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Cross-border interconnection (IC) projects are central to achieving the European Union's goals of energy market integration, system resilience, and security of supply. However, their implementation often encounters financial and policy challenges stemming from uneven distribution of costs and benefits across the countries and exacerbated jurisdictional differences and information asymmetry. This paper proposes an approach that reorients the current framework and practice of cross-border cost allocation (CBCA) policy to one that embeds economic theory that informs the project assessment and negotiation process. We present a conceptual framework that integrates bargaining theory and incentive design into the CBCA. It considers the joint interests of project promoters, National Regulatory Authorities (NRAs), and the European Commission (EC) when assessing investments and co-funding from the Connecting Europe Facility (CEF). A new role for CEF, not as an ex-post subsidy, but as a directed policy instrument enables elicitation of true values of benefits and incentive-compatible cost allocation that aligns national and EU objectives. We conclude with policy recommendations for enabling implementation of cross-border investments in the EU's evolving energy grid policy.

Keywords: Electricity grid; Cross-border investment; Cost allocation; Information asymmetry; energy policy.

JEL Classification: C7; D0; L94; Q4.

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Cost Sharing of Cross-Border Grid Projects in the EU: An Incentive-Based Negotiated Framework

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Cross-border interconnection (IC) projects are central to achieving the European Union's goals of energy market integration, system resilience, and security of supply. However, their implementation often encounters financial and policy challenges stemming from uneven distribution of costs and benefits across the countries and exacerbated jurisdictional differences and information asymmetry. This paper proposes an approach that reorients the current framework and practice of cross-border cost allocation (CBCA) policy to one that embeds economic theory that informs the project assessment and negotiation process. We present a conceptual framework that integrates bargaining theory and incentive design into the CBCA. It considers the joint interests of project promoters, National Regulatory Authorities (NRAs), and the European Commission (EC) when assessing investments and co-funding from the Connecting Europe Facility (CEF). A new role for CEF, not as an ex-post subsidy, but as a directed policy instrument enables elicitation of true values of benefits and incentive-compatible cost allocation that aligns national and EU objectives. We conclude with policy recommendations for enabling implementation of cross-border investments in the EU's evolving energy grid policy.

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1. Introduction

The European Union (EU) seeks to deepen its energy market coupling, decarbonization, and system integration policy objectives through the expansion of cross-border electricity and gas interconnections (IC). Since 2013, the EU's policy on cross-border infrastructure is governed by the Trans-European Networks for Energy (TEN-E) regulation and the financing instrument Connecting Europe Facility (CEF) (EU, 2021a; EU, 2021b). The TEN-E regulation put in place regional cooperation as the mechanism to identify cross-border relevant infrastructure bottlenecks and to select projects, labelled projects of common interest (PCI) that yield transnational benefits in terms of energy security and improve efficiency by enabling resource sharing and cross-border balancing.

The PCIs benefit from streamlined permitting process, regulatory enhancement, and are required to carry out cross-border cost allocation (CBCA) as a precondition to apply for financial support under CEF. The CBCA aims at bringing in beneficiary pays -principle for projects where the traditional user pays -principle does not lead to agreement on the project. The PCIs are selected every two years; the currently valid Union List was adopted in 2026 and includes 235 projects in electricity, hydrogen, CO₂ transport and smart electricity and gas grids (EU, 2026).

However, the realization of many projects is often hampered by disagreements among participating firms and national regulatory authorities (NRAs) regarding the distribution of investment costs. These disagreements among the firms and even national regulators can be underpinned by political dynamics and the difficulty of justifying that investments in foreign infrastructure would be beneficial. Despite these efforts, many projects encounter financial and policy challenges due to the uneven distribution of costs and benefits among the jurisdictions. These challenges are further exacerbated by the presence of information asymmetry and jurisdictional differences.

While the current use of CEF mechanism provides financial incentives, it does not fully align and internalise the incentives when firms need to cooperate on a joint investment prospect. The sufficiency of the CEF budget for the purpose has been highlighted by the firms and member states. The presence of the CEF funding, albeit modest in size, as a subsidy mechanism may lead to strategic behaviour by some actors and thus, contrary to its intention, complicating the

decision process. The Commission has proposed to considerably increase the CEF funding in the next budget period 2028-34 (EU, 2025). Given the needs for significant grid enhancement in the EU, a larger CEF budget may further increase this tendency.

The literature on CBCA is rather sparse and while it addresses some aspects of this important policy issue, they do not offer a comprehensive and implementable alternative approach. Venizelou and Poullikkas (2024) present an overview of the state of technical and economic issues of interconnections in Europe. Schittekatte et al. (2021) suggest that, to secure lasting financial and political commitment, the cost allocation should result in similar benefit-to-cost ratios for the parties involved. CERRE (2025) examines the economic and regulatory challenges of sharing the costs, benefits, and investment risks of cross-border electricity infrastructure. The report recommends adopting layered governance structures, centralizing the CBA process, splitting congestion income based on investment shares, and streamlining financing mechanisms. ACER (2026) present five policy options each representing different degrees of intervention in the current practice for cost sharing of cross-border electricity infrastructure. Sun et al. (2020) argue that the externalities arising from the interconnection projects such as environmental impacts should also be considered in the cost-sharing agreements of interconnectors.

This paper develops a conceptual framework in which the EC, acting as a co-funder and facilitator in negotiations between firms and their respective NRAs, proposes a novel solution. The proposed framework discusses how the use of CEF funding can be redirected strategically. This approach aligns the incentives of the stakeholders and elicits the firms' true valuation of the unobserved private benefits from the interconnection to produce better outcomes consistent with welfare maximization.

The remainder of the paper is organised as follows. Section 2 presents the background to cross border cost allocation problem in the EU. Section 3 discusses the theoretical basis of the proposed framework. Section 4 presents the conceptual basis of the proposed framework while Section 5 presents a simple analytical illustration of this. Section 6 is conclusions and policy recommendations. The Appendix extends the EU's optimisation objective to the case of efficient allocation of CEF funds a portfolio of projects.

2. Background

The development of cross-border interconnections in the EU involves multiple actors and coordinated decision processes. The Cross-Border Cost Allocation (CBCA) mechanism, based on the cost-benefit analysis (CBA) prepared by the European Network of System Operators for electricity and gas (ENTSO-E and ENTSOG, respectively), implemented by the NRAs and supervised by the Agency for the Cooperation of Energy Regulators (ACER), defines how the investment costs of interconnection projects are shared among national stakeholders through network tariffs.

The assessment of prospective projects is carried out biannually by the ENTSOs as part of the mandatory Ten-Year Network Development Plan (TYNDP) process. The national regulators use the TYNDP CBA as the basis with the aim that the CBCA should allocate all costs to be included in tariffs. Cost could also be allocated to non-constructing countries if the project brings them clear benefits (ACER 2023).

The EU's co-funding of cross-border projects through CEF may be granted to complement the national contributions if a project meets certain criteria including significant positive externalities, such as security supply, innovation or solidarity, and the project is not «commercially viable» within the regulatory framework. ACER or the NRAs have no official say in whether or how the EU co-funding for the project is provided or not, this being a separate decision by the Commission.

Firms also hold private information about their expected or true benefits of an interconnection project. Without credible means to accurately determine this information, joint decision-making can be distorted: high-benefit firms may understate their valuation to reduce their share of total project costs, while low-benefit firms may oppose or block beneficial projects. In the coming years, designing innovative and implementable incentive-compatible cost-sharing methods and co-funding mechanisms will be essential for efficient and timely cross-border investments in Europe.

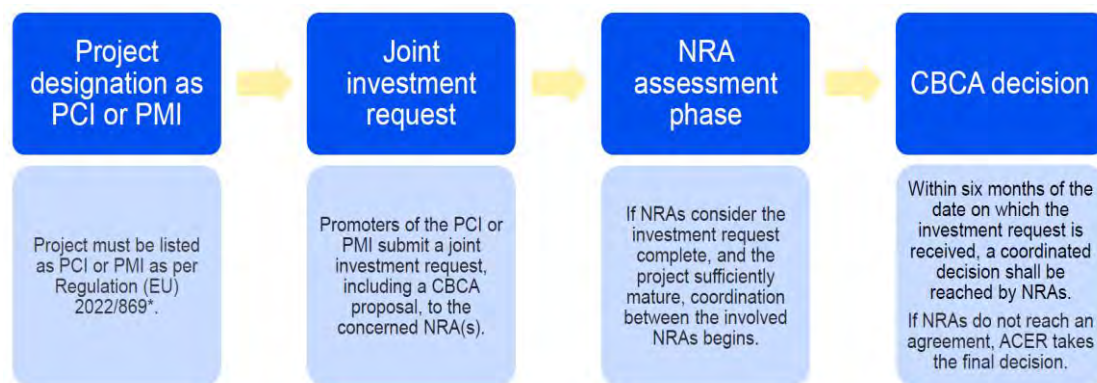
2.1 Current CBCA Framework and Process

The current process leading from identification to investment decisions in electricity interconnection projects in the EU consists of a sequence of steps. These are summarized as follows and are shown in Figure 1.

- Scenario development and system modelling – Ten-Year Network Development Plan (TYNDP), based on an approach that combines bottom-up (national energy and climate plans) and top-down (EU target achievement), identifies candidate projects that address cross-border relevant bottlenecks.
- Cost–benefit analysis (CBA) – Each project is assessed for economic efficiency, security of supply, and market integration benefits.
- Project designation – Promising candidates are labelled as Projects of Common Interest (PCI) or Projects of Mutual Interest (PMI).
- Joint investment request – Project promoters submit joint applications to their respective NRAs.
- Regulatory decision – NRAs coordinate on cost allocation; if consensus fails, ACER issues a binding decision.
- EC Financial support – The EC may subsequently consider partial funding through the CEF facility.

Figure 1: The CBCA Process

Source: ACER (2025)



2.2 Limitations of the Current CBCA Framework

Occurrence of uneven distribution of costs and benefits and the presence of net losers and gainers among the stakeholders is commonplace in many socially beneficial projects and cost-benefit analysis of them. However, the current support framework and the implementation process of the CEF has not managed to fully align the incentive compatibilities arising from uneven distribution of costs and benefits across the firms and jurisdictions. It may even be

argued that the current framework and the use of CEF co-funding have contributed to strategic behaviour among the project stakeholders and has led to funding requests that exceed resources that are needed or available.

While the current CBCA process ensures a degree of procedural coordination, it does not explicitly address the presence of information asymmetry or incentive compatibility among the project stakeholders. Each firm's valuation of benefits it draws from a project is private information, and cost allocations are often negotiated under uncertainty about other firms' valuations. This can result in inefficient project selection, excessive delays, or even lead to ad hoc compensation arrangements.

Moreover, the ex-post use of the EC co-funding, currently considered after NRAs' initial CBCA decisions, reduces its potential as an effective mechanism to reveal the 'true' valuations of benefits or align the incentives of stakeholders. The analytical framework developed below proposes a more integrated design in which the EC co-funding plays an active and facilitating role designed to improve efficiency and cooperation. The proposed framework repurposes the CEF as an economic instrument by using it ex-ante in the process.

3. The Theoretical Case

The conceptual approach proposed in this paper draws upon some established elements of economics including welfare economics, bargaining theory, mechanism design, and incentive regulation. Together, they provide a basis for designing a new framework for cross-border cost-sharing under asymmetric information. Central to this approach is to recast the EC's co-funding role as a potential welfare-maximizing instrument.

3.1 Designing incentive compatible and fair outcome

From a welfare economics perspective, a beneficial interconnection project is one that increases aggregate welfare across all participants. The challenge to the policy maker is to design procedures or incentives that allows a fair balance between the distribution of gains (e.g., via cost shares or subsidies) without sacrificing efficiency.

The Kaldor–Hicks criterion implies that a cost-benefit analysis (CBA) of a project is socially beneficial, when gains and losses are unevenly distributed, provided that the winners can potentially compensate the losers (Kaldor, 1939; Hicks, 1939). The Pareto criterion suggests a

stricter benchmark: i.e., each stakeholder must experience a positive net benefit. Cost sharing may become relevant when costs and benefits of an interconnection project are asymmetrically distributed between the countries or when one country incurs a loss while benefits accrue to another country. The criterion is considered here with a view to achieving Pareto improvement in a feasible cross-border cost-sharing context incentivised by a third party, in this case, the EU through the CEF mechanism.

The mechanism design should provide methods for eliciting unobservable private information through structured rules or incentives. In this setting, the EC faces a mechanism-design problem: i.e. how to structure the co-financing offers of cross-border investments such that firms are incentivised to reveal their true willingness-to-pay (WTP) for the project. An incentive-compatible mechanism ensures truthful reporting is each firm's optimal strategy. The EC's partial funding through the CEF can be interpreted as a transfer payment, from the EU benefits to project promoters to adjust the marginal cost of participation to better align private incentives with social welfare maximization.

3.2 Bargaining and Cooperation

The allocation of costs and benefits among a cross-border interconnection participants can be formulated as a cooperative bargaining game. The Nash Bargaining Solution provides a normative reference for a fair division of a cooperative surplus. It suggests that, under symmetric information and rational negotiation, allocation of project cost shares should be proportional to participants' benefit valuations.

However, in the presence of unobservable private information, bargaining outcomes may deviate from efficient ones. Firms with greater informational advantage, e.g. through more accurate scenarios of the future, can influence the outcome (e.g., a cost allocation) in their favour. A central question is then how a facilitator (here, the EC) can design an incentive mechanism that increases the likelihood of a beneficial project being developed while improving the welfare of all participants and fairness of the outcome.

An interconnection project, by definition, requires the parties involved to agree on the joint development of a project. Therefore, the realisation of the benefits to each party also depends on the benefits of other firm(s). All firms with a potential net benefit have an interest in the project being developed. In the case of a no agreement outcome none of the parties including the EC can realise their benefits and all parties will forego an opportunity for a Pareto improvement.

Therefore, a quasi-cooperative bargaining setting emerges where firms cooperate to secure the implementation and associated benefits of the project while they compete on minimising their share of total costs (Brandenburger and Nalebuff, 1996). Where a cooperative bargaining is not feasible, such a quasi-cooperative bargaining represents an improvement to a non-cooperative bargaining.

3.3 Recasting the EC's role

In regulated network industries, asymmetric information between firms and regulators is common. Incentive regulation and price-cap mechanisms seek to motivate efficient behaviour despite information gaps. By analogy, the EU's co-financing through CEF can serve as a regulatory instrument that conditions project implementation on observed willingness-to-pay to participate in the project. This mechanism design transforms the EC's financial role through CEF from a passive support to an active incentive regulation within a cross-border bargaining environment.

4. The Conceptual Case

4.1 Outline

To make a coherent new framework for CBCA, we retain some key aspects and objectives of the current framework. Additionally, we propose a set of economic assumptions and steps to enhance the effectiveness of the current approach to CBCA and outline a different CEF mechanism and policy framework.

A key assumption in the proposed framework is that each actor, i.e. the EC and the project promoting firms, would only pay for a share of the total costs that is smaller than their benefits. The objective of the EU's energy system integration is to enable the benefits and positive externalities of market coupling, such as security of supply, innovation or, solidarity. Cross-border interconnections generally have shallow as well as deep system benefits for the participating firms. However, these benefits are best known to respective firm and largely unobservable to other firms and the EC.

Building on the theoretical case presented earlier, this section proposes a conceptual framework for how bargaining and incentive design can be combined to improve the procedure and outcome of cross-border cost allocation negotiations. The suggested framework is inspired by

a Kaldor-Hick's type of solution to undesirable distributional outcome of socially beneficial projects where net gainers can potentially compensate net losers (a common occurrence). We internalize the principle of side-payments to compensate net losers by relating the firms' share of total costs to their privately valued benefits.

In the current CBCA framework, cost and benefit analyses are combined into a single evaluation exercise. The proposed approach, in effect, separates these elements conceptually where the value of benefits to individual firm is treated as being private and unobservable to other actors, while total project costs are known. The EC's CEF co-funding acts as a policy instrument that bridges these information gaps.

4.2 Setup and Information Structure

Consider a cross-border project jointly proposed by two firms A and B that operate in two neighbouring member states. The project technical characteristics, e.g., total investment costs (C) and technical features such as transmission capacity (K), are known.

Each firm $i = \{A, B\}$ derives a private benefit b_i from the project, reflecting both the shallow (local) as well as deep (system-level) benefits in their respective jurisdictions. These shallow and deep benefits are observable only to the respective firm; neither the partner firm nor the EC can observe them directly or reliably. This setting resembles a common case of information asymmetry in regulatory economics and commonly occurring in incentive regulation of natural monopolies such as power grids.

4.3 Negotiation and Cost-Sharing Dynamics

The EC's objective is to promote projects that enhance EU-wide market coupling and deliver system-level welfare gains and externalities. Within its budget constraint, the EC commits to covering a given fraction X of total project costs through CEF co-funding mechanism. This CEF contribution reflects the EC's valuation of the EU-wide benefits of the project from market coupling.

The remaining investment cost of the project ($100 - X$) is to be shared among the participating firms that promote that project. Each firm will only contribute a share of total investment costs that is smaller than its private benefits. Thus, the negotiated outcome will reveal implicit information about the value of the benefits to each firm. If the EC's co-financing is designed appropriately, this process can lead to incentive-compatible and Pareto-improvement outcomes.

Firms A and B engage in a negotiation process to determine their respective shares of project investment costs, c_A and c_B . The process resembles a cooperative game with transferable utility. The EC's contribution through the CEF can effectively enhance the feasible bargaining space by lowering the cost shares that the firms must cover.

The project can proceed if the total willingness-to-pay of the project promoting firms reaches $(1 - X)C$. If the combined willingness-to-pay of firms falls short of this amount, the project is abandoned, or alternative designs may be considered. The EC may adjust its co-financing share to induce participation and maximize total welfare but the CEF co-funding share is not to exceed the valuation of the EU-wide monetary and non-monetary benefits of market coupling.

4.4 Eliciting Preferences through Menu of Options

An optional extension of proposed framework is that the EC's funding through CEF funding portfolio can consist of different versions or designs of a given IC project. The EC can present the project promoting firms with a Menu of Options of the type used in regulatory economics literature for a given project while being indifferent between these alternatives (e.g., Laffont and Tirole, 1993). The attributes of the alternative project designs can, for instance, consist of:

- EC's share of total efficiently incurred project costs,
- The size of the project, and
- Total cost of each alternative design. The EC can then present the firms with a set of design options while being indifferent between them in terms of its share of costs.

Under this scheme, the project promoting firms will negotiate among themselves and choose among the alternative project designs that represents the highest values to them. Under this approach, the negotiating firms are incentivised to reveal their preferences and the value they attach to the alternative designs, and, in the process, they will reduce information asymmetry for the EC.

4.5 Financing and derisking of investments

A note on the relevance of the proposed framework for the proposed framework is in place. This framework can also facilitate the financing of cross-border projects in the face of regulatory, policy, and demand uncertainty. A more directed use of the CEF co-funding signals to financiers that the projects are not only socially beneficial, but they are also commercially viable and pareto-improving. This is also underscored by utilising the revealed valuation of project benefits through willingness-to-pay for cost shares (and menu of options) that increases

the confidence of NRAs and financiers in the viability of the proposed projects, i.e. costs are less likely to be overstated, and benefits are not understated to secure CEF as subsidy.

5. The Analytical Case

5.1 The Setup

Let the total cost of a project be C and the EC's co-funding share of the project be $X \cdot C$, where $0 < X < 1$. The residual cost $(1 - X) \cdot C$ is to be financed by the promoting firms A and B. Each firm i will derive private deep and shallow benefits b_i from the project, which are best observable only by that firm. Each firm's utility is:

$$U_i = b_i - c_i$$

where c_i is the contribution of firm i to the residual project cost after the CEF contribution. The participation constraint requires $U_i \geq 0$, meaning each firm's participation is contingent upon its expected benefit exceeding its share of the residual cost.

5.2 Bargaining Equilibrium

The firms' bargaining problem can be represented as a Nash product maximization:

$$\max_{c_A, c_B} (b_A - c_A)(b_B - c_B)$$

subject to $c_A + c_B = (1 - X)C$ and $b_i \geq c_i$. Solving yields equilibrium cost shares that are proportional to their benefit valuations:

$$c_A^* = \frac{b_A}{b_A + b_B} (1 - X)C, \quad c_B^* = \frac{b_B}{b_A + b_B} (1 - X)C$$

Each firm's cost share thus reflects its valuation of the benefit to the firm, ensuring that both participation constraints are satisfied and total cost of the project cost is fully covered by A, B, and the EC. The equilibrium shares represent a stable and fair compromise within the quasi-cooperative game described earlier.

In sum, the outcome of the bargaining process via the Nash Bargaining Solution, yields an equilibrium that exhibits the following properties:

- **Incentive compatibility and proportionality:** The equilibrium cost shares c_A^* and c_B^* are proportional to the firms' revealed valuations of their private benefits b_A and b_B .

Misrepresenting b_i risks failure of the project and thus a zero payoff, which ensures truthful revelation of value of benefits in equilibrium.

- **Individual rationality (Participation):** The solution ensures $U_i = b_i - c_i \geq 0$ for both firms, given the project proceeds only if $\sum b_i > (1 - X)C$.
- **Pareto efficiency:** The resulting cost allocation is Pareto efficient within the feasible set of cost-sharing arrangements.
- **Cost coverage:** The condition $c_A^* + c_B^* = (1 - X)C$ ensures the residual cost of the project is covered by sufficient private willingness-to-pay.

5.3 EC's Optimization Problem (single project)

We formalise the EC optimisation problem in the case of a single project. The Appendix presents the case where the EC considers co-funding of multiple potential projects. Let the total project cost be C . The combined private benefits of project promoters are $B = b_A + b_B$. The EC chooses a co-financing share $X \in [0,1]$ so that promoters must cover the residual investment cost $(1 - X)C$. The project proceeds only if $B \geq (1 - X)C$. The EC's net welfare when the project is implemented can be written as

$$W(X) = B + XC - C = B - (1 - X)C$$

Optimal rule for a single project. The EC should choose the smallest X that makes the project feasible, subject to any policy cap X_{cap} or other constraints. Solving the participation constraint gives the minimum unlocking share:

$$X_{\min} = \max \left\{ 0, 1 - \frac{B}{C} \right\}$$

and the EC's preferred co-financing is

$$X^* = \min \{X_{\min}, X_{\text{cap}}\}$$

Intuitively, fund just enough to convert an otherwise infeasible project into a feasible one; avoid over-subsidy because once feasibility is achieved further increases in X merely reallocate cost from promoters to the EC without creating additional private willingness-to-pay (unless the EC values extra funded capacity beyond feasibility). This approach aims to achieve the smallest EC top-up that secures implementation of the project, avoids EU budget constraints and rules, or committing to X above the level justified by the EC's valuation of benefits.

6. Conclusions and Policy Recommendations

Cross-border interconnectors are essential for achieving the EU's core goals of integrated energy markets, security of supply, and decarbonisation. Yet, their implementation often encounters financial barriers arising from asymmetric information and uneven distribution of costs and benefits among project promoters.

This paper contributes to the discourse on improving the Cross-Border Cost Allocation (CBCA) framework by integrating incentive compatibility and information revelation into the cost-sharing process. By reconceptualizing the Connecting Europe Facility (CEF) co-financing not only as an ex-post subsidy but as an endogenous policy instrument, the framework allows the EC to elicit firms' true, unobserved benefit valuations and align national, private incentives with overarching EU-wide welfare objectives.

Main features of the proposed framework

The proposed framework implies several practical modifications made to the current CBCA procedures. These changes are aimed at enhancing transparency, reduce delays, and improve the welfare outcomes without requiring extensive procedural overhaul of the existing co-funding framework.

- **CEF as strategic policy instrument:** The CEF co-funding will be used to unlock investment, rather than a static subsidy.
- **Welfare benefits:** It increases the EU-wide welfare benefits of market coupling from CEF co-funding.
- **Conceptual separation of costs and benefits:** Unlike evaluations that merge these in a CBA, it treats the value of benefits as unobservable private information to be elicited.
- **Quasi-cooperative bargaining:** Creates a setting where firms co-operate to secure EU benefits while competing to minimize their individual cost shares, leading to a fair bargaining solution.
- **Value revelation through choice:** Uses the CEF instrument, negotiation, and menu of options to reveal private valuation and preferences.

The proposed approach that reorients the practice of CBCA policy to one that embeds economic theory that informs the project assessment and negotiation process. It provides regulators and policymakers a sound basis for determining equitable and efficient cost shares under asymmetric information by utilizing the Nash Bargaining Solution. It highlights how the EC,

through the CEF, can best act as a facilitator. By setting a funding share that reflects the EC's valuation of EU-level system benefits from improved market coupling, the CEF co-financing instrument targets national actors' bargaining positions and incentivises them to reveal their willingness-to-pay.

The resulting cost allocation outcome ensures that each firm's contribution is proportional to its private benefit, thereby respecting individual rationality while achieving overall efficiency. An incentive-compatible co-financing can reconcile local-regional and EU-wide objectives and cooperative investment across member states.

Policy recommendations

Based on the conceptual and analytical findings, the proposed framework leads to the following actionable policy recommendations for refining the CBCA process:

- The EC should calibrate its co-financing share X as a strategic incentive signal rather than a static, one-size-fits-all subsidy rate determined *ex post*. This requires setting X to the maximum value of the EU-wide system benefits to shift the bargaining frontier, expand the negotiation space and induce participation where necessary.
- The determination of the optimal share X should be explicitly and transparently linked to objective and subjective valuations of EU-level system benefits (e.g., security of supply, first of a kind innovation, integration value, system resilience). This ensures that EU funds are used efficiently and justifies the EC's contribution to projects.
- Embedding the principles of cooperative bargaining (e.g., the proportional sharing rule) into the CBCA procedures will enhance predictability, transparency, and acceptance of cost allocation decisions, thereby aligning the interests of Member States with those of the EU.
- The framework in practical settings will require cooperation between the EC, ACER, NRAs, and ENTSO-E to refine data requirements and modelling approaches for benefit estimation.

Future research can extend the proposed framework to related cases that would further strengthen the link between economic theory and principles on the one hand and regulatory and policy practice in the EU.

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Declaration of AI and assisted technologies in the writing process

During the preparation of this work, the authors used Gemini 3 Pro (Google) to refine the conceptual clarity and structure of the manuscript, and in addressing the strategic alignment of theoretical and analytical aspects of the proposed framework including the technical Appendix. The tool was also utilized to help apply these into actionable policy recommendations. The authors have also manually reviewed and revised the generated suggestions to ensure they accurately represent the technical nuances of the TEN-E regulation and Connecting Europe Facility (CEF) funding mechanisms. The authors take full responsibility for the intellectual content, the validity of the analytical model, and the final findings presented in this paper.

Appendix

EC's Optimization of CEF Funding Problem with Multiple Projects

When the EC allocates a limited Connecting Europe Facility (CEF) budget Z across multiple candidate projects, the single-project rule generalizes into a portfolio problem. Index projects by $j = 1, \dots, N$. For each project let total cost be C_j , EC share $X_j \in [0,1]$, and combined private benefits of promoters $B_j = \sum_i b_{i,j}$. Let $W_j(X_j)$ denote the expected net welfare contribution of project j (net of costs and private contributions). The budget constraint is $\sum_j X_j C_j \leq Z$.

Objective and Lagrangian

The EC chooses $\{X_j\}$ to maximize total expected welfare:

$$\max_{\{X_j\}} \sum_{j=1}^N W_j(X_j) \quad \text{s.t.} \quad \sum_{j=1}^N X_j C_j \leq Z$$

Forming the Lagrangian introduces λ , the shadow price of one euro of CEF.

Core allocation rule — equi-marginal principle. For any project receiving interior funding ($0 < X_j < 1$) the first-order condition implies

$$\frac{\partial W_j(X_j)}{\partial X_j} = \lambda C_j$$

or equivalently

$$\frac{1}{C_j} \frac{\partial W_j(X_j)}{\partial X_j} = \lambda$$

This means the EC should allocate support so that the marginal EU welfare gain per euro of CEF is equal across all funded projects. In plain terms, direct additional euros to the project where the next euro buys the most extra EU benefit and continues reallocating until marginal returns are equalized.

The marginal view

- **Threshold effects:** some projects are near feasibility; a modest increase in X_j can flip them from infeasible to feasible and produce a large discrete welfare gain. These projects typically show very high marginal welfare per euro and deserve priority.
- **Non-uniform shares:** a uniform co-financing rate is inefficient; project-specific X_j targets scarce funds where they change outcomes most.
- **Diminishing returns:** for projects already feasible, additional EC support usually yields smaller incremental welfare gains, so funding should shift to higher-return uses.

Practical approaches

- **Partial funding allowed:** estimate each $W_j(X_j)$ and its marginal curve, then adjust X_j until marginal welfare per euro is approximately equal across funded projects.
- **Binary funding only:** rank projects by expected welfare per euro and fund in descending order until the budget is exhausted; treat near-threshold projects as high priority.
- **Under uncertainty:** use scenario analysis to compute probability-weighted marginal gains and base allocations on expected marginal returns.

Policy implications

- **Calibrate CEF shares project-by-project** rather than applying a single fixed rate.
- **Prioritise marginal unlocks** where small EC contributions produce large net EU gains.
- **Publish the marginal-benefit rationale** to improve transparency and acceptance among NRAs and promoters.
- **Respect operational constraints** (legal caps, regional balances) by adding them as explicit constraints; the equi-marginal principle remains the normative benchmark even when constraints alter the feasible allocation.

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