Power System Transformation toward Renewables:

An Evaluation of Regulatory Approaches for Network Expansion

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Executive Summary

(1) Motivation

The integration of fluctuating renewables poses challenges on the development of transmission grid capacity. In this paper, we address the rationale for regulation of transmission investment under a renewable integration process characterized by the gradual substitution of conventional power (e.g., coal) with renewable energy sources (e.g., wind). This transition towards a low carbon electricity sector can have temporary or permanent exogenous shocks on transmission requirements. Different regulatory regimes for electricity transmission investment are studied in such a context: a combined incentive price-cap mechanism, a cost-based rule, and a non-regulated approach.

(2) Research Performed

We assume a market design with nodal pricing based on real power flows. A single Transco holds a natural monopoly on the transmission network and decides on network extension. Accordingly, we assume that the Transco maximizes profit, which consists of congestion rents and – depending on the regulatory regime – a fixed income part. Whereas the Transco is not involved in electricity generation, an independent system operator (ISO) manages the actual dispatch in a welfare-maximizing way. The ISO collects nodal payments from loads and pays the generators. The difference between these payments is the congestion rent, which is assumed to be transferred to the Transco. We model a welfare-maximizing benchmark (*WFMax*) in which a social planner makes combined decisions on network expansion and dispatch, as well as three different regulatory cases in which we assume the Transco to be unregulated regarding network expansion (*NoReg*), cost-regulated (*CostReg*), or price-cap regulated (*HRV*). We compare these cases to a baseline without any network expansion. The different regulatory cases are analyzed for four stylized cases of changing generation capacities in a simple two-node network over a timeframe of 20 years. Both nodes are connected by a capacity-constrained transmission line in the initial period.

There are two conventional generation technologies with different marginal costs. The cheap conventional technology is assumed to be located at node 1, the expensive technology at node 2. Renewable power is dispatched without marginal costs, which is true for both wind and solar power. The four stylized cases of generation capacity changes are:

I. The static case: There are no changes in generation technologies over time.

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II. Temporarily increased congestion: Increasing generation capacities of renewable sources at node 1. There is an overlap of renewables phasing in and conventional generators phasing out, such that congestion is temporarily increased.
III. Permanently increased congestion: Growing renewable capacities at node 1 over-compensate the phase-out of conventional power plants at this node, giving rise to permanently increased congestion.
IV. Permanently decreased congestion: Renewable power generation increases equally at both nodes, such that conventional generation is completely phased out. Consequently, transmission congestion vanishes.

(3) Results

We find that incentive price-cap regulation performs satisfactorily under a renewable-integration process only when appropriate price weights in the price-cap formula are used. Ideally constructed weights, brought back from welfare-optimal steady-state equilibrium, generally restore the beneficial properties that incentive regulatory mechanisms are well-known for in static settings. Previous period (Laspeyres) weights may lead to either over- or under-investment compared to a welfare optimum benchmark. However, depending on the expected evolution of network congestion, either Laspeyres, current period (Paasche), or average Paasche-Laspeyres weights appear to be appropriate choices. With a proper handling of weights, stranded investments might not be a problem anymore. Welfare results are presented in the Table which shows relative differences to the baseline for the welfare-maximizing benchmark (*WFMax*) and the regulatory cases *NoReg*, *CostReg*, and *HRV* (under Laspeyres, Paasche, average Paasche-Laspeyres weights and ideal weights).

Table: Welfare changes relative to the case without extension

	Weights	Static	Temporarily increased congestion	Permanently increased congestion	Permanently decreased congestion
		1	2	3	4
WFMax		0.29%	1.28%	11.62%	0.00%
NoReg		0.00%	0.00%	9.25%	0.00%
CostReg		0.00%	1.27%	9.22%	0.00%
HRV	Laspeyres	0.25%	1.01%	9.02%	-0.17%
	Paasche	-0.11%	0.38%	9.39%	-0.32%
	Average Lasp.-Paasche	0.29%	0.89%	9.21%	-0.32%
	Ideal	0.29%	1.28%	11.62%	0,00%

(4) Policy Implications

Price-cap regulation might still provide adequate outcomes (in terms of welfare convergence) under renewable integration, as long as proper types of weights are used. Ideal weights always lead to convergence to the welfare optimum, but are not available for the regulator in complex networks. Accordingly, the regulator might actually choose the best practically available weights that can be observed from market outcomes under incentive regulation for each assumed congestion behavior:

- No exogenous change of network congestion: Average Laspeyres-Paasche weights provide the best results due to quick network expansion, but Laspeyres weights also work well.
- Temporarily increased congestion: Laspeyres weights work best; average Laspeyres-Paasche weights fall somewhat short.
- Permanently increasing-congestion: Paasche weights work best, while average Laspeyres-Paasche weights provide the second best outcome.
- Permanently decreasing congestion: Incentive regulation with other than ideal weights does not lead to desirable outcomes, as the Transco is rewarded for network investments that are obsolete in later periods (stranded investments).