, on net, have the effect of raising total load payments.

Conclusion

The results of the three methods are:

Method	Congestion Cost Estimate
Simple	$900
Societal	$ 70
Load Payments	-$210

The dramatic difference in the results, and the seemingly unusual negative result for the Load Payments method, occur without the need to assume anything unusual about the system, since the example used is one with straightforward, normal parameters.

A word of caution: all of the above uses a short-run perspective. That is, it freezes the mix of generation plant. While this is exactly the approach taken by many congestion estimation analysts, including the NYISO's current congestion estimation efforts, it fails to account for the effect that the addition of transmission may have on the emergence of new generators or the retirement of existing generators. In the longer run, a drop in the East's price could be expected to trigger increased retirements that would push the East price at least part way back up toward where it started. Similarly, an increase in the West price can be expected to spur more entry of new generators in the West that would push its price back down toward where it started.

Quantifying these longer-term effects is beyond the scope of this paper, since the goal of this paper is simply to better understand the factors that drive the results that are produced by short-run methods for estimating congestion.

Congestion Example – Calculations

Base Case

West Demand = 80 MW	West Price = $40
East Demand = 90 MW	East Price = $50

East imports 26 MW from West (90 – 64 = 26) = I_0
Congestion = ($50 - $40) = $10 per MWh

Note: Reference bus is located in West.

TCC revenue for East TO = (26 MWh) x ($10 per MWh)
= $260

Simple Congestion Cost = 90 x (50 – 40)
= 90 x 10
= $900

Net Congestion Payments = 900 – 260 = $640

Total Bill East = LBMP payments – TCC revenue
= (90 x 50) – 260
= 4,500 – 260 = 4,240

Total Bill West = (80 x 40) = 3,200

Total Systemwide Bill = $7,440

Change Case

West Price = $45
East Price = $45

East imports 40 MW from West = I_1

No congestion

No TCC revenue

Societal Cost Savings from Eliminating Congestion
= East Incremental Cost Savings – West Incremental Cost Incurred
= $47.50 - $42.50) x 14
= <u>$70</u>

Total Bill East = 90 x 45
= $4,050

Total Bill West = 80 x 45
= $3,600

Total Systemwide Bill = <u>$7,650</u>

Load Payments Approach

Reduction in Systemwide Bill from Eliminating Congestion = 7,440 – 7,650
= <u>-$210</u>

In other words, eliminating congestion causes load payments to rise; the Load Payment Congestion Cost estimate is negative. An alternate calculation of the load payment congestion cost can be found as follows:

At starting point: 80 MW of West load buys at West's $40 price
26 MW of East load buys at West's $40 price
64 MW of East load buys at East's $50 price

Total payments = (106)($40) + (64)($50)
= $7,440

With unlimited transmission, all load buys at $45 price.

Total payments = (170)($45)
= $7,650

Elimination of congestion causes load payments to rise by $210.

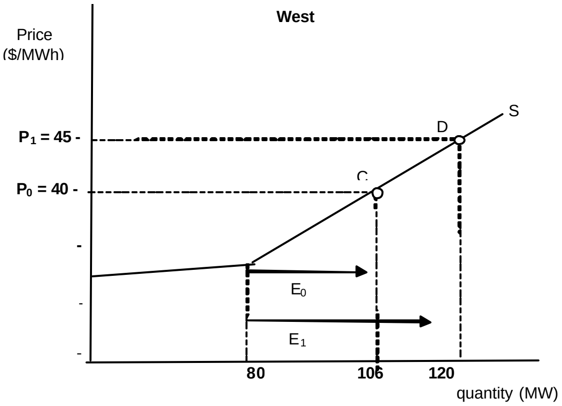
Load Payments Congestion Estimate = -$210

Summary

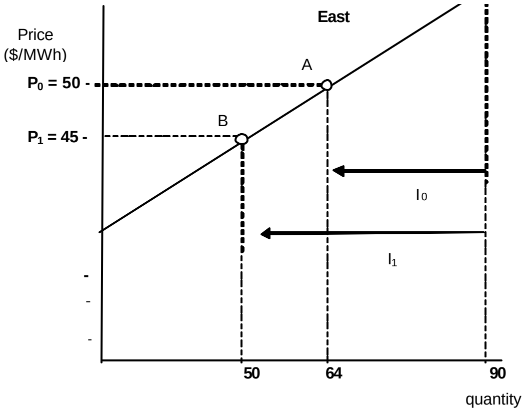
Simple Congestion Cost = $900

Societal Cost of Congestion = $70

Load Payments Congestion Cost = -$210



West Load = 80 MW
When new transmission is added, West ramps up from C to D, West LMP rises from \$40 to \$45.



East Load = 90 MW
At A: Congestion exists
Imports, I_0, of 26 MW take place
At B: Congestion is eliminated
Imports, I_1, of 40 MW take place