

Government Subsidies for Industrial Symbiosis: Is it Always Worth It? Assessing Effectiveness and Efficiency through Agent-Based Modeling

Topic: Input-Output Analysis: Sustainable Production and Consumption policies (7)

Author: Melissa Mollica

Co-Authors: Alberto Nastasi, Luca Fraccascia

The concept of Circular Economy proposes an alternative path to the dominant “take-make-use-dispose” economic development model by promoting reuse, recycling, and recovery strategies. Among these, Industrial Symbiosis (IS) enables the substitution of virgin inputs with by-products and wastes generated by other firms, thereby reshaping material flows and inter-firm production linkages. In input-output terms, IS modifies technical coefficients of production and alters the structure of interdependencies within the economic system.

Despite its environmental and economic potential, IS remains underdeveloped due to technical, financial, operational, and institutional barriers. Policy intervention is widely recognized as a potential driver. Governments may grant subsidies and financial aids to support investments and the implementation of sustainable solutions, as well as impose taxes and penalties to discourage pollution and unsustainable behaviors. However, given the variety of available instruments, policymakers require structured guidance to ensure both effectiveness and efficiency of their intervention under budget constraints.

In this paper we propose an agent-based (AB) model grounded in an Enterprise Input-Output (EIO) representation of production interdependencies to assess the effectiveness and efficiency of different subsidy programs for IS. Specifically, the paper aims to answer the following research questions: (RQ1) Which type of subsidy program is most effective in achieving the government’s objectives within a given industrial context?; (RQ2) Given a limited budget, how can the government design the program most efficiently from the economic perspective?

To answer the research questions, we modeled through agent-based modeling (ABM) the development of an ISN within a production system where the interactions are characterized by input-output linkages. Firms operate within two interdependent industries connected through input-output technical coefficients. Waste producers must invest in treatment technologies before engaging in symbiotic exchanges, while waste users may substitute primary inputs with treated waste. In this context, the government can provide two types of subsidies: (1) subsidies for IS investments, and (2) subsidies for the waste exchange.

The simulation was informed with data related to a representative IS case involving the substitution of clinker in Portland cement production with Ground Granulated Blast Furnace Slag (GGBFS). The input data were collected from a combination of scientific literature, specialized databases, and official institutional sources. Economic and operational parameters regarding demand levels, production coefficients, and cost factors were taken from the ABM literature on IS. Environmental impact parameters were obtained by cross-validating data from authoritative sources such as international energy reports, lifecycle assessment databases, and industry associations (e.g., European Cement Association).

Results show that policy effectiveness depends primarily on the allocation and design of instruments rather than on the absolute level of financial support. For instance, if IS requires the enhancement of existing infrastructures or their building ex novo, providing financial support to the upfront investment is the priority. Nevertheless, granting funds for this kind of investments may be useless if operations are hampered by economic or logistic barriers. Indeed, inefficient outcomes may arise due to budget exhaustion and imbalances in the budget allocation between the tools. Moreover, effectiveness and efficiency are not necessarily aligned, implying that cost-effectiveness criteria should be applied only when comparing policies with similar performance outcomes.

The novelty of this paper is threefold. First, the integrated use of ABM and EIO allows assessing the effectiveness of different subsidy programs by explicitly comparing policy scenarios with a

counterfactual baseline (i.e., the system behavior in the absence of government intervention), thus enhancing the robustness of the results. Second, unlike existing studies in the literature of IS that typically analyze a single instrument or assume unlimited public resources, this is the first study that simultaneously considers investment subsidies, waste-purchasing subsidies, and budget constraints. Third, it contributes to the policy literature for IS adopting a dynamic and systemic perspective, which has been recognized as essential to properly analyze the effects of policy on the development of IS.