Input-Output Modeling Amidst Crisis: Tracing Natural Gas Pathways in the Czech Republic During the War-Induced Energy Turmoil

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The current geopolitical landscape, particularly highlighted by the Russian invasion of Ukraine, has brought the issue of energy security into sharp focus, especially for European countries like the Czech Republic, which have historically relied on Russian natural gas. This research aims to dissect the intricate interplay between energy security and natural gas usage in the Czech Republic, providing a comprehensive analysis amidst these turbulent times.

In conducting this study, we employ a domestic input-output model based on the year 2019, which serves as a critical period for understanding the Czech Republicâ€™s energy supply chain before the geopolitical upheaval. This model is built on a foundation of diverse data sources, including economic data from Supply and Use tables, physical accounts of natural gas use by Czech industries from the Czech Statistical Office, average natural gas prices for industries in 2019 from Eurostat, and prices from the Title Transfer Facility (TTF) in the Netherlands. The TTF data is particularly significant as it is the primary reference for natural gas trading in Europe, and it enables us to assess the impact of the increase in natural gas prices following the onset of the Russian invasion.

Our approach is multi-dimensional, incorporating both energy input-output demand and price models to unravel the potential economic ramifications in scenarios where the availability of alternative energy sources is constrained. Given the challenges associated with substituting Russian gas, a key aspect of our methodology is the application of network analysis techniques, including node and edge betweenness centrality measures and the hypothetical extraction method. These techniques allow us to pinpoint structurally important elements within the countryâ€™s natural gas consumption network. Node betweenness centrality is instrumental in identifying critical transmission sectors within supply chains, offering insights into their relative importance based on the amount of embodied natural gas they transmit. Meanwhile, the hypothetical extraction method provides a comprehensive gauge of a sectorâ€™s significance by simulating the complete removal of its forward, backward, and internal connections, thus indicating its criticality to the economy. Furthermore, the use of Structural Path Analysis (SPA) allows us to trace the flow of purchases of intermediate products instigated by final demand purchases of final products. This SPA approach, combined with energy data, enables us to quantify the embodied energy at each stage of the supply chain, ultimately reconstructing it into a tree-like structure representing energy consumption across different economic sectors.

Our findings reveal significant implications of natural gas price fluctuations on key manufacturing industries in the Czech Republic, notably those engaged in international trade, such as the mineral, chemical, automotive, metalwork, machinery, paper, and rubber and plastic industries. These sectors are particularly vulnerable to energy supply and price disruptions. In parallel, we highlight the crucial role of sectors that provide essential goods and services to households, like energy, food, and transportation. The analysis indicates that strategic interventions may be necessary in the event of severe disruptions to protect both domestic demand and the competitive edge of nationally vital sectors like the automotive industry.

This study underlines the importance of understanding the potential repercussions of interventions at various levels of the countryâ€™s supply chain. As energy security remains a dynamic and evolving challenge, our research contributes significantly to the ongoing discourse on energy

resilience, particularly for countries in Central and Eastern Europe, and provides a framework for other nations facing similar complexities.