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Assessing the value of power interconnections under climate and natural gas price risks

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A B S T R A C T

The value of transmission capacity is hard to assess due to the presence of different issues: physics of power networks, economics of power systems and reliability criteria. Evolving supply and demand trends, however, create interest in increased transmission capacity, especially between jurisdictions with complementarities. Assessing the value of such interconnections is key in analyzing the viability of these projects. Based on a data set containing 10 years of hourly power flows and prices, daily temperature and natural gas prices, as well as climate change forecasts for 2020 and 2050, we simulate export revenues for a DC (direct current) interconnection between Quebec (Canada) and New York (US) under different natural gas price scenarios and extreme heat events. Our innovative approach, combined with an extensive data set, provides a prospective assessment of the value of new transmission projects. Our results suggest that future natural gas prices would be the main driving factor of future revenues on a transmission line, with climate change having a relatively much smaller impact on future revenues.

1. Introduction

Increasing electricity transmission capacity is required but challenging. In North America, for instance, new transmission will be required as part of the solutions to many of the issues identified by the North American Electric Reliability Corporation in its long-term planning assessment [26]: higher level of variable generation, fossil-fired and nuclear generation retirements and continued increase in natural gas-fired generation, among others. Intra and inter-regional transmission projects can indeed provide many benefits in the context of evolving power markets. Similar situations obviously arise in all parts of the world. Investment in transmission, however, is more challenging than ever. With increased competition in power systems, the traditional regulated approach to transmission expansion becomes more difficult to implement as there are less vertically-integrated utilities and increased open access requirements. Benefits of transmission assets are now shared by more players, in different jurisdictions, making the alignment of incentives more difficult to achieve. Merchant transmission has developed as a new approach to transmission investment, but it faces multiple obstacles, such as market power, lumpiness of investment, strategic behavior and difficulties in coordination. See Refs. [8,22] for more on the theory and evidence on merchant transmission.

Benefits of increased transmission capacity are, however, more and more documented. In a Northern European context, [40] underscores transmission expansion benefits, resulting from increased competitiveness, security of energy supply and environmental sustainability. These benefits create a potential for electricity trading. In a North American context, [5] documents eight potential benefits of transmission investments: production cost savings, reliability and resource adequacy benefits, generation capacity cost savings, market benefits (competition and liquidity), environmental benefits, public policy benefits, employment and economic development benefits and other project-specific benefits.

These benefits are often greater for transmission investments between regions where more complementarities can be found, for instance between regions with a large price differential. However, in the absence of common regulators, regulated transmission investments are difficult to justify, often resulting in limited inter-regional transmission links. Merchant transmission has therefore a larger role to play in interconnecting markets, as well as other types of "non-traditional transmission developments". These new approaches are driven by incumbent or new entrants and financed through tariffs or contracts (see Refs. [6,18]). Such initiatives are indeed observed between the province of Quebec (Canada), with

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plenty of relatively cheap hydropower, and the US Northeastern region, characterized by a high and growing reliance on natural gas and ambitious RPS (renewable portfolio standards) goals. Three high-voltage direct current transmission projects are indeed being studied, linking Quebec and New York City [41], Quebec and Vermont [39] and Quebec and New Hampshire [28]. These projects can only be completed if the expected commercial benefits, for developers, are large enough to justify their investment. As production costs of renewable power sources from the exporting regions (e.g. Quebec) are fairly stable, uncertainty for these projects is rooted in future demand levels and market prices, in the export market.

This paper proposes a novel approach to assessing the value of an interconnection. Expected revenues generated by such interconnections, under different climatic scenarios (driving demand levels) and natural gas prices (driving market prices) are simulated for 2020 and 2050, using 10 years of hourly trade and market prices, as well as temperature and natural gas prices. The observed data constitute the basis of the simulation, from which distributions with more "extreme heat" days, reaching at least 90° Fahrenheit (°F), equivalent to 32° Celsius (°C), and various levels of natural gas prices (averages of approximately $4, $5.5 and $8 per million British Thermal Units or MMBtu) are created.

In Section 2, a literature review presents the energy economics literature on the value of transmission capacity, providing the context for our approach. It also reviews the evidence on climate change and extreme heat events on electricity demand, and the link between natural gas and electricity prices. Section 3 describes our data sets and methodology. In Section 4, our main results are presented and discussed. Section 5 provides some additional discussion on costs and revenues of such merchant transmission projects, in order to better understand their possible net benefits. Finally, Section 6 concludes.

2. Literature review

2.1. The value of transmission capacity

The potential benefits of transmission investments are well recognized. See for instance [40] and [5], as already mentioned in the introduction. The literature on power system integration, which directly implies transmission links, also considers a series of benefits, as shown in Table 1. See Refs. [4,42,11,45], and also [37] for a discussion.

Beyond recognizing these potential benefits, measuring them is much more challenging. The relatively small literature on the value of transmission capacity can be divided in two groups: papers using network models to simulate a power system with and without a given transmission link, and papers abstracting from power network specificities to focus on the economic modeling of the power market. Such distinctions between economic and engineering considerations have been documented in Ref. [47] and more recently discussed by Refs. [8,19]. We now review some of the main papers on this topic.

Table 1
Potential technical benefits from power sector integration.

Improved reliability and pooling reserves	Diversity of generation mix and supply security
Reduced investment in generating capacity	Economic exchange
Improved load factors and increased demand diversity	Environmental dispatch and new plant siting
Economies of scale in new construction	Better coordination of maintenance schedules

[3] uses a model of a simplified version of a two-area interconnected competitive electricity market to develop a tool to assess reliability and economic benefits of transmission expansions. Their tool (REliability and MARKet, REMARK) requires a relatively detailed level of characterization of the network. It optimizes the system under different transmission scenarios and provides some benefit assessments, based on different assumptions for demand, supply and value of lost load. While in principle this approach can be extended for various cases, the modeling effort can be quite large to adjust to a particular situation. While the tool aims at assessing transmission benefits, it focuses on the short and mid-term (1 year of operation), and is not designed to look at longer term trends, such as a shift in demand due to climate change or different price scenarios for fuels (e.g. natural gas). [7], in a similar approach, investigates the economic impacts of connecting Norway and Great Britain. [9] considers the case of Great Britain in light of its interconnections.

[46] considers a real case, very close to the abstract example of [3]: the Alberta (Canada) competitive electricity market, consisting of two interconnected areas, with a highly congested transmission link. Their analysis is centered on various scenarios for additional power plants and transmission capacity, while loads remain inelastic. While such an approach provides valuable estimates on short term benefits for consumers and producers, it is not designed to assess long-term risks affecting the fundamentals of the market. Also, as in Ref. [3], it focuses on a single competitive market, and not on the interconnection of two different markets, where merchant transmission investors are locked-in without regulatory protection.

Still within a single market [2], explores how small investment in transmission capacity can have important competitive impacts, by increasing competition between producers only interconnected with limited transmission capacity.

[8], building on an approach initially developed in Refs. [20,21], moves away from the detailed modeling of power systems to focus on the energy price impacts of increasing transmission between two different competitive markets. Their approach to value electricity transmission consists in assessing, both for the transmission owners and society in general, the impact of the changing market prices due to an increasing transmission capacity between the two markets. Indeed, with increasing transmission capacity, there is an increasing possibility to take advantage of market price differences, but also a declining price difference. For a given level of interconnection, their approach allows one to estimate how much the market benefits from the transmission link, and how much the owner of the link can capture in terms of price differential between the markets. The key assumption in their approach is the value used for the elasticity of supply, which directly affects the price level, as export possibilities grow with the transmission line capacity. The model built under this approach takes advantage of hourly market prices and flows between two markets. Unconstrained and constrained trading hours are characterized and the addition of transmission capacity decreases the number of hours of constrained trade in their simulation. Demand and supply in both markets are held fixed, although responding to price. While this approach is an interesting contribution to the literature on the value of transmission investments, it relies on the availability of market prices from two contiguous (or at least connected) markets. In addition, it is designed to assess the incremental value of transmission, rather than the future value of transmission under different demand and supply scenarios.

Our approach is closer to the economic approach of [8] than to the network simulation one. However, we do not model electricity markets but focus on the possible use and revenues of the transmission line. We take advantage of hourly market prices and flows between two markets, for an extensive period of time (2000–2009)