An integrated energy-economic model for the energy transition: insights on critical raw materials exploitation

Topic: Input-Output Modelling: Energy Policies - III
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In recent years, the need to undertake an energy transition has been increasingly prominent in the political debate and the effects of such an ongoing transition are leading to increasing global energy investments. The switch to the vast adoption of low-carbon technologies would lead to less environmentally-impactful energy production processes, however, it surely requires structural economic changes in terms of global supply chains. In particular, the concern around such technologies regards their relevant critical raw materials (CRMs) content, which consequently opens important geopolitical and energy security implications, and their role in global job creation/loss. These two dimensions are currently under investigation in the scientific literature and a comprehensive answer represents a substantial research gap. Such a complex context needs to be represented within complex and integrated modelling frameworks. Energy System Models (ESMs) are usually the favourite choice when dealing with the impact evaluation of long-term global energy scenarios. However, it is necessary to create a link between ESM and other macroeconomic tools to keep into account the above-mentioned complexities. This is the purpose of DYNERIO, an integrated modelling framework developed by the authors, composed of three soft-linked modules: (i) an ESM, responsible for optimizing sustainable technological pathways under specific policies constraints, usually minimizing the least total net present cost (NPC) of the energy system configuration; (ii) an environmentally-extended multi-regional input-output (EEMRIO) model, reflecting results of ESM onto non-energy industries and capturing the overall economic impact, including influence on employment, of the pathway; (iii) a third module consisting of a system of linear equations allowing to dynamically assess region- and technology-related CRMs extraction and recycling (dynER). This study presents an application of the DYNERIO framework within an extended global energy transition case study aiming at providing extended energy-related and economic insights. Two global energy scenarios have been implemented: in the first scenario the ESM provides a least-NPC-oriented transition trajectory shaped under policy constraints classifiable as â€œstated and announcedâ€•; the second scenario builds upon the first with the significant difference regarding the relaxation of some policy constraints and the change of the objective function of the ESM, which in this case is the minimization of the total CO2 emissions. The deployment of energy technologies and the production of their respective services, coming as a result of the ESM module, are then provided as inputs of EEMRIO and dynER modules allowing for the assessment of the implications on CRMs exploitation. A sensitivity analysis is also provided on materials and technology prices.