Betweenness-based framework to identify critical transmission sectors for environmental pressure mitigation

Topic: Input-Output Tables as a Network II
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The industrial system contributes to environmental pressures in two ways: directly using resources and energy or generating pollutants and wastes in industrial production, and indirectly driving the uses of resources and energy or the generation of pollutants and wastes through supply chains. To develop sector-specific policies for mitigating environmental pressure, previous studies primarily focus on identifying important sectors that directly generate environmental pressures (a.k.a production-based accounting) or indirectly drive supply chain-wide pressures (a.k.a consumption-based accounting). In addition to those sectors that are key direct sources and indirect drivers, however, there exist sectors that are neither main sources nor key drivers of environmental pressure but are also important to environmental pressure mitigation as transmission centers. For example, suppose there are three sectors in the economy in which sector 1 generates emissions and supplies to sector 2, sector 2 provides to sector 3, sector 3 produces final products, and sectors 2 and 3 do not generate any emissions. According to either production-based or consumption-based accounting, sector 2 will not be identified as important. But it can contribute to reduce economy-wide emissions by improving its production efficiency, i.e., using less inputs of sector 1 to produce unit output. In this study, we aim to develop a method to identify such critical transmission sectors which can help mitigate environmental pressures through improving production efficiency.

Identifying critical transmission sectors can guide developing sector-specific policies to improve production efficiency for environmental pressure mitigation. Such policy is potentially more effective than demand-side policies guided by consumption-based accounting, because improving production efficiency often is equivalent to reducing cost. Therefore companies and firms in those sectors may be more willing to implement suggested policies. We anticipate this new framework of identifying critical transmission sectors can complement production-based and consumption-based accounting frameworks for sector-level environmental pressure mitigation strategies.

We develop a betweenness-based framework to measure the importance of transmission sectors. In particular, an input-output (IO) economy is considered as a network in which nodes are sectors and links are intermediate transactions. The betweenness of a sector is generally defined as the amount of environmental pressures generated by all supply chain paths passing through the sector. We apply two methods to quantify the betweenness of sectors: a structural path betweenness based on supply chain paths extracted by the structural path analysis (SPA), and an improved random walk betweenness based on supply chain paths extracted by random walk simulation.

We use a 135-sector Chinese IO table in 2007 with a carbon dioxide environmental satellite account to demonstrate the proposed betweenness-based framework for identifying critical transmission sectors. We find that those critical transmission sectors identified by our approaches are not always identifiable by either production-based or consumption-based accounting frameworks. This indicates that our approach can provide additional insights on the roles of individual sectors playing in economy-wide environmental pressures which cannot be obtained using existing methods. Improving production efficiency in those critical transmission sectors can help mitigate economy-wide environmental pressures.