The transition to a circular economy (CE) requires multiple agents in supply chains (SCs) to take different initiatives over time. However, different agents have competing objectives, which may not align with a circular transition. Furthermore, the use of frameworks such as Circulytics [1] to assess circularity at the agent level may result in burden-shifting from one agent to another.

Although SC and superstructure optimization models have been widely employed to find optimal circular network designs [3-8], most models rely on centralized optimization of network-level objectives rather than considering the objectives of different agents. Understanding how well agent- and network-level objectives align and whether optimal CE network designs benefit some agents at the expense of others would enable the development of more holistic agent-level circularity indicators and help stakeholders prioritize efforts to improve circularity.

In addition, with the exception of [9], most CE frameworks only apply to a specific case study, limiting their generalizability to different case studies or systems in which material from one application is used for another.

Previously, we developed a generic framework for dynamic modeling of CE networks that considered multiple agents and used it to study the value chain for single-use polyethylene terephthalate (PET) plastic packaging in the U.S. [10].

Here, we formulate this framework as an optimization model and consider an extended version of the PET value chain that includes polyester textiles and chemical recycling. LCA is combined with the planetary boundaries framework [11-13] to assess environmental impact. We use multi-objective optimization to find trade-off solutions that balance network-level circularity, environmental impact, and different agents' net present values and Circulytics scores over a 15-year time horizon.

Our findings agree with previous work that there are trade-offs between circularity and sustainability. For the PET case study, combining glycolysis and mechanical recycling of packaging with "downcycling" of textiles to lower-quality fiber applications outside the PET value chain minimizes environmental impact, while "upcycling" of textiles into packaging via methanolysis and mechanical recycling of packaging maximizes circularity. However, all Pareto-optimal trade-off solutions outperform the baseline linear economy. Although improved network-level circularity generally leads to increased agent-level circularity, the reverse is not always the case. Furthermore, improvements in one agent's circularity often come at the expense of other agents' circularity or environmental impact. Therefore, there is a need for improved agent-level circularity indicators that avoid burden-shifting.

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