EFFICIENT ALLOCATION OF MONETARY AND ENVIRONMENTAL BENEFITS IN MULTINATIONAL TRANSMISSION PROJECTS

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Overview

There are multiple countries involved in, or affected by, multinational grid investments needed to cope with energy and environmental targets in Europe. Adequate cost-benefit allocation schemes are necessary for stimulating national support since there is no supra-national planner to decide upon those large-scale, lumpy cross-border infrastructure investments, in contrast to the US where FERC provides rules for inter-regional projects that are cost efficient. Using a bi-level optimization program for transmission and generation expansion, in combination with cooperative game theory, I present a way to determine an efficient cost-benefit allocation.

Our case study considers a project portfolio of three planned interconnectors in the North Sea Offshore Grid (NSOG) that are scheduled to be in operation by the year 2030. Together with a stylized analytical example, we show that cooperative investment strategies might give asymmetric and, in some cases, negative benefits although aggregated net-benefits are positive. The presented allocation method copes with the latter, in addition to the sequence of project deployment and strategic opportunities among the participating countries. Moreover, our results indicate that multinational transmission expansion planning yields convex cooperative games which are in the core.

Methods

The paper present a bottom-up framework for efficient allocation schemes of monetary and environmental benefits that arise from multinational grid investments by introducing a stylized and illustrative example of asymmetric welfare impact, in combination with a real case study of a planned project portfolio in the NSOG. It cope with some of the shortcomings in transmission expansion planning (TEP) by using a bi-level investment model where generators are allowed to respond to transmission investments with a detailed market dispatch in order to capture a variety of flow patterns and seasonal variation in the hydro-dominated systems that borders the NSOG. In contrast to the majority of the reviewed literature, the application of Shapley Value in TEP is extended to consider more than only welfare metrics to assess possible trade-offs for the benefit allocation. For instance, some countries might see a beneficial trade-off in e.g. increased share of renewables, or reduced CO2 emissions, despite weak monetary welfare effects. Finally, a discussion on how multinational TEP problems might always yield convex cooperative games where the Shapley Value is in the center of the core.

Results

The Shapley Value is used to calculate allocation of benefits acquired by the grand coalition, i.e. if all countries cooperate, and the results shows that countries indirectly involved could get compensated by a amount equivalent to their negative net-benefit. The opposite would have been the case for free-riders having a positive net-benefit, where they would have to pay an equivalent amount to the countries actually paying.

The allocation method ensures that all countries are better off cooperating. Moreover, it incorporates each country's strategic position in terms of forming other coalitions, in addition to its marginal contribution, or importance, for adding more value to the system. Even the sequence of project development is somewhat incorporated into this method, as the marginal contribution is calculated as an average off all possible deployment sequences. In contrast to conventional allocation methods, where you pay in proportion to what you get, our approach ensures that you also get compensated for the underlying value that you provide a system.

Finally, the results show that cooperative multinational expansion planning games are convex since the incentives for joining a growing coalition, increases. That is, the characteristic function used to calculate the Shapley Value is supermodular. We can therefore say that the Shapley Value gives stable allocation schemes (in the core), in contrast to the traditional allocation alternatives that proved to be unstable.

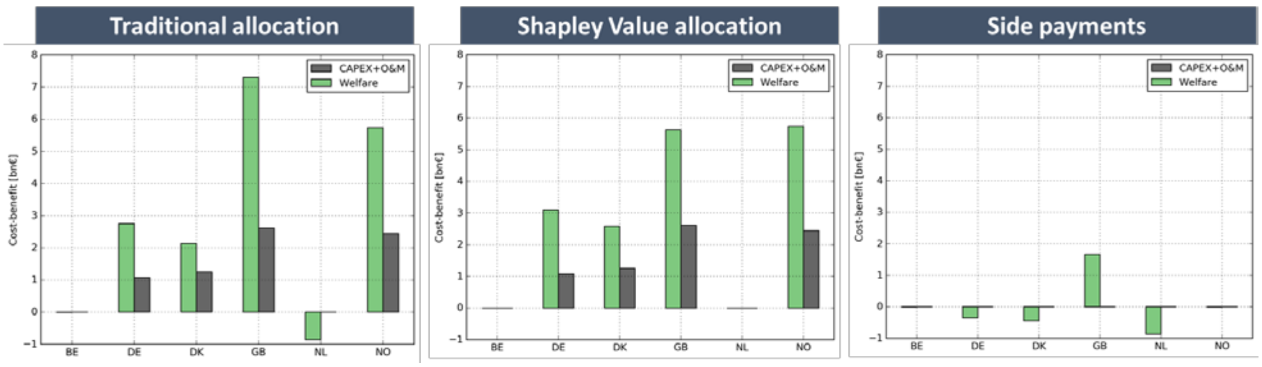

Figure 1 – An illustration of traditional cost-benefit allocations (left plot) with more controversial allocation methods based on cooperative game theory (middle plot). Side payments are used to bridge the gap (right plot).

Conclusions

The presented work has brought some fundamental insight to asymmetric benefit effects of multinational investments, and suggested a powerful method to balance out those effects with side-payments that satisfies a range of requirements - such as beneficiaries pay, sequential deployment dependence, and strategic aspects - in addition to a multi-objective view on those benefits. Mechanisms for allocating and trading the final side-payments will be among the future research topics, with an elegant balance between techo-economic and policy aspects.

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