US-China Bilateral Metal Trade and Energy Transition in the Landscape of Global Value Chain Pressures, Geo-Economic Fragmentation, and US-China Tensions

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Extended Abstract

The impetus to attain environmental sustainability has become a central concern for researchers, policymakers and stakeholders within the realm of sustainable development. The path to achieving this lies heavily in transitioning towards cleaner energy sources, a sentiment echoed by sustainable development goal (SDG) 7 (Estevão & Lopes, 2024). This energy transition, however, is connected to the availability of metal-centric raw materials supplied by mineral resource nations worldwide (Ali et al., 2017). These metals, used as critical raw materials in the manufacturing process of clean energy technologies, have spurred the trade of these resources, even among global superpowers (Islam et al., 2024). Specifically, the United States and China, two predominant superpowers, have a substantial volume of bilateral metal trade that primarily feeds their clean energy technology manufacturing processes (Perger, 2022). This considerable mineral/metal trade, however, is subject to various global risk phenomena, such as global value chain pressures, geo-economic fragmentation, and other conflict-induced risks (Hammond & Brady, 2022). Given this context, our research proposes two significant research questions:

(i) How does the bilateral metal exports between the United States and China influence their energy transition? and
(ii) How do diverse global risks and bilateral tensions influence their metal export-oriented clean energy transition?

In the era of globalization, international trade, particularly the metal trade, is heavily influenced by the functioning characteristics of global value chains, diverse geo-strategic/economic issues, and the relationship between trading nations. Specifically, the global supply chain, a crucial element of international trade, relies heavily on transportation networks such as shipping and aviation (Martínez et al., 2025). This interconnected system ensures a steady flow of goods, but its fragility is evident during disruptions, which can significantly affect global transportation (Beaudoin & Lawell, 2018). The shift towards manufacturing sustainable commodities—including solar photovoltaics, wind turbines, and electric vehicles—has highlighted the importance of the critical mineral trade (Islam et al., 2024; Yan et al., 2017). Both the United States and China are actively importing essential metal resources from each other to meet their sustainability goals, despite facing challenges from geo-economic fragmentation that disrupt international trade (Ascari et al., 2024). This fragmentation has been accelerated by events like Brexit, US-China trade disputes, and the Covid-19 pandemic (Shu et al., 2024). The ongoing trade tensions have revealed vulnerabilities in global supply chains, underscoring the need for more resilient practices (Bu,

2024). These challenges highlight the critical role of US-China metal trade in supporting their clean energy transitions, as disruptions in the supply of critical metals could hinder their clean energy objectives, emphasizing the necessity for stable and resilient supply chains.

Motivated by the aforementioned practical scenarios of research question, we examine how bilateral metal exports between the US and China impact their energy transition, taking into consideration global value chain pressures, geo-economic fragmentation, and US-China tensions. Our analysis uses a monthly dataset from January 1998 to December 2022 and applies cross-quantilogram and wavelet local multiple correlation techniques due to the fat-tailed features of data properties. Our findings reveal that China's metal exports to the US are positively correlated with the US's clean energy transition from bearish to booming market conditions. Conversely, US metal exports are also positively connected with China's clean energy transition in bearish market situations. Additionally, the long-run negative correlations of diverse risks are more pronounced than the short-run correlations. The US-China tensions exert a more significant dependency, while global value chain pressures yield a lesser dependency/correlation with the metal exports-driven clean energy transition of the US and China. Meanwhile, geo-economic fragmentation falls into the medium category of negative correlation.

The contribution of this paper to the field of applied energy and energy-centric risk affairs is multifaceted. *First*, this is the pioneering study that incorporates the bilateral mineral trade between two superpowers (the US and China) to analyze the influence of this trade on the promotion of their energy transition processes. *Second*, considering the time-varying (short-run and long-run) correlation of novel risk parameters, such as global value chain pressures, geo-economic fragmentation, and US-China tensions, with the material exports-driven clean energy transformation of the US and China can add significant value to the environmental risks assessment literature. *Third*, this study creates short-run and long-run risk factors by following Baur & Smales (2020) and investigates their role in the US-China mineral export-induced energy metamorphosis. This approach contrasts with previous literature, such as Islam et al. (2023a, 2023b, 2024), which typically examined the influence of aggregate risk dynamics on mineral trade and its impact on the global energy transition process. These investigative strategies can be beneficial for assessing the material usage behavior in the energy transformation process and the risk behaviors associated with energy metamorphosis-laden environmental management and sustainability. Finally, we suggest fostering effective diplomatic dealings and cooperation between the US and China to mitigate multifaceted risks and tensions, thereby facilitating smooth metal trade and achieving their energy transformation targets.

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