# Integrating Input-Output Analysis with Optimization for Regional Energy Planning: A Case Study of Seoul's Energy Transition

Topic: Input-Output Modelling: Energy policies (2)
Author: Jiwoo Shin
Co-Authors: Hana Kim

Jiwoo Shin, Hana Kim* (KAIST)

As the primary economic engine of South Korea, generating 22.5% of the national GRDP and hosting 18.3% of the population, Seoul serves as a critical case study for urban green transitions. The "6th Seoul Regional Energy Plan" outlines an ambitious roadmap for carbon neutrality through massive financial commitments in the Energy, Building, and Transport policy sectors. However, such large-scale "Green New Deal" initiatives often face the macroeconomic challenge of the "crowding-out effect." Traditional Input-Output models used for policy evaluation are frequently criticized for assuming infinite resource availability, thereby ignoring the fact that public investments must be financed through budget reallocations that may displace private capital. This study addresses this gap by asking: How can a megacity like Seoul finance its energy transition while maximizing regional economic resilience under strict fiscal constraints? We explore a normative policy design that seeks an optimal investment structureâ€”one that minimizes the opportunity costs of fiscal withdrawal while maximizing the net output increase across the megacityâ€™s industrial web.
To provide a robust evaluation, this research proposes an integrated modeling framework coupling a simulation-based optimization algorithm with Multi-Regional Input-Output (MRIO) analysis. Grounded in a "budget-neutral" framework, we assume that green investments are financed solely by reallocating existing municipal budgets utilized specifically within Seoul. The methodology employs a "Grid Search" algorithm to identify the most efficient reallocation path under two rigorous constraints. In the first stage, all 83 intermediate-level industrial sectors are ranked by their Leontief inverse coefficients to identify candidates for reallocation. By prioritizing sectors with smaller Leontief inverse coefficients for budget reduction, the model systematically minimizes the negative ripple effects on the regional economy. In the second stage, the model iteratively adjusts a "Threshold Ratio"â€”a uniform reduction percentage applied to these candidate sectorsâ€”in 0.1% increments. The optimization model differentiates fiscal caps based on the investment scale of each policy sector to ensure realistic financing. For the Building and Energy plans, a 10% sectoral reduction limit was sufficient to cover the required investment. However, the Transport sector, which accounts for a massive 91.6% of the total budget due to capital-intensive railway and infrastructure projects, faced a "financing gap" under the initial 10% constraint. To bridge this gap and achieve fiscal solvency, the reduction cap for the Transport scenario was extended to 20%. This dual-cap approachâ€”10% for Building/Energy and 20% for Transportâ€—reflects the practical necessity of larger reallocations for high-cost infrastructure while still preventing any single industry from bearing an excessive fiscal burden.
With consideration of the crowding-out effects, the economic impacts of energy transition budget adjustments were analyzed using the 2020 MRIOTables from the Bank of Korea. All nominal budget values from 2025 to 2045 were converted to 2020 constant prices via the Producer Price Index (PPI). The optimization results were derived at five-year intervals to capture the temporal dynamics of the transition. These results demonstrate that shifting funds from low-multiplier sectors toward the Energy and Building policy programs yields substantial net benefits despite the fiscal withdrawal. For the initial target year 2025, the Building and Energy sectors achieve net output increases of approximately 28.6 billion KRW and 4.9 billion KRW, respectively. For the Transport sector, the initial 10% reduction cap was insufficient to cover its massive investment requirements, necessitating an expansion of the cap to 20%. Even under this more aggressive reallocation, the

model maintains a positive net ripple effect, confirming that strategic reallocation based on Leontief inverse coefficients can effectively mitigate the disruption caused by large-scale fiscal shifts in a megacity environment.

The novelty of this research lies in its transition from descriptive multiplier analysis to an algorithmic policy design tool that explicitly incorporates the crowding-out effect. By identifying the precise "Optimal Threshold Point" where the municipal budget is rebalanced, this study provides a more rigorous defense of urban green investments against standard macroeconomic skepticism. The findings provide Seoulâ€™s policymakers with a "Fiscal Self-sufficiency" toolkit, proving that a strategically reallocated green budget can transition from a fiscal burden to a net economic catalyst even under stringent constraints. Ultimately, this framework provides a replicable model for global megacities striving to balance carbon neutrality with urban fiscal stability and long-term economic resilience.