Cross-Border Electricity Transmission Network Investment: Perspective and Risk Framework of Third Party Investors

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Abstract: In Europe, significant amount of interconnection capacity investments are expected in the next decades. However, the risks associated with transmission network investment in the cross-border context are rarely discussed. In this paper, we develop a conceptual framework to assess the cross-border transmission network investment risks from the third party investor perspective. Risks are examined in relation to cost benefit perceptions in different phases of projects to shed lights of the dynamics in the life cycle of the project. The risk framework also takes into account the energy governance at different institutional level to characterize the uncertainties from cross-border coordination. The proposed risk framework is applied to the European case study.

Keywords: cross-border network investment; transmission investment risk analysis; European case study

1. Introduction

A significant amount of renewable energy capacity is expected in the next decades worldwide and in Europe. Large economic and environmental benefits are estimated for interconnecting clean energy [1,2].

In literature, several authors discuss the interplay between investment risk and cost of capital in the regulated industry. They are mainly based on the public policy design consideration in the national context [3–5]. Other transmission investment research mainly focuses on the expansion methodologies [6–8]. For gas interconnection investments, Boersma compared the institutional settings at national and supranational level in Europe and that of state and federal level in the U.S. [9]. Boersma argues that the lack of cross-border gas network investments in Europe are hindered by: (1) the heterogenous national regulations; (2) the lack of decision making power and clear mandate of energy regulatory authority at the European level. Similar institution settings could be observed for electricity interconnection investments in Europe.

A multi-dimensional risk map to analyze the transmission network investment in liberalized electricity market has been proposed by Rabensteiner [10]. Four main types of transmission network investment risks are categorized: (1) microeconomic and operational risks; (2) macroeconomic and capital market risks; (3) rate case risks; (4) sovereign risks. The risk exposure of the transmission network investment in the analysis of Rabensteiner is based on the nature of the industry and its underlying regulatory design mainly at national level.

A salient feature of the electricity transmission interconnector investment is that it stands at the conjunction of international, national and local social/regulatory context. While the role of interconnections underpinning the electricity market integration is widely acknowledged, it is less often observed that investors incentives consider the transmission network investment risks
in the cross-border regulatory framework. Consequently, very limited academic research focuses on the impact of the cross-border context on investment risks. Effective regulation requires that the policy makers and regulators have sufficient knowledge of the investor incentives, in order to create adaptive rules that change the incentives and encourages efficient interconnection investments. Therefore, this paper expands the risk mappings from Rabensteiner in the cross-border settings with the experiences and lessons from the European electricity market.

In this paper, the third party investor perspective is chosen to explain the investment difficulties for the cross-border electricity transmission network and the resulting investment gap from private investment. The third party investor perspective distinguishes from that of the transmission system operator (TSO). For instance, the risk assessment from European Network of Transmission System Operator for Electricity (ENTSO-E) on interconnection investment is mainly concerned with risk profiles for national TSOs [11]. Glachant explores the regulatory framework at Member State level in Europe by examining the regulatory risks for TSOs and their remuneration level [12]. Unlike the TSOs that are active in the cross-border network planning, the third party investors are in less advantaged position with asymmetric information in the national and European network planning process. Furthermore, the interconnection asset owned by the TSOs is often part of their regulated asset base (RAB). The interconnection investment incentive and risk perception of the TSO investor is shaped by other business activities and regulatory mandate. While not focusing on project specific asymmetric risks, the discussion in the case study involves the risk mitigation for third party investors where applicable. The analysis further points out that the noncontractible risks, which are the uncertainties arising from conditions such as the price, quantity, quality or other implementation details that could not be accurately foreseen and written in the contract ex-ante, are where transmission investment policy improvement is needed.

The transmission network is usually seen as one-off investment with high capital cost and low operational cost. As Helm points out, this cost structure implies that the investor is exposed to the ex-post governmental appropriation risk [4]. The public sector has the incentive to drive down the price towards marginal cost once the investment is done. However, the simple ex-ante and ex-post division highlights political risk with the implicit assumption that national regulatory authority has dominant position in regulatory contract renegotiation. Although it is widely acknowledged that the political risk has significant implication for investment, there are other elements to take into account, in particular in the cross-border context. The first element is the asymmetrical information between third party investors and regulators on the cost and benefit of the project. The second factor at play is transboundary energy governance and the associated decision making structure. These dimensions are not neglectable as they answered two important questions for investors: (1) what sources of uncertainties change the cost benefit perception in different project stages; (2) under the cross-border energy governance, how the decision making structure under cross-border energy governance exerts impact on uncertainties.

In order to view the cross-border transmission network investment in a synthetic way, building block approach is employed in the analysis to explain the action processes and stakeholder interactions. The chronological analysis shows how cost and benefit perceptions of the transmission investment may evolve in different building blocks and how they can be translated into investment risks. Furthermore, to understand the investment risks in the cross-border context, transboundary energy governance is included in the risk analysis framework. Instead of viewing the risks in each building block as separate phenomenon, the dissection of decision making and stakeholder interactions at supranational and national level provide a unified analytical tool to explain the source of cross-border uncertainties and its evolving nature. Regulatory competence division in different institutional levels for planning, permission and project remuneration, reconfiguration of market rules and the change of pricing borders in the electricity market, and the implication for the interconnection investment risks are examined in the European case study [13].
The main contributions of this paper are three fold: (1) a conceptual framework for transmission network investment risks is developed in cross-border context from third party investor perspective; (2) the uncertainties are examined in relation to cost benefit perceptions in different phases of the project and transboundary energy governance, in order to add dynamics and cross-border characteristics to the risk analysis; (3) proposed risk framework is explained by the European cross-border network investment case.

2. Transmission Network Investment Building Blocks and Stakeholders

This section provides an overview of transmission network investment using the building block framework. The framework splits up investment into the development phase and operational phase with an introduction of regulated asset base, in order to reflect the crucial investment aspects in chronological order.

2.1. Transmission Network Investment Building Blocks

A structural framework is provided by Rious to analyse the TSO functions and the coordination of different tasks under such ownership [14]. In the cross-border context, a building block approach to analyse the transmission network investment is proposed [15]. Expanded from Rabenstein’s illustration, Figure 1 gives an overview of stakeholders and building blocks of the transmission network investment in the liberalized market [10]. The columns indicate a distinction of the main actors responsible for the network investment: planner, regulator and investor. In many national systems, in particular, under TSO ownership in Europe, the network planner and investor are the same entity. The rectangular blocks indicate the main building blocks: (a) Network planning that sets out the planning methodology and procedures; (b) Ownership that deals with the roles and coordination between system operator and asset owner; (c) Financing that governs the source of financing and the cost of capital determination; (d) Cost and benefit allocation that addresses the distribution of project costs and benefits among different stakeholders or countries (e) Market operation that deals with the institutional and technical issues that impact the efficiency for providing available capacity.

![Figure 1. Overview of transmission network investment.](image-url)
2.2. Transmission Network Investment Process

In the transmission network investment process, the planner proposes the potential transmission network projects. The planning of transmission projects usually involves scenario forecast, stakeholder consultation, market and network study as well as cost benefit analysis (CBA). To compute the CBA, these components are usually taken into account on the costs side: (1) life cycle cost that includes the costs incurred during the life cycle of the assets; (2) social environmental costs which includes the right of way costs and sometimes the costs for biodiversity and visual impact on landscape; (3) system resilience and security costs that include the costs of system interruption under normal and extreme events and the costs of mobilizing demand to react to certain system conditions; (4) CO2 emission costs which are the costs of greenhouse gas emission by thermal power plant in the system; (5) network loss that accounts for the thermal losses as a result of the power flow in the newly invested network assets in a system as a whole. On the benefit side, the main benefit indicator i.e., the increase of social welfare as a result of the new investment resulting in changes in generation surplus, consumer surplus and congestion rents, is calculated in the system as a whole and quantified for each connecting country or third countries that are impacted [16].

The regulator is usually involved in tariff setting, project approval, remuneration rule making and the electricity market design. While the regulator examines or performs its own CBA during project approval, the national authority’s view on the interconnection investment and cross-border market integration are first and foremost shaped by the perception of effectiveness of the national energy policies to achieve energy objectives that fundamentally shape the national authority’s view on the interconnection investment and cross-border market integration. Some qualitative conclusions could be drawn by looking at the cost and benefit perception at two extreme ends.

At one extreme, there is the view of the national based security of supply, which assumes that the existing national energy mix is rigid and too costly to adapt. Furthermore, the interconnection flow is not always reliable, so that the national generation capacity is very effective tool that could be guided by national decision maker in guaranteeing system reliability. Under this view, the cost of interconnection is perceived much higher and fewer countries find it is in their interest to build large interconnection capacities.

At the other extreme, there is the super grid view that assumes a strongly interconnected system makes the overall system cost lower in comparison with heterogeneous national based generation system, in order to ensure the fulfilling of system demand in the short and long term. In particular in well integrated market where the market rules are efficient and transparent, the utility of cross-border network assets high, the production of renewable energies have complementing effect across large geographical area and smooth the temporal difference in demand. In this view, the cost of construction interconnection capacity and joining the market is perceived much lower compared to the added value.

The investors evaluate the project by carrying cost benefit analysis and performing risk analysis for the proposed transmission network projects. They can take the following actions: (1) to reject the investment; (2) to determine the commensurate cost of capital for the accepting level of risk; (3) to find ways that reduce or mitigate the perceived risk and require the risk premium for the adjusted risk level. The conventional view holds that the highly risk phase of transmission network investments are the planning and construction period where the cost and regulatory uncertainties are higher.

After construction period, the efficiently incurred capital expenditure (CAPEX) will be sold into the RAB as regulated asset and evaluated by the regulator periodically. The regulated asset base is devised as an accounting concept to determine the value of past investment, calculate depreciation and allow investors a return for sunk assets. Though the inclusion of RAB components varies in different countries, the most basic elements are the depreciation and remuneration values. The asset base is periodically updated to include the newly incurred CAPEX. The design specifications of the CAPEX inclusion into the RAB depend highly on the regulations in place. The next section focuses on the risk analysis in planning and the market design changes on the regulated asset base and the RAB design specifications.
3. Risk Formulation

In Section 2, we discuss the costs and benefits of the proposed transmission investments in static manner. As Hart notes in his incomplete contract theory, the original contracts are always incomplete and leave out important things in the long run [17]. The determinant factor for the use of asset is who has the residual control right. This perception is particularly important for regulatory contract regarding transmission investments that are irreversible and have long asset life. It is therefore useful to add a dynamic view of the project cost and benefit in different phases to carefully examine the investment uncertainties. To formulate the interconnection investment under the concept of residual control right, a risk mapping method that takes into account the temporal and cross-border governance dimension is introduced. Afterwards, transmission investment risk categories are described using different building blocks.

3.1. Risk Mapping Method

This analysis adds two dimensions to the existing risk framework: (1) the temporal dimension that is related to changing cost benefit perceptions in comparison with the initial CBA during different project phases; (2) the actor involvements and regulatory competence division at different institutional levels.

In order to analyze how the cost benefit perceptions evolve over time, it is useful to use the building block concept which discusses how the interaction of different building blocks and stakeholders leads to investment decisions. Coupling the building blocks and the risk categories takes the view that the transmission network investment in the cross-border context can be seen as continuous renegotiation process between regulator and investor over the life time of asset [18]. From the third party perspective, we look at the cost side in the financing building block by the evaluation method of the incurred costs and the treatment of shock of macroeconomic shocks. For the project benefits, the asset utilization rate is used as the main indicator to predict whether the asset is deemed by regulator as efficient and useful under planning and market uncertainties. The planning and demand uncertainties together with electricity market design change may result in variations of power flow pattern and consequently impact the transmission asset utilization. The regulatory formula to deal with input cost represents the current view on the historical cost and the inflation treatment reflects the view of asset value in the macroeconomic environment.

The cross-border energy governance is at the heart of the interconnection investment uncertainties [8]. From the third party investor perspective, a clear regulatory competence division at the supranational and national level, coordinated decision making within the same institutional level and the institutional arrangement to orchestrate the cross-border problems makes the interconnection investments more favorable. The residual control power under transboundary energy governance structures are divided into objective setting, result enforcement, incentive design and market rule making at different institutional level, mapped into the building block context. Firstly, the coherence of the generation and climate objective setting at supranational and national arena, its consistency over time and result enforcement are determinant to efficient transmission planning. Secondly, heterogenous regulations across jurisdictions are perceived to increase investment uncertainties with higher transaction costs. Therefore, the incentive design and regulatory competence to orchestrate investments at supranational level plays an important role to reduce the cross-border uncertainties and attract cross-border network investments. Thirdly, regulatory competence for market rule making determines the nature of the cross-border electricity market and may redefine the border in electrical terms. The function of cross-border energy governance and its impact on interconnection investment is context specific. The analysis in each building block is illustrated in the European case study under multi-level governance framework that features the European integration process with the examination of interactions from public and private actor at national and supranational level.
We provide a summary of guiding questions that third party investors should ask when considering the cross-border transmission network investment in Table 1. The risk analysis is dived into these guiding questions with the European case study.

Table 1. Guiding questions in risk mapping.

| Cost/Benefit of The Network Investment | Supranational/National Regulatory Competence |
|---------------------------------------|---------------------------------------------|
| At which project phase does the perceived costs or benefits of the cross-border network investment change? | Is there a clear mandate for stakeholder involvement and decision making at the national/supranational level? |
| How does the embedded risk imply change of perceptions for cost or benefit of the investment? | Is there a coordinated decision making process and matching regulatory competence in transmission, generation investments and electricity market design at the same jurisdiction level? |

3.2. Risk Categories

3.2.1. Risks in Design and Planning

The main regulatory uncertainties for regulated transmission network investments are: demand and permit delays. Traditionally, the vertically integrated utilities that own both transmission and generation assets could co-plan the generation and transmission network investments. The investment coordination efficiency is realized by the integration of generation and transmission operation and investment within the same firm. In liberalized market, the generation investment decisions such as location, volume and timing are no longer available and thus posed challenges for transmission network planner. In the liberalized electricity market, transmission network planning is mainly based on the light-handed scenario forecast approach [12].

The scenario forecast approach usually involves the forecast of future generation and demand by the planner and adjusted with feedbacks by industry or consumers during the public consultations. This planning method implies substantial long-term forecast uncertainties. The cross-border context complicates the scenario approach by adding the difficulty to hold stakeholder input accountability across jurisdictions. The demand uncertainties are embedded during the life cycle of the transmission projects and raises concern for the investment benefits when the future unfolds. The segmentation of regulatory competences for transmission project identification, authorization and generation coordination at national and supranational level also play an important role to shape demand uncertainties for third party investors.

Permit delay is a major source of risk for investors in the design planning phase. It usually implies unpredictability and cost overruns. The implication of permit delays on the cost overruns and cash flow of the proposed projects has to be taken into account when making the investment decision.

3.2.2. Financing Risk and RAB Specifications

The difficulty for the regulators to gain sufficient information to determine a long-term asset value leads to the prevalent ex-post review for the incurred investment and operational cost. In each predefined regulatory period, RAB specifications are reviewed. The periodic review of the RAB includes subjects such as current asset base value, adjustment from depreciation, inflation, the forecast of the future capital expenditures, cost of capital and other financial assumptions [19,20]. This review and reset process, in particular under incentive-based regulation, has an underlying assumption that the stable input cost/price level as well as stable financial condition in between the regulatory period. Therefore, the uncertainties rising from RAB specifications is examined with regard to these assumptions at two essential timings: the initial value determination when the project CAPEX is sold into the RAB and the RAB revaluation. The design specifications of the CAPEX inclusion into the RAB usually depend highly on the connecting countries. The inclusion of input cost change mainly incurs during and after the construction phase, while the inflation mainly appears in the operational phase.
The regulatory formula to deal with inflation reflects the view to treat two main cost components of the network investment: (1) the historical costs; (2) inflation.

In comparison with the domestic investment regulations where the TSO investors are responsible, the investors on cross-border network face higher transaction costs from heterogeneities in regulations, which include the different regulatory treatments for input cost uncertainties and the RAB evaluation formulas. When there is supranational regulatory authority that orchestrates the cross-border network investment, it can also play a role on the asset remuneration.

3.2.3. Market Risks

In a liberalized market, the electricity generation are produced by a variety of technologies and fuels resulting in diverse generation cost patterns. Moreover, generation and load patterns in combination with network constraints made the basis for price formation on short-term electricity markets and have important impact on transmission network investment in the long term. The change of cross-border market rules will likely alter the function of the network assets because it results in the change of price differences between the connecting countries and asset utilization. In the market risk for cross-border network investment, one main question raised is what constitutes the price border and how the border evolves with the change of market design. In general, the TSO investors can expect to have their investment cost approved and remunerated by the regulators if they can prove that the investment need is substantiated by the national network development plan. Anticipating market design changes, attention should also be paid to changes that may result in a significant increase or decrease of interconnection capacity utilization rate, which may in turn alter the perceived project benefits from the regulator.

4. European Case Study

4.1. Risks in Design and Planning in the European Case

4.1.1. Planning Uncertainties

The current European cross-border network planning process, Ten Year Network Development Plan (TYNDP), developed by the European Network of Transmission System Operator for Electricity (ENTSO-E), is non-binding by nature [21]. The Agency for the Cooperation of Energy Regulators (ACER), as the regulatory authority at EU level, plays only an advisory role that reports to the European Commission on the TYNDP process.

A critical aspect for third party investors is that the TYNDP scenario inputs are updated every two years. The stakeholders are invited to contribute to scenario development by consultation. As Zachmann points out, there is a lack of accountability for the information submitted by the stakeholders and raises the question of investment credibility [22].

Given the highly dynamic nature of the European and national energy policies, it is very difficult to plan the cross-border network in advance for the very long time horizon. For instance, the Second Renewable Directives set the national renewable target for 2020. However, not all member states have decided on post 2020 national renewable target before the next RES directive [23]. Moreover, for the period up to 2030, whether there will be national renewable target set following a top down approach remains to be seen. At the same time, the regulatory measures from the EU to deal with nonfulfillment of the 2020 national targets are still open questions. To cover future governance and renewable energy possibilities, two main storylines are incorporated in the 2016 TYNDP scenario development: (1) whether a strong European coordination framework is in place; (2) whether the progress to reach the 2050 roadmap is on track. Consequently, the envisioned installed capacities for renewable and fossil fuel technologies under different story lines vary widely. This gap creates difficulty for transmission planner to identify transmission investment locations and volumes that are robust across the scenarios.
On the transmission network side, the life cycle of network assets is extremely long, 40 years or longer, whose investment is also irreversible. If binding targets post 2020 and generation investment trends remain ambiguous, the location and volume risk for the transmission network investment may arise in the asset life time. If the change of planning assumptions appears in the planning or construction phase, the cost benefit result of the proposed transmission investment is likely to change and this affects the project approval process. Moreover, if the assumptions of generation load is overthrown in the operational phase and consequently affect the utilization of the line, the risk of stranding asset further increases. From the contract perspective, one way to mitigate such risk for third party investor is through regulatory agreement that includes stable revenue stream and a long term regulatory period with the regulator, engaging in a regulatory contract on behalf of future consumers. The cap and floor scheme introduced by the U.K regulator on its interconnections represents such a regulatory trend with guaranteed 20 year regulatory period with stable revenue interval [24]. As the transmission investor has very limited control over the scenario risk stemming from future generation and load demand, the planning risk should be mitigated from public side with improved governance by introducing accountable scenario inputs from users.

4.1.2. Permitting Delays

In Europe, regulatory authorities at national and local level in the connecting countries are responsible for the cross-border network investment permission. The projects of common interest (PCI) are the cross-border projects selected from the TYNDP process, which are deemed to have European importance and granted the label by the European Commission (EC) to facilitate regulatory and financial process. However, according to ACER, more than half of the delays in PCIs are caused by permitting grant [25]. The average delay in PCI caused by permit issues is two years. The main reason for permit delay is related with environmental issue permitting and the NIMBY effect.

The Not in My Back Yard (NIMBY) effects describes the objections from households and local community towards infrastructure projects in their immediate proximity and have significant importance for the project implementation time line in Europe. To mitigate the NIMBY effects for new transmission projects from the investor perspective, broader public engagement and involvement of local communities from the early planning stage are advised. For instance, consultations that directly involve local communities for proposed transmission network project and internet-based information campaigns including for example educational apps for non-experts to emphasis the importance of grid development and operation are rolled out and are perceived as an effective approach [26].

There have been attempts to address the permit delay problem within EU in the Trans-European Networks-Energy (TEN-E) regulation. It envisages the set-up of a single national competent authority within each Member State as a one stop shop to grant permit within 3.5 years for PCIs. However, there has been large difference among Member States in the implementation of the one shop stop.

4.2. Financing Risks and RAB Specifications in the European Case

Unlike the U.S, where the federal regulator FERC is responsible to orchestrate the interstate transmission investments and has the right to grant rate adder to projects, the European supranational regulatory authority ACER does not possess the regulatory competence to determine the remuneration for interconnection projects. The tariff determination and asset remuneration are the responsibility of the national regulators.

4.2.1. Input Cost/Price Risk

The input cost uncertainties may arise when novel technologies are used. For the construction phase, there is a high risk of cost overrun, caused by e.g. supply chain bottlenecks or delays associated with deploying novel technology. For instance, in case of construction delay for the grid connection of offshore wind in Germany, the responsible TSO is obliged to compensate wind developers with 90% of their foregone revenues [27].
Another important consideration for the interconnection investment is the exchange rate and macroeconomic uncertainty. The input cost for labor and the input price, i.e., remuneration of the investment in the local currency of the host country, is subject to volatility of the exchange rate against other currencies.

The investment risk arises when these additional costs are excluded by the regulator to include from the regulated asset base. The investor could protect himself by: (1) adopting technology and construction set ups with less volatile factors; (2) securing insurance against technology or exchange rate risk from a third party; (3) sharing the input cost risk with consumers by a clarified compensation methodology.

4.2.2. Inflation Risk

As Helm points out, after the construction, the investor cannot do much about the CAPEX of sunk assets with management efforts once the investment is done [4]. Inflation risk arises when the inflation level deviates from the forecast value and has unexpected impact on the project cash flow.

The impact of inflation on the asset value mainly depends on RAB valuation methodology. Since RAB values are periodically reviewed in each regulatory period, the reevaluation of RAB could expose investors with inflation risks in the operational period. In countries where the historical cost i.e., the book value method is used for reevaluation, the asset value may be eroded in times of high inflation.

Under the inflation adjusted historical cost method, the effect of inflation erosion on the asset value could be smoothed out by indexing inflation on the residual asset value, i.e., the total value less the depreciation. The inflation risk for investor highly depends on: (1) the extent of automatic pass-through of costs; (2) the regulatory lag, which means the extent of pass through of unexpected costs in the RAB and the time lag between cost incurring and remuneration [5]. As Burns notes, following the oil crisis in the 1970’s, regulators identified the following three factors for the additional cost to be included in automatic pass-through mechanism for integrated utilities: (1) large cost variation; (2) volatile; (3) outside the control of the management [28]. From the investor perspective, timely adjustment of the inflation and full pass-through of the uncontrollable cost should be pursued in the regulatory contract negotiation using similar argument.

4.3. Electricity Market Risks in the European Case

The development of cross-border electricity market has been accumulated efforts from EU and the Member States. The EU has pursued the Internal Energy Market (IEM) by creation of common market design. Currently, the day-ahead market coupling in Europe integrates different national day-ahead markets to optimize the economic efficiency when allocating the available cross-border capacity. The cross-border intraday market project aims at integrating the different intra-day markets for continuous trading. The governance of the market integration in Europe feature horizontal interaction between national TSOs and power exchanges. After the market closure, the TSOs are responsible to keep the generation and demand balanced close and in real time. A coupling mechanism of the national balancing markets is under discussion. It is important to note for third party investors that the European electricity market structure should not only be viewed at the moment of investment. The IEM has been a continuously progressing project with evolving rules.

On the other hand, energy mix remains the responsibility of Member States, which gives national regulatory authorities the possibility to devise market rules to safeguard the national security of supply. The implication for interconnection investor is that the network utilization may subject to the market design changes from both European and national level.

One example of impact of changes to the national market on investment approval is the Greenlink between UK and Ireland. The interconnection project experienced big shifts by the UK regulator Ofgem for project approval. Initially the proposal of 500 MW interconnection projects was rejected by Ofgem following the cost benefit analysis. A key assumption in the cost benefit analysis was wind
penetration would be too low in Ireland to export to UK due to the Irish market design [29]. In times of high wind, due to a technical cap of 50 percent for intermittent generation in the Irish day-ahead market, wind could be curtailed in the market. Consequently, other more expensive generators would be dispatched instead and additional interconnection capacity does not boost the wind export from Ireland via the planned Greenlink. However, following the Irish electricity market reform proposal that envisions the removal or higher cap value for intermittent energy in the day-ahead market, higher penetration of wind is expected. In turn, it is likely to result a lower DA market price in the Irish side of the interconnection to make the electricity trade more beneficial for UK consumers [30].

Another important market factor currently under discussion is the reorganization of price zone boundary and potential changes of the asset status as interconnection. The value of electricity is differentiated geographically, because of the transmission network constraints. When the network capacity is ample and there are no congestions, the price of electricity is the same across the whole system. In case network congestion occurs, the system splits into interconnected smaller markets matching the predefined bidding zone borders. The value of electricity is thus different across various bidding zones.

Currently, the bidding zone borders in Europe mostly conform to national borders. However, as this zone configuration does not correctly reflect the congestion patterns, there have been calls and disputes for further dividing the existing bidding zones into smaller ones [31]. In its position paper, ACER calls for new bidding zones that fulfill the following criteria: (1) congestion appears only on the border between bidding zones and there is no congestion within bidding zone; (2) internal exchanges within bidding zones do not create loop flows through other zones [32]. However, the change of bidding zone borders could lead to volume and market risks for the transmission. From the investment perspective, the change of bidding zone borders raises two issues, in particular for third party investors: (1) the credibility of the existing investment and (2) the financing regulation for the newly defined cross-zonal network investment. While smaller bidding zones improves economic efficiency of the electricity market as a whole, there is not sufficient discussion on how to assure existing or future transmission network investors against this type of volume/market risk from changing rules for capacity allocation.

The impact of market rule adaptation on the transmission network investor largely relies on the regulatory reputation. As Stern noted, the regulated asset base that was initially devised for accounting has been used as investment protection tool in recent years. The effectiveness of regulated asset base as protection tool relies on its implementation quality rather than simply embracing the concept [33]. Joskow pointed out that the capital cost of transmission network is usually treated through the permitting of utility planning and cost of service approach [34]. However, the regulated asset base applies only to the regulated investment. In addition, there are several European countries that introduced incentive-based CAPEX treatment [11]. In the contract negotiation, it is important to note that also the diversity of regulatory culture i.e., the values and functions placed on interconnection in each energy regulatory regime as explained in Section 2 plays an important role in the RAB design specifications.

4.4. Risk Mapping for the European Case

The risk analysis in the European context demonstrates how uncertainties in different building blocks change the costs and benefits from the initial CBA at the project planning stage. Figure 2 shows that the proposed risk analysis framework allows us to map the European interconnection investment risks with the temporal and governance dimensions. The chronological order of risks in different building blocks enables the discussion of the risk mitigation measures for third party investors. It also points to areas where the transmission policy needs improvement, e.g., the coordination of long term investment and midterm market design. The location on the governance dimension and its analysis shed lights in the investment condition for third party investors. For instance, the overlapping governance on long term planning at national and supranational level without clear coordinating mechanism could increase the uncertainty perception for the third party investor. At the same time,
segmented authorities without orchestration over short medium term issues such as permitting may increase the transaction costs and could also be perceived to increase uncertainty.

![Risk mapping of cross-border network investment in Europe.](image)

**Figure 2.** Risk mapping of cross-border network investment in Europe.

5. Conclusions

While we recognize that there is no panacea for risk identification and mitigation, this paper provides the conceptual framework for risk mapping that enables evaluation of investment risks and mitigation method from the perspective of third party investor. The revelation of investment risks in different phases not only explains the lack of private investment in cross-border electricity interconnection, but also gives important forethought to open up discussion for better transmission policy design by public regulators.

An array of investment risks are identified following the building block approach including: from network planning methods, financing uncertainties and market rule changes. Since the network asset life cycle may well exceed the energy regulation and market structure at the moment of investment, a dynamic risk analysis should take into account the uncertainties in different phases of the project. Though complex in detail, what these diverse investment risks have in common is they all change the cost and benefit weighing of the transmission network investments. Another important lesson to draw from the risk mapping is that these risks are embedded in different phases of the projects spanning: planning, permission over construction and operation phase. It can be concluded the cross-border network investment may have altering cost benefit perception by the regulators in the host countries during the life cycle of the project.

The perception of costs and benefits of the transmission network asset may be continuously changed due to a number of factors involving: (1) unfolding planning uncertainties after project commission; (2) input cost, price changes and macroeconomic shocks; (3) electricity market design changes. Furthermore, we sought to characterize the risk in each building block by the single or multi-levelness of the energy governance. The notion is helpful with unified logic to explain how regulatory competence are divided or how actions on interconnection investments are interacted at different institutional level and its evolving nature. Defining the location in the governance dimension allows us to steer the discussion and perform comparison for risk implications from the cross-border complexities for different regions.

The case study merits several observations. In Europe, the patchwork of national based energy policies and the limited predictability for the generation investment policies in the medium to long term add to non-transparency and uncertainties from the investor perspective. The risk analysis in the case study also differentiates contractible uncertainties where risk mitigation measures are discussed for third party investors and non-contractible risks such as the change of the rules and state of energy world. From contract point of view, this paper highlights the importance of managing the
cross-border transmission investment as continuous renegotiation process in the life cycle of the project. From the policy design perspective, the ex-post asset inefficiency resulting from the planning process and market rule changes are worth further research for policy improvement. In order to provide investor with credible and predictable investment climate and benefit consumers with lower risk premium, the cross-border transmission network governance should be carefully crafted to coordinate the long term planning process, market development and investment regulatory framework to ensure the planning efficiency and asset utilization.

While one should recognize that interconnection in broader geographical areas may embrace higher dimensions of complexity without the European IEM framework, the political aspect is beyond the discussion of this paper that focuses on the transmission network industry and should be investigated in further research.

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