A Quasi-Input-Output model to evaluate emission factors of purchased electricity from interconnected grids

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Electicity generation is a major source of atmospheric emissions (e.g., greenhouse gas, sulfur dioxide). With increasing electricity trade among power grids, accounting for emissions embodied in purchased electricity from interconnected grids is necessary for designing effective environmental policies. However, calculating emissions embodied in purchased electricity from interconnected grids is difficult, because it needs to trace the purchased electricity to the source of its generation through the complex grid network. To address this challenge, previous studies proposed approximate estimations using a variety of techniques such as iterative algorithms and adjusting direct electricity trades. Those methods are computationally demanding or simply cannot derive accurate solutions.

We solve this problem by realizing and exploiting the isomorphism between the intergrid electricity transmission network and the Input-Output (IO) model of an economy. Specifically, for a certain grid, electricity is generated (with the correponding enironmental impacts) and then mixed with the purchased incoming electricity from other grids, generating the toal electricity flux which in turn flows to consumers and other grids. Analogously, for a sector in the IO model, valued added is generated, and then combined with inputs purchased from other sectors, resulting in the total output which is in turn allocated to final consumption and other sectors.

Despite the correspondence between the structures of the two models, one cannot directly apply environmentally extended IO model to the electricity transmission network for emission accounting, since the activities generating environmental impacts are at different logical components (i.e., electricity generation for grid network vs. total ouptut for IO models). Therefore, we propose a Quasi-Input-Output (QIO) model, and derive two formulas for calculating emission factors of electricity consumption in an interconnected grid network, based on the quasi-Leontief inverse matrix and the quasi-Ghosh inverse matrix, respectively. We then show the equivalence between the two methods.

Empirically, we use two cases to compare our QIO model with other methods from previous studies. One is electricity trade between grids of 53 major countries/regions on the Eurasian Continent, and the other is the electricity trade between more than 100 interconnected Power Control Areas (PCAs) in North America. These two case studies show that our QIO model comes to approximately the same result as the iterative method. In addition, we also prove the equivalence between our QIO model and the iterative method (if infinitely executed). Moreover, our QIO model doesnâ€™t need strong assumptions that other methods such as electricity trade adjustment rely on.

The QIO model we developed for the electricity transmission network represents a novel application of the IO theory. It can be readily applied to account for other evironmental impacts (e.g., water consumption) of purchased electricity in interconnected grids. We anticipate our model will be widely used in environmental policymaking with the rapid development of electricity trade markets. Furthermore, we also expect the theoritical framework of this approach can be applied to environmental accounting in other interconnected systems.