Decoupling Transition Patterns in the Global Economy: A Multi-Regional Structural Decomposition Analysis

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The relationship between economic growth and environmental burden has long been debated. Understanding the process of decoupling global economic growth from COâ„ emissions is crucial for exploring pathways toward a low-carbon global economy. This study addresses the following research question: how and why do countries follow different decoupling pathways between economic growth and COâ„ emissions?

According to the Environmental Kuznets Curve hypothesis, environmental burden tends to increase with economic growth in the early stages of development (i.e., coupling). However, once an economy reaches a certain level of development, the environmental burden decreases despite continued economic growth (i.e., decoupling).

The decoupling indicator can be expressed as an elasticity, defined as the percentage change in environmental impact (e.g., carbon footprints) divided by the percentage change in gross domestic expenditure (GDE) over a given period. Specifically, Tapio (2005) classifies a countryâ€™s decoupling state into eight categories. However, these threshold values such as 0.8 that separate coupling from weak decoupling are not necessarily grounded in theoretical considerations and are instead determined empirically.

Beyond the arbitrariness of thresholds, a key limitation lies in the static nature of conventional classifications. Two-point comparisons based on initial and final years may classify countries into the same decoupling states despite markedly different trajectories. Such differences in transition pathways may reflect different underlying decoupling mechanisms.

To address these limitations, this study defines an attribution vector for each country that characterizes the transition patterns of its continuous decoupling states. Hierarchical clustering is then applied to identify country groups with distinct transition patterns and endogenously determine the thresholds separating them. This transition-based framework allows decoupling processes to be analyzed dynamically rather than as static states.

The empirical analysis uses the World Inputâ€“Output Database covering 44 countries from 2000 to 2014. Inputâ€“output tables deflated to constant 2014 prices enable consistent estimation of per capita GDE and carbon footprints and decomposition of structural drivers.

Cluster analysis identified nine clusters exhibiting distinct decoupling transition patterns. Comparing state-based (Tapio) and transition-based classifications, several clusters span multiple Tapio decoupling states, indicating substantial overlap between the two schemes. For instance, India and Indonesia are grouped in the "persistent coupling transition" cluster despite different Tapio states, suggesting that endogenously determined thresholds differ from conventional ones.

Furthermore, to identify the factors underlying the different decoupling transition patterns among clusters with similar GDE growth, we decompose changes in the per capita carbon footprint of each country into six factors using structural decomposition analysis: emission intensity, production technology, trade structure of intermediate goods, trade structure of final goods, sectoral composition of final demand, and per capita final demand (i.e., GDE).

Across most clusters, emission intensity improvements produced the largest reduction effect, while GDE growth was the main driver of increases. However, when comparing clusters within the same stage of economic growth but exhibiting different decoupling transition patterns, changes related to trade structure played a decisive role.

In the clusters that achieved less favorable decoupling transitions, shifts in intermediate input sourcing reallocate emissions-intensive production across borders, thereby giving rise to carbon leakage through international trade in intermediate goods. On the other hand, in the clusters that achieved more favorable decoupling transitions, restructuring of upstream resource supply networks for the electricity sector reduced reliance on Russian suppliers and increased sourcing from EU member states or domestic producers.

These results indicate that international trade does not necessarily exacerbate carbon leakage. Rather, the structure of intermediate input sourcing plays a critical role. Reconfiguration of trade structures that reduce dependence on carbon-intensive suppliers, either through recovery of domestic sourcing or a shift toward lower-emission foreign partners, can contribute to mitigating consumption-based emissions with continuous economic growth.

The novelty of this study lies in identifying limitations in conventional state-based classifications and proposing a transition-based framework with endogenously determined thresholds. These findings suggest that decoupling should be understood as a development-dependent transition process rather than a static state, with important implications for structurally differentiated climate-policy design.