

Supply chain risks and the green energy transition

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Abstract

This note aims at opening the discussion on ways forward for quantitative economy-wide modelling on two issues: *Supply chain risks* and *The green energy transition*. It identifies three groups of challenges on both issues: theory, modeling mechanics and data, including policy information.

1 Introduction

The overview paper in this organized session introduces ten themes for a White Paper “*Moving forward: research priorities for global trade analysis*”. This short paper develops a bit deeper two of those themes: “Supply chain risks” and “The green energy transition”. These two themes are separate, but they are related through the recognition that current CGE approaches have limited granularity to fully capture some important aspects of supply chains. This note is far from exhaustive and aims primarily at providing some points for discussions with participants. The ultimate goal is to solicit wider inputs into the white paper, hence this paper poses some key questions, including: Can existing CGE modeling capture new realities unfolding in the wake of multiple crises that the world economy is experiencing? What new modeling approaches and data, including policy information, may be required?

2 Supply chain risks

2.1 Overlapping crises and overlapping analysis

The past years have painfully illustrated the exposure of global supply chains to disruptive events: natural disasters and the covid pandemic, wars and terrorist attacks affecting crucial shipping lanes and sudden trade policy shifts have been leading to profound adjustments in supply chains.

Supply chain risks and dependencies on foreign inputs are typically analyzed by a variety of complementary tools that involve multiple layers of information (see e.g. Arriola et al., 2024):

- Detailed trade statistics to identify direct import dependencies;
- Assessment of degree of concentration in suppliers (or the flipside: degree of diversification of supplies) to flag potential for vulnerabilities and potential to source from alternative suppliers;

- Mapping of trade statistics to input-output tables to assess how dependencies affect up- and downstream industries;
- Inter-Country Input Output (ICIO) tables and Trade in Value Added (TiVA) indices to assess indirect dependencies arising from internationally diversified supply chains;
- Industry- and firm specific assessments of dependencies on critical inputs sourced abroad, such as Neon gas and palladium sourced from Ukraine or helium sourced from Gulf countries.
- Road, sea and air transport data are used to assess logistic bottlenecks.
- High- frequency price statistics to gauge the cash-flow and expenditure impacts.

2.2 Challenges for modelling

Whilst they are very powerful in mapping the economy-wide and inter-country effects and market adjustment mechanisms, CGE models are capturing the impacts of those events only partially, given the limited granularity and time lags in official statistics. They cannot absorb the richness of the multiple layers of information. A fuller set of modeling tools (e.g. micro-models of specific supply chains) and granular and ‘real-time’ data may be needed to provide more comprehensive insights into the exposure of supply chains to disruptions, both natural and man-made.

While much information is already available from public and private sources, much data work needs to be done to enhance the value and use of data. Better linking and integrating various layers of information (micro-macro linking), both within counties and across countries will have to be done to better understand patterns of production and trade. The mapping and linking of different statistics with each other faces issues of combining information that is collected for different purposes and with different statistical concepts (e.g. trade statistics, and input-output tables, firm-level data).

Clearly, vulnerabilities occur at the individual firm (or even plant-) level, and propagate through the economy. Inter-firm trade is called for in place of intercountry trade. Linking micro and macro levels is a central challenge here, and the CGE approach already provides an overarching framework to consistently integrate micro and macro aspects with market feedbacks. When individual firms are modeled, their production function can include both critical (non-substitutable) and standard inputs. Sourcing can occur both domestically and internationally. Firm behavior can be modelled in different ways, including as a (non-) linear optimization problem with constraints or using heuristics often found in agent-based-models. A central issue here is the mapping of individual firm behaviour to aggregate outcomes.

A firm-based network can be represented as a (very big) Input-Output (IO) adjacency matrix where each firm has its own input-output structure and individual firm-IO matrices are linked through inter-firm transactions (like an Inter-country IO, but much bigger). However, complete coverage of hundreds of millions of firms in the global economy is impossible. However, samples of individual firm IO tables can be constructed by combining different

sources: firm data (e.g. ORBIS), conventional IO tables and knowledge of firm-to firm transactions (which is available in some countries, e.g. Japan and Belgium). Synthetic samples – i.e., a sample of synthetic firms that matches certain structural characteristics such as size distribution etc. – can be constructed to incorporate crucial characteristics while avoiding modeling individual existing firms (see Hillman, et al., 2021).

A somewhat different, and arguably easier challenge relates to transport costs. Recent shocks to the world economy have shown the vulnerability of supply chains to even small disruptions in sea and air transport when they occur at critical bottlenecks. The IMF Portwatch platform continuously monitors disruptions in maritime trade flows and provides an analytical extension to map those into economic indicators and even a ‘nowcast’ of international trade statistics to help improve the timeliness of trade statistics. See [PortWatch](#).

Transport models can be used to better understand the impacts on different transport modes on specific routes, the re-routing and substitution of modes when a blockage occurs, while their subsequent impact on domestic and international supply chains can be analyzed with CGE models or specific sector models. The GTAP data base already distinguishes 4 modes of transport, and for modeling purposes the transport margins can be shocked to mimic a specific transport disruption.

In summary, the challenges for modelling of supply chain risks can be grouped into:

- **Challenges for theory:** micro-modelling of specific supply chains with better understanding of short-term substitutability and a better understanding of debt- and liquidity constraints within the industries to understand financial vulnerability; tap into specialist transport models to understand changes in transport cost when some shock occurs;
- **Challenges for modeling mechanics:** develop methods and technical means to combine aggregate CGE modeling with detailed micro models
- **Challenges for data:** more disaggregated trade data (beyond HS6) and better concordances with industry statistics are needed to develop more disaggregated IO tables; Hence, more granular data, more real-time data; constructing (synthetic-) firm level IO data using firm-to-firm information and relating them to trade flows; protocols, concordances and quality assurance mechanisms to assure that combined data meet high standards.

3 Green energy transition and trade

3.1 Green energy technology is growing faster than fossil fuels

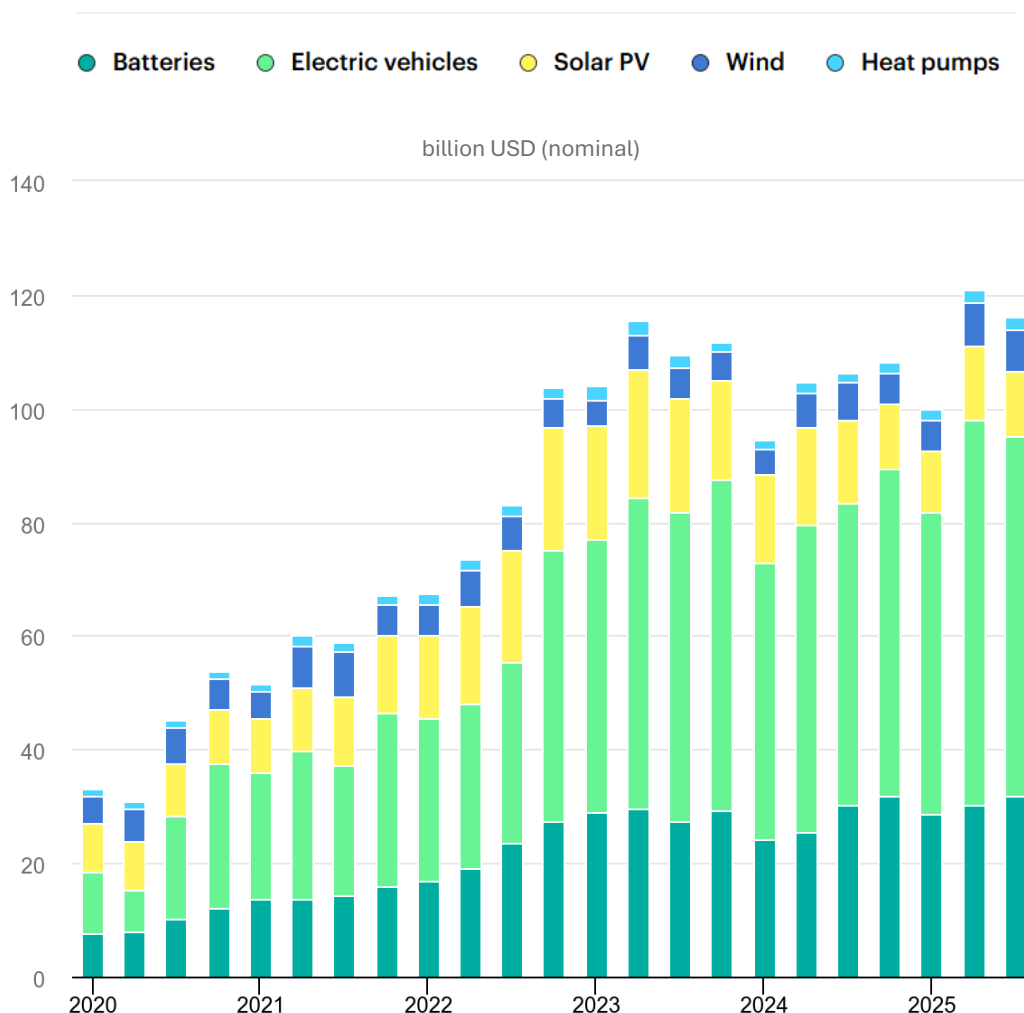
Despite recent policy changes in some countries the deployment of clean energy technologies is projected to keep rising under all IEA (2026) scenarios. According to the IEA, the combined global market value for clean energy technologies has grown 20% on average per year over the past decade, to reach nearly USD 1.2 trillion in 2025, and is expected to double to around USD 2 trillion in 2035, even under conservative policy assumptions. This is roughly the size of the global crude oil market in 2025.

In several market segments – most notably automobiles – low-emissions fuels are not only competing with fossil fuels, but increasingly with the rising demand for electricity for other uses on existing infrastructure.

International trade in clean technology products has been growing spectacularly and has reached USD 290 bln in 2025. Trade will continue to play a key role for the future deployment of clean technologies.

The global transition to greener energy has implications for international trade that go beyond reduced demand for primary energy furnished from coal, gas and oil. Wind and solar installations do not require a quasi-permanent flux of trade between suppliers and users; they are investments with a multi-year life time that require maintenance and repair services, generating local employment, but not requiring tradable primary energy inputs. For this reason, the green energy transition has significant implications for future commodity trade. New suppliers of these technologies have been emerging, notably China and other Asian economies for solar PVs and batteries, while countries relying on fossil fuel exports for economic growth will likely see slowing demand for their main export commodities.

Figure 1: Value of international trade for selected energy technology products



IEA (2026), Value of international trade for selected energy technology products, 2020-2025, IEA, Paris <https://www.iea.org/data-and-statistics/charts/value-of-international-trade-for-selected-energy-technology-products-2020-2025>, Licence: CC BY 4.0.

The production of energy from renewable sources, its storage and use also rely on different inputs compared to conventional energy. Access to critical minerals and metals has become a prime determinant for competitiveness in the energy transition, next to mastering new production processes at large scale. The supply chains for green energy, in other words, are different, involving different players and altering trade flows in significant ways. These supply chains are also exposed to new challenges and vulnerabilities. Geographic concentration of production and of some critical inputs is a primary concern for clean energy supply chain resilience. For example, IEA (2026) shows that the economic impact of a disruption would

differ across technologies, but China assumes a central role for essentially all clean technology supply chains.

Policy makers have been responding to such concerns with measures to promote domestic activities (subsidies and tariffs) and a range of actions to assure access to critical inputs (bilateral agreements).

3.2 Challenges for modeling

CGE models have a long and successful track record in modeling aggregate energy supply and – demand in a multi-sector setting that allows for crucial feedback loops through the macro -economy. Bottom-up approaches, on the other hand, allow for detailed modeling of individual energy technologies, including detailed mapping of their supply chains, while they are limited in modeling market mechanisms and macro feedbacks.

Consequently, various approaches have been proposed and to combine the two approaches to yield more comprehensive insights (see for example Faehn et al, 2020, Weitzel et al., 2019).

Both the top-down CGE approach and the bottom-up energy systems approach tend to focus more on the energy supply side than on the demand side, allowing for smooth substitution between alternative sources of supply depending on price differentials.

However, renewable energy installations are capital goods that are often imported. Unlike intermediate inputs like oil and gas, trade will be influenced by investment decisions in green energy equipment, and less on the marginal rate of substitution between inputs. Those investment decisions under uncertainty about future price developments and uncertainty about future policies are insufficiently – if at all – captured in current CGE modelling.

Some of those investments are also decentralized. Investing in solar PVs for example is an important means of decentralized electricity generation by individual households. The exploitation of those technologies is somewhat similar to the small farmers' optimization problem to decide which part of the harvest to keep for own consumption and which part to sell on the market. Both decisions depend critically on transport (transmission) infrastructure and associated costs.

While the adoption of clean energy technologies can be viewed as an investment decision under uncertainty, government policies have been playing a key role in absorbing a part of that uncertainty, both on the demand side and the supply side. Border policies as well as behind-the border policies today present an intricate mix of incentives to stimulate production and use of cleaner energy. Reducing emissions were once a main driver behind

those policies. However, they are increasingly motivated by the objective of reducing dependence on foreign supplies.

In summary, the challenges for modelling of the green transition can be grouped into:

- **Challenges for theory:** how to map decentralized energy generation in the production structure? In as far as green energy comes from the aggregate 'energy sector' there is no problem with existing models. How to model investments in clean energy capacity, both in the aggregate 'energy sector'; and at the household level? How can relevant demand and supply side policies be mapped to model parameters?
- **Challenges for modeling mechanics:** how to best combine bottom-up detailed (engineering) modeling with top-down CGE modeling?
- **Challenges for data:** Detailed estimates for cost structures of different clean energies are needed – at a global scale; input costs for green technology capital goods and operational costs; how are those green capital goods accounted for in trade statistics and in national input-output tables and in ICIOs? (In principle, the TiVA structure identifies trade flows by use type.) How are individual investments in decentralized energy generation taken into account in existing data? Which policy information on the demand and supply side of clean technologies is available and how can it be made comparable between jurisdictions?

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